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Review Article

A morphological approach to reviewing the literature on evaluation and selection of Commercial-Off-The- Shelf equipment for Defense

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Abstract

To reduce the time and costs associated with the lifecycle of military equipment for continued operational effectiveness, Departments of Defense purchase Commercial-Off-The-Shelf (COTS) products. In this way, design and development costs are passed on to the manufacturer. At the same time, it is possible to take advantage of the rapid pace of technological advances in the industry. However, due to the nature of Defense equipment, COTS must be carefully evaluated and selected to mitigate the risks associated with entering government stockpile products that do not perform as intended or fail prematurely throughout their lifecycle. The present study develops an analytical framework to consolidate the prevailing research on COTS selection and evaluation for Defense use, identifies gaps, and proposes future research. We adopted a morphological analysis approach to systematically review the identified studies. We create a morphological structure with five dimensions specified by the Input-Process-Outcome (IPO) approach; it functions as a repository of the literature and allows the researcher to make changes as the literature portfolio grows, given its flexible representation and modularity.

Keywords: commercial-off-the-shelf, life cycle, evaluation and selection process, defense, morphological analysis.

1. Introduction

Defense budgets for research, development, and innovation of new equipment have been mitigated around the world. This situation has forced Defense Procurement Directorates to assess the existing procurement process and find a less expensive approach. A commonly suggested option to reduce development time and costs is the acquisition of commercially available elements, to the detriment of exclusive (high-cost) ones developed explicitly for defense equipment. This idea is intrinsic to Commercial-Off-The-Shelf (COTS) (Hall & Naff, 2001). In Figure 1, available below, it is possible to verify a night vision monocle, an off-the-shelf product, provided by the Brazilian Army, whose purpose is to allow the soldier to operate in a night environment by amplifying the residual light of the environment.

Figure 1. LORIS night vision monocular.
Source: Brazilian Army website (Brasil, 2023).

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Thus, the use of off-the-shelf equipment, or COTS, in complex applications has become a prevailing practice. Among the reasons for the adoption of COTS, the commitment of engineering managers to reduce life cycle costs for the same operational use of the developed component can be highlighted (Julian et al., 2011).

Still, according to Julian et al. (2011), the adoption of COTS brings the following advantages and is not limited to:

a. reduction of costs associated with the acquisition linked to the research, development and innovation of new military equipment;
b. cost reduction of the life cycle of a product;
c. strengthening the supplier base by directing development costs to the industry; and
d. maintenance of technological superiority through the rapid absorption of state-of-the-art technologies.

While COTS allows us to take advantage of the rapid pace of technologies available on the market, there are significant risks associated with the use of COTS products in military systems (Alford, 2001). According to Mathopo & Marnewick (2017), COTS products may not reach the failure rates required of military equipment.

According to Hodson et al. (2020), although there is a *NASA recommendation Engineering & Safety Center* (NESC) for the use of military specification approved components (MIL-SPEC) in their missions, the use of COTS electrical, electronic and electromechanical components in space systems is a fact, as some manufacturers in the commercial industry have developed controls stringent process controls driven by advanced technologies and the commercial marketplace, often equivalent to or exceeding government controls for MIL-SPEC parts.

Empirical evidence suggests that the successful acquisition of COTS equipment is related to practical methodologies for selecting and evaluating potential candidates (Basir et al., 2015). Selection and analysis are performed according to customer requirements to enable selection of the appropriate COTS equipment portfolio (Tarawneh et al., 2011).

Garg (2017) through his literature review work in recent decades mentions the pioneering approach of Kontio (1995), called Off-The- Shelf -Software components (OTSO) which considers value (functionalities, quality, design issues and strategic), as well as cost (development, acquisition and integration) as the main COTS evaluation criteria. Several other OTSO-inspired approaches subsequently emerged.

For the ranking of candidates for the supply of COTS equipment, in a multi-criteria decision-making scenario (functionality, cost, reliability, compatibility, etc.), some authors have decided to combine methods such as Analytic hierarchy Process (AHP), for determination of weights, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), for ranking, exploring its possible ramifications (Shyur, 2006; Ajalli et al., 2017; Rocha Junior et al., 2022).

As it becomes necessary to evaluate more subjective and complex criteria, more advanced techniques can be used, such as the deterministic model proposed by Garg (2022), which uses fuzzy and fuzzy sets combined with the modified distance approach.

In the present work, we explored the literature to obtain essential information about the process of evaluation and selection of COTS products with application in the Defense sector, which requires high rates of reliability and approval by military standards (MIL-SPEC), we identified research gaps and we proposed topics for future studies.

The rest of this article is organized as follows: Section 2. Methodological Aspectsbrings the methodological aspects of the research; in Section 3. Bibliographic Selection Review Protocol, the protocol adopted in the bibliographic selection of the portfolio of scientific works is detailed; in Section 4. Methodology, the methodology we adopted is explained; in Section 5. Morphological Analysis Results, the results of the Morphological Analysis and guidelines for future studies are presented and, finally, Section 6. Conclusionspresents the conclusions of this research.

2. Methodological aspects

This section provides methodological support for the present study. The steps used to select the articles that make up the bibliographic portfolio and used in the bibliometric analysis are presented, thus allowing a comprehensive understanding of how we achieved the objectives.

We adopted the Morphological Analysis as a methodological procedure in this research. Through the use of Morphological Analysis, according to the approach proposed by Ritchey (2011), a review of the existing literature is carried out to identify new research possibilities in the emerging theme "Selection and Evaluation of COTS for the Defense sector".

Originating in botanical science, Morphological Analysis is used in scientific disciplines to recognize and examine the complete set of possible relationships or configuration opportunities contained in a multidimensional phenomenon (Zwicky, 1969; Ritchey, 2011), such as Lean Sigma, in services (Sunder et al., 2018) , knowledge management in the supply chain field (Sudhindra et al., 2014) and dynamic capabilities as a theoretical basis (Ganesh & Marathe, 2019). This approach organizes the literature into a conceptual structure called Morphological Structure, classifying it into dimensions, sub-dimensions and variants (Goel et al., 2019).

A Zwicky box and Cross Consistency Matrix (CCM) (Zwicky, 1969), developed by cross-tabbing the dimensions, sub-dimensions and identified variants, provide a comprehensive set of research gaps, which are then qualified using logical rules (Sunder et al., 2018). Furthermore, the modular nature of Morphological Structure allows adding new dimensions and emerging variants to existing ones for future research (Prashar, 2022). Thus, Morphological Analysis introduced a new form of conceptual representation of the Literature on the intersection of domains for selection and evaluation of COTS for military use.

In this article, we address the following stages: (a) development of a protocol for reviewing the bibliographic selection; (b) deployment of a descriptive analysis; and (c) application of Morphological Analysis to portfolio elements. The main objective was to identify the state of the art on the subject and research gaps and, consequently, propose opportunities for future studies.

3. Bibliographic selection review protocol

This section presents the steps for selection of the bibliographic portfolio, which aims to gather publications with relevant content and scientific recognition in line with the chosen research topic.

3.1. Preliminary selection of raw article databases

This preliminary phase comprises the activities described in detail below:

3.1.1. Definition of search axes and keywords

We define the axes as (i) Product Requirements; and (ii) Defense. These axes were determined according to the objective of the study: to identify trends in the selection and evaluation of COTS products for military use. Then, keywords were defined for each search axis. The choice of these words was based on previous reading of some articles related to the research. As the searches were more comprehensive in English, we defined the keywords only in English.

Thus, we performed the searches with the following Boolean search phrase: *("Product Requirements" OR "Requirements Management" OR "Requirements Engineering" OR "Technical Requirements" OR "Decision Support" OR "Knowledge Management" OR " Evaluation and Selection Process" OR "Product Testing" OR "Product Design" OR "Product Configuration" OR "Product Development Process") AND ("Defense Equipment" OR "Defense Procurement" OR "COTS of defense" OR "COTS-based decision-making system" OR "COTS selection" OR "off-the-shelf commercial")* .

3.1.2. Database selection

The databases were selected according to their alignment with the research area and availability on the CAPES journal portal (Coordination for the Improvement of Higher Education Personnel). The databases were: Scopus, Science Direct, Springer Link, Web of Science (WoS), Engineering Village (COMPENDEX), IEEE Xplore and World Scientific.

3.1.3. Setting limit search filters

Due to the scarcity of articles published in congresses and journals on the research topic in the last five years (2019 to 2023), we decided to increase the spectrum of journals, not imposing a chronological limitation.

3.1.4. Keyword Adherence Test

The keyword adherence test was performed by reading the titles of the articles. Three articles aligned with the research theme were selected and tested. The keywords were aligned with those previously defined. Thus, the search continued using the previously highlighted keywords.

3.1.5. The design of the preliminary portfolio of articles

According to the methodology described above, the research took place between 02/17/2023 and 03/03/2023.

3.2. Article filtering

From the initial portfolio of 1,442 (one thousand four hundred and forty-two) studies, we removed 804 (eight hundred and four) duplicate articles belonging to previously selected databases, that is, a reduction of 25%, leaving a total of 1,078 (one thousand and seventy and eight) studies. Although a pre-selection was carried out directly in the databases, it was possible to verify the existence of references and documents from other areas (medicine, biology, radiology, food, etc.) outside the scope of this review. After this step, considering the exclusion of books/book chapters and also of titles that did not correspond to the objectives and axes of research outlined, 189 (one hundred and eighty-nine) studies remained.

Through the *Scimago portal Journal & Country Rank* (developed from the information contained in the Scopus database – Elsevier), it was possible to verify the ranking quartile of the journal of the study publication, the citations per document and the SJR index. Although the references were tabulated in this way, it was decided not to compose an exclusion criterion for the references, given the scarcity of relevant studies on the research topic related to the Defense sector.

The reading and evaluation of the abstracts began, with the aim of selecting the academic works that adhered to the research. Thus, 29 (twenty-nine) publications remained as the final portfolio. The review protocol steps are described in Chart 1, available below.

Chart 1. Literature Review Protocol.

Step 1: Searching for studies (in English) in databases using advanced search with Boolean operators	**Results**
	1442
Scopus	528 (+)
science direct	232 (+)
springer link	22 (+)
Web of Science (WOS)	48 (+)
Engineering Village (COMPENDEX)	261 (+)
IEEE Xplore	340 (+)
Scientific World	11 (+)
Duplicate studies in databases	364 (-)
Step 2: Initial selection based on Exclusion Criteria (EC)	1078
EC 1: Books and book chapters	85 (-)
EC 2: Titles/Journals with research areas outside the scope (medicine, biology, radiology, food, nature, etc.)	804 (-)
Step 3: Content selection of pre-selected studies based on the Selection Criteria (CS)	**189**
CS 1: Reading abstract	29
Study Portfolio	**29**

Source: Adapted from Prashar (2022).

4. Methodology

The Morphological Analysis approach offers a form of conceptual representation of the innovative Literature on the insertion of the theme in academic research (Prashar, 2022). The steps of the approach they are presented below.

4.1. A descriptive analysis of the included articles

A descriptive analysis was performed for the fundamental, methodological and chronological classification of the 29 (twenty-nine) articles identified in "*3. Bibliographic Selection Review Protocol*" for Morphological Structure.

While the fundamental classification seeks to find the key themes to determine the broader dimensions of the Morphological Analysis structure, as well as the country of origin of the research, the methodological classification categorizes the research methods used. At the same time, chronological analysis reveals temporal trends in studies.

As for the methodological classification, it can be observed that 41% of the articles are conceptual, 34% focus on a literature review and only one reference deals with a case study.

Regarding geographic distribution, sixteen studies are from the United States of America and nine from the United Kingdom. It is possible to observe that this concentration of references belongs to countries with a thriving Defense industry.

As for the chronological classification, the theme has been studied and improved since 1991.

Finally, regarding the distribution of journals, it is noted that the references are well distributed in different journals, congresses and conferences that dealt with this research topic.

Through Figure 2, available below, it is possible to graphically verify such classifications.

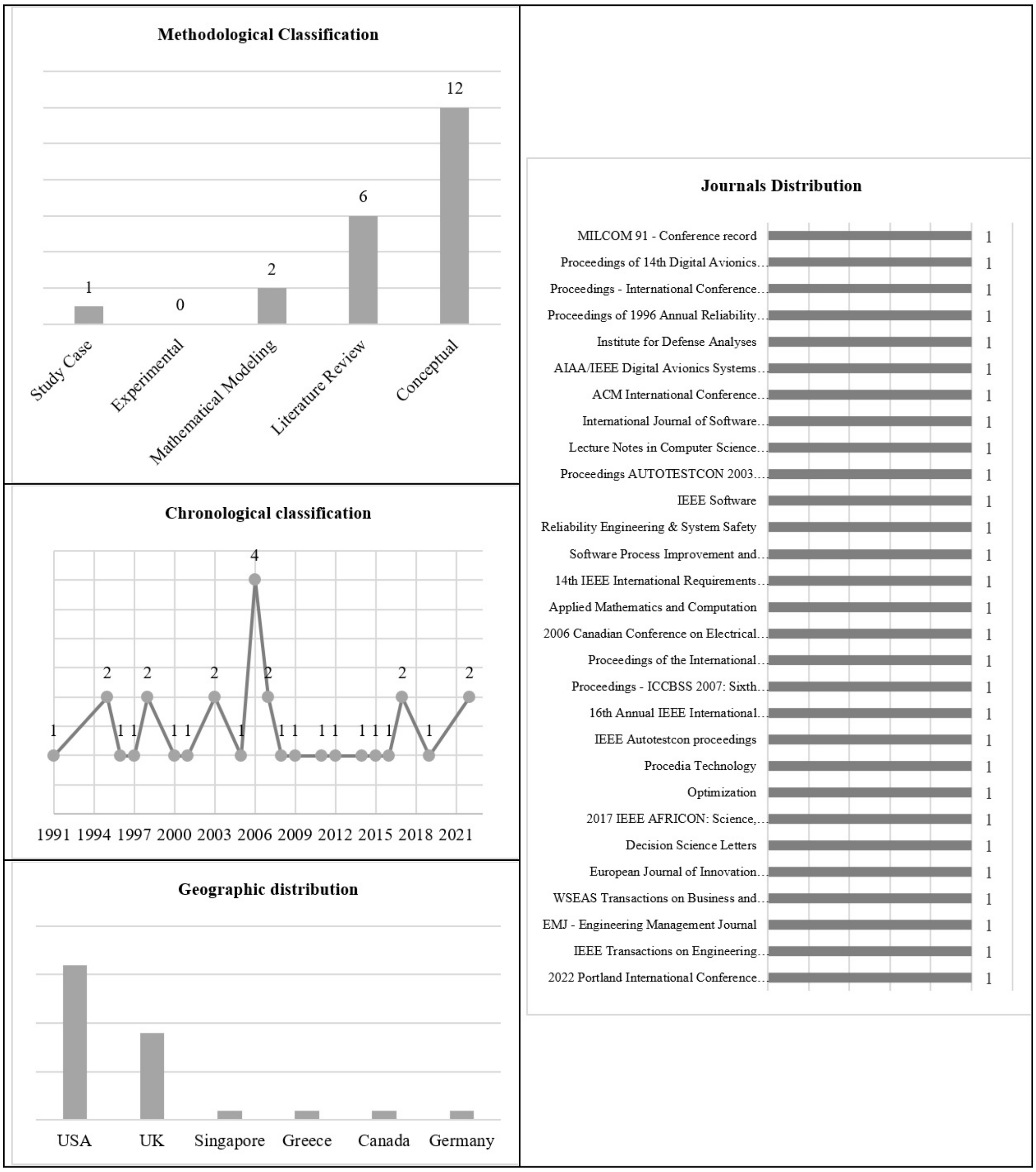

Figure 2. Descriptive analysis.
Source: Adapted from Prashar (2022).

4.2. Morphological analysis procedure

The number of 29 (twenty-nine) studies selected according to the methodology discussed in item " *3.2 Article filtering*" were read and interpreted. The steps taken in the procedure are listed in Figure 3 and are described in detail below.

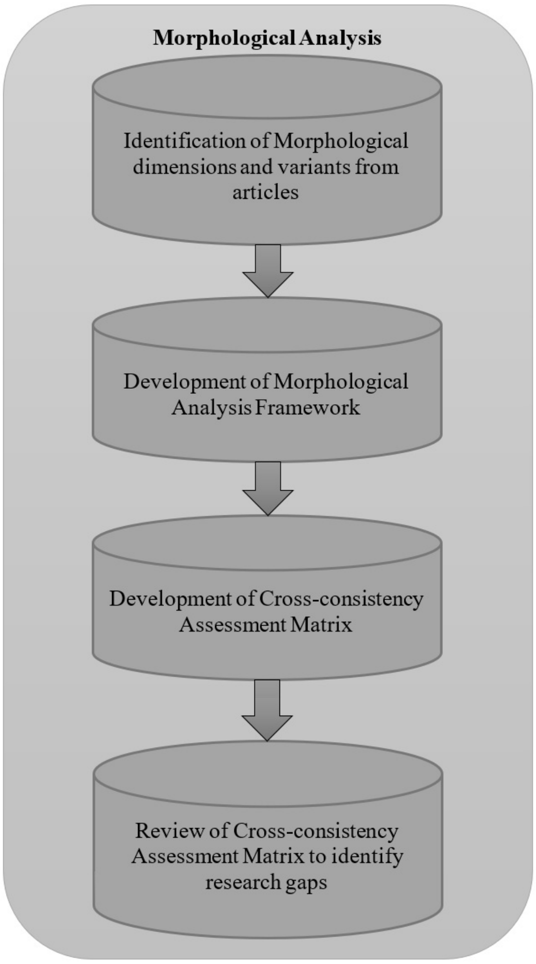

Figure 3. Steps of Morphological Analysis.
Source: Adapted from Prashar (2022).

Step 1: Classify and define the dimensions of the phenomena under study. A dimension refers to the distinct structural or conceptual component of a complex phenomenon and can constitute its inputs, process, output, control or limit. We obtained the dimensions and variants adopted in the structure of the Standard Industry Morphological Analysis Classification System (SIC), OSHA (2021), and are specified in Chart 2.

Step 2: Build a morphological or *Zwicky* box, the graphic demonstration of all (n) dimensions identified in an n-dimensional matrix, as shown in Chart 3. Each axis of the matrix is arranged in the number of variants appropriate for that dimension represented on an axis. Each cell in the Zwicky box corresponds to a configuration, a combination of (n) variants. Each variant in one dimension interacts with others in the remaining dimensions to create a configuration. The present study has n = 5 dimensions with 12, 7, 6, 13 and 5 variants, respectively. Therefore, the total number of potential configurations is 12 × 7 × 6 × 13 × 5 = 32,760. However, it should be noted that not all 546 configurations are research opportunities, as configurations may not add value and fall into a logically inconsistent category. Such inconsistencies must be eliminated before research opportunities are identified. A Cross Consistency Matrix (CCM) is constructed (step 3) to simplify the task.

Step 3: The development of the *Cross Consistency Matrix* (CCM) takes place in this step and is shown in Chart 4. The CCM is a matrix (n × n), where n is the total number of variants in all dimensions (n = 43 in our study). It offers an objective approach to identifying research gaps (Ritchey, 2011) by simplifying various configurations into variant pairs. For example, in the case study, the CCM allows revision of 1,849 (less than half) pairs of variants, rather than a massive 32,760 configurations involving five variants each. In this matrix, variants between dimensions are recorded in rows and columns. Each matrix cell is linked to the interaction between paired variants of different dimensions, which allows the determination of the upper limit of the search gaps. In our CC M, crossing 43 × 43 = 1849 variant pairs between highlighted dimensions 713 cells. Some of these interactions may have already been studied in the literature (marked in Chart 3). Furthermore, just like the *Zwicky box*, identifying a gap does not necessarily imply the theoretical or practical contribution of that gap. Identification must occur through a strategy (Step 4).

Step 4 : Identify research gaps through the gap-finding strategy, as recommended by Sunder et al. (2018) and Baliga et al. (2021), occurs at this stage. According to this strategy, the critical criterion for detecting research gaps is to establish a logical relationship of promising scientific research in the face of gaps obtained by crossing variants of different dimensions. In our CCM, crossing 43 × 43 = 1849 pairs of variants of the respective sizes showed 713 crossed cells. Of these 713 cells that intersect, variant pairs, which have previous research, were excluded. We then sought to independently qualify the remaining empty cells' research gaps based on their understanding of the Literature. Paired variants of different dimensions were compared, and all relationships that resulted in logical inconsistencies were removed after this detailed analysis. Gaps were identified based on their relevance to literature and practice. Any discrepancies were resolved with additional research into industry practices; thus, a final listing of gaps was established. When researching the relationships between the variants in the literature, it is essential to highlight that no reference was made to causality, and only the mutual consistency of the variants was analyzed. CCM also allows you to identify research gaps in more than two dimensions, as shown in the *Zwicky box* in Chart 3.

Concerning the data presented through the Cross Consistency Matrix (Chart 4), we can infer the following:

- The region in gray color was excluded in the cross-Consistency Matrix to avoid double counting when crossing dimensions;
- By excluding the gray region, we have a total of 713 research gaps, of which 52 opportunities mapped in the literature were identified;
- Of these 52 mapped opportunities, it is possible to verify the concentration of 13 studies related to construction projects aimed at cost reduction and 9 projects focused on product quality, given the cross combination of V10, V40, and V41 corresponding to dimensions D1 and D5;
- It is also possible to observe that 4 studies mapped by crossing V11 and V13, in dimensions D1 and D2, show concern in relating demand forecast in the context of production planning with logistics;
- The regions in blue, which correspond to the amount of 713 – 52 = 661 still unexplored research gaps, may or may not contribute to the generation of a research opportunity, and it is up to the researcher to evaluate each case; and
- Finally, the researcher in front of the Cross Consistency Matrix (CCM) must evaluate the research gaps that generate research questions and potential topics that may contribute to the academic environment, bringing innovation and scientific relevance.

5. Morphological analysis results

The Cross Consistency Matrix (CCM) visualizes the 661 research areas still unexplored (in blue color), also called research gaps. The combination of variants of different dimensions makes it possible to carry out combinations suggested by scholars (Sunder et al., 2018).

CCM therefore allows for pairwise comparison of variants of different dimensions and acts as a scholarly study counter with a visual presentation of potential research gaps.

As previously mentioned, of the 32,760 (5 dimensions and 43 variants) possible configurations of the CCM, the researcher must ignore the relationships that promote normative, logical or empirical inconsistencies (Ritchey, 2011)

The researchers' judgment is required to assess the research potential of these combinations of variant pairs in light of any inconsistencies or absence of significant relationships.

Pairs were analyzed without any reference to causality or direction of association between the two variants. This process resulted in the identification of 661 research gaps (in blue in Chart 4) that researchers can consider for further examination after reviewing their research potential.

It should be noted that the CCM in-depth analysis may also reveal additional research gaps (beyond the 661) that cross variants of three or more dimensions or more than three variants of any two dimensions.

Although space limitations preclude detailed discussions of all these 661 gaps (Chart 4), some examples of possible research questions arising from such pairs are presented in Chart 5, available below.

Based on the research questions identified in Chart 5, we elaborated potential topics for academic research, as shown in Chart 6. Thus, the identification and analysis of gaps in the CCM is concluded, with the consequent proposition of innovative research topics from a scientific point of view on the chosen topic.

Chart 2. Dimensions and Variants.

D1: Study environment	D2: PCC Functions	D3: Technologies facilitators	D4: Capabilities fingerprints	D5: Performance result
V1: Metal fabricated	V13: Demand forecast.	V20: IoT / IoT.	V26: Real-time capabilities.	V39: Operational flexibility.
V2: Transport equipment.	V14: Capacity planning and control.	V21: Big data and analytics.	V27: Dynamic adaptability.	V40: Cost reduction.
V3: Electronic and electrical equipment.	V15: Aggregate Planning/Sales and Operations Planning.	V22: Machine Learning/ Deep Learning/ Neural Networks.	V28: Traceability and visibility.	V41: Product/process quality.
V4: Measurement, analysis and control instruments.	V16: Master Production Schedule (MPS).	V23: Cloud manufacturing services.	V29: Synchronization	V42: Reduction of delivery time.
V5: Industrial and commercial machines.	V17: Material Requirements Planning (MRP).	V24: Additive Manufacturing.	V30: Autonomous.	V43: Productivity.
V6: Food processing.	V18: Production scheduling/rescheduling.	V25: CPS/CPPS	V31: Servitization.	
V7: Chemical industry and related.	V19: Full PPC Function.		V32: Scalability and reconfiguration.	
V8: Renewable and non-renewable energy.			V33: Distributed/decentralized planning and control.	
V9: Textile.			V34: Collaboration and cooperation.	
V10: Construction project.			V35: Mass customization.	
V11: Logistics service.			V36: Sustainable/green.	
job shop and flow shop manufacturing configurations.			V37: Context awareness.	
			V38: Intelligent programming and control on the factory floor.	

Source: Adapted from Prashar (2022).

Chart 3. Morphological Analysis Chart.

D1: study settings				
V3: Electronic and electrical equipment.	**V4: Measurement, analysis and control instruments.**	**V7: Chemical industry and related.**	**V10: Construction project.**	**V11: Logistics service.**
Selection of electronic avionics systems	Automated Test Equipment (CATE) Case Study	Case study of products for Chemical, Biological, Radiological and Nuclear Defense	Support model to select COTS	Life cycle and logistics **(Zikos et al., 2022)**
(Trujillo, 1995)	**(Burrus et al., 2012)**	**(Mathopo & Marnewick, 2017)**	**(Julian et al., 2011) (Mathopo & Marnewick, 2017)**	USAF Lifecycle
Electronic Hardware Selection (USAF, NAVY)			FMDBA as a COTS selection and evaluation criterion (Garg, 2022)	**(Kenneth, 2000)**
(Thames, 1998)			Ensuring successful implementation of business items into Air Force systems **(Kenneth, 2000)**	Life Cycle and its Impacts on the Insertion of COTS in Military Systems
COTS case study for an electronic payment system **(Garg, 2022)**			“Buy Early” Approach **(Kohl, R. J. (2005)**	**(Bil & Mo, 2013)**
			Repositories to manage COTS selection **(Wanyama & Far, 2006)**	Lifecycle Impacts of Entering COTS in the Government Inventory
			Multicriteria decision making (AHP) and TOPSIS for weapon selection **(Dağdeviren et al., 2009)**	**(Hull et al., 1997)**
			MCDM with AHP for selection and evaluation of COTS components **(Verma & Mehlawat, 2017)**	COTS Maintenance/Support
			COTS procurement incorporating supplier business factors **(Miller & Yeoh, 2006)**	**(Burrus et al., 2012) (Pizzica, 1998)**
			Approach to dealing with conflicts between COTS requirements and characteristics in the context of a selection and evaluation process **(Alves & Finkelstein, 2003)**	
			Testing in COTS **(Gutterman, 2003)**	
			Lessons Learned: COTS Selection – British Army **(Hull et al., 1997)**	
			COTS selection process **(Kontio, 1995)**	
			COTS selective filtering approach **(Basir et al., 2015)**	
			Guidelines for selecting military COTS equipment **(Demko, 1996)**	

Chart 3. Continued…

D2: PCC Functions				
V13: Demand forecast.	V14: Capacity planning and control.	V15: Aggregate Planning/Sales and Operations Planning.	V16: Master Production Schedule (MPS).	V19: Full PPC function.
Life cycle and sustainability of parts and components **(Zikos et al., 2022)**	Purchasing planning based on military requirements	Life Cycle Dimension	Repositories (separate and individualized) to manage the selection of COTS (macro process) **(Wanyama & Far, 2006)**	COTS selection management through a progressive filtering approach **(Basir et al., 2015)**
(Bil & Mo, 2013)	**(Julian et al., 2011)**	**(Zikos et al., 2022)**		
(Hull et al., 1997)	Pros and Cons of COTS Integration in the US Army	**(Julian et al., 2011)**		
(Burrus et al., 2012)	**(Hawkins & Gravier, 2019)**	Planning for the insertion of COTS in the USAF		
	COTS selection planning based on non-technical elements **(Carvallo et al., 2006)**	**(Kenneth, 2000)**		
	Approach to dealing with conflicts in the selection of COTS **(Alves & Finkelstein, 2002)**	Need for planning for acquisition of COTS for military use **(Hull et al., 1997)**		
	Approach to testing COTS for military use **(Gutterman, 2003)**			
	Sustainability planning and maintenance of military COTS **(Burrus et al., 2012)**			
	(Pizzica, 1998)			
D3: Enabling Technologies		**D4: Digital capabilities**		
V21: Big Data and Analytics	V25: CPS/CPPS	V28: Traceability and visibility.	V32: Scalability and reconfiguration.	V37: Context awareness.
Structure using ANP and TOPSIS **(Shyur, 2006)**	Approach to dealing with inconsistencies during the COTS selection and evaluation process **(Mohamed et al., 2007a)**	Proposes a weighted scheme for the COTS component that provides visibility and traceability **(Julian et al., 2011)**	COTS reliability in military equipment **(Demko, 1996)**	Analyzes the military context
Weapon selection using AHP and TOPISIS **(Dağdeviren et al., 2009)**		Matrix formulation for selecting COTS components **(Verma & Mehlawat, 2017)**		**(Julian et al., 2011)**
Selection (MCDM) of COTS software **(Kontio, 1995)**				**(Thames, 1998)**
MCDM optimization model for selecting and evaluating COTS components **(Verma & Mehlawat, 2017)**				Highlights the importance of military standards in the field of Defense equipment
The business model for selecting COTS **(Miller & Yeoh, 2006)**				**(Trujillo, 1995)**
Selection of COTS by non-technical criteria **(Carvallo et al., 2006)**				Advantages and risks of including COTS in the selection of military equipment **(Pizzica, 1998)**
Approach to MCDM through the analysis of functional and non-functional criteria **(Basir et al., 2015)**				Highlights the importance of MIL-STD in the use of modified COTS **(Gutterman, 2003)**
				COTS for military use, a challenge with the necessary adaptations **(Demko, 1996)**
				Military context impacted by COTS **(Hull et al., 1997)**

Chart 3. Continued…

D5: Performance result				
V39: Operational flexibility.	V40: Cost reduction.	V41: Product/process quality.	V42: Reduction of delivery time.	V43: Productivity.
flexible method	COTS selection process on new equipment development	A systematic approach to mitigating risks to acceptable levels **(Julian et al., 2011)**	Proposal for an FMDBA approach as an efficient tool (Reduction of time) in multicriteria problems (MCDM) **(Garg, 2022)**	Resolves requirements conflicts in the context of COTS selection **(Alves & Finkelstein, 2003)** **(Mohamed et al., 2007b)**
(Julian et al., 2011)	**(Julian et al., 2011)**	MIL-STD Standards **(Trujillo, 1995)**		
The flexibility of requirements to enable the acquisition of COTS	**(Trujillo, 1995)**	How to Succeed When Selecting Electronic Hardware COTS		
(Gansler et al., 2008)	**(Hawkins & Gravier, 2019)**	**(Thames, 1998)**		
(Kenneth, 2000)	**(Burrus et al., 2012)**	Integration of developed products and COTS **(Hall & Naff, 2001)**		
(Wanyama & Far, 2006)	**(Garg, 2022)**	COTS testing using MIL-STD ensures quality for the performance expected by military equipment **(Gutterman, 2003)**		
(Zikos et al., 2022)	**(Kontio, 1995)**	Selecting COTS Equipment for Defense **(Mathopo & Marnewick, 2017)**		
(Shyur, 2006)	**(Hedman & Andersson, 2014)**	Adherence to MIL-STD **(Dağdeviren et al., 2009)**		
	(Pizzica, 1998)	An approach that contemplates quality in the selection of COTS **(Verma & Mehlawat, 2017)** **(Miller & Yeoh, 2006)**		
	(Gutterman, 2003)	Use of non-technical criteria in the selection of COTS **(Carvallo et al., 2006)**		
	(Hull et al., 1997)	**(Hull et al., 1997)**		
	(Mathopo & Marnewick, 2017)	**(Kontio, 1995)**		
	(Kenneth, 2000)	**(Burrus et al., 2012)**		
	(Kohl, 2005)	**(Basir et al., 2015)**		
	(Dağdeviren et al., 2009)	**(Demko, 1996)**		
	(Verma & Mehlawat, 2017)			
	(Miller & Yeoh, 2006)			
	(Alves & Finkelstein, 2003)			
	(Bil & Mo, 2013)			
	(Hull et al., 1997)			
	(Burrus et al., 2012)			
	(Basir et al., 2015)			
	(Demko, 1996)			

Source: Adapted from Prashar (2022).

Chart 4. Cross Consistency Matrix (CCM).

		D1: Study setup												D2: PPC functions							D3: Enabling Technologies						D4: Digital capabilities												
		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30	V31	V32	V33	V34	V35	V36	V37	V38
D2: PPC functions	V13				1							4																											
	V14				1						2	1																											
	V15											2																											
	V16																																						
	V17																																						
	V18																																						
	V19										1																												
D3: Enabling Technologies	V20																																						
	V21										4				1																								
	V22																																						
	V23																																						
	V24																																						
	V25										1																												
D4: Digital capabilities	V26																																						
	V27																																						
	V28										1																												
	V29																																						
	V30																																						
	V31																																						
	V32										1																												
	V33																																						
	V34																																						
	V35																																						
	V36																																						
	V37			2							4	1			1	1																							
	V38																																						
D5: Performance result	V39										2	2		1	1	3	1					1																	
	V40			1	1			1			13	2		2	2	2						2				1			1					1				2	
	V41			2	1			1			9			1	3	1						3							1					1				3	
	V42			1							1																												
	V43										1															2													

Source: Adapted from Prashar (2022).

Chart 5. Representative example of a pair of CCM variants representing research gaps.

Pair of dimensions associated	Pair of associated variants representing each research gap	Possible research question based on identified research gaps
D1 and D2	V10 and V13; V12 and V14	What is the approach/methodology for equipment selection with predictability of replacement items, being flexible and modular and controlling Defense resource needs on a fixed time frame?
D2 and D3	V14 and V21	What method/technique establishes the planning and control of the capacity/resources for the acquisition of Defense equipment, allowing the processing of a large amount of data/needs from the client?
D2 and D4	V37 and V13	What would an Intelligent Manufacturing artifact that would enable demand forecasting in the context of planning and scheduling the acquisition of commercial equipment for the Defense sector look like?
D2 and D5	V16 and V40 and V41	Which artifact allows you to plan/manage the risks associated with the acquisition of commercial equipment for use in the Defense sector?
D4 and D5	V29 and V32 with V40 and V41	Is there an artifact for selecting and evaluating trade items in a flexible production environment that ensures equipment quality and can be utilized in different Department of Defense procurement settings?

Source: Adapted from Goel et al. (2019).

Chart 6. Proposals for possible research topics.

Research Topics (RT)	Dimensions	Set of variants	Potential research topics
RT-1	D1-D2	V1-12 and V13 and V14	Empirical research on design/approach to selecting COTS for use in the Defense sector, including data analysis and control capabilities. The study addresses the development of a methodology/approach for flexible production planning.
RT-2	D2-D3	V14 and V21	Adoption/application project of Multicriteria Decision tool/artifact (MCDM) to manage large volumes of information and allow capacity planning and control to be addressed in the context of Defense.
RT-3	D2-D4	V14-15 and V38	Elaboration of a modular artifact that allows traceability and visibility of information, in real time, for Production Planning and Control (PCP), focusing on the needs of the military customer.
RT-4	D2-D5	V16 and V40 and V41	Planning mapping and processing activities to select COTS for military use in order to reduce total Life Cycle costs and ensure product quality given its specific low failure rate nature.
RT-5	D4-D5	V29 and V32 and V40 and V41	An artifact that allows the synchronization of COTS selection and evaluation processes, with military quality specifications (MIL-SPEC), in a flexible, scalable and modular production environment simultaneously.

Source: Adapted from Prashar (2022)

As already mentioned, potential research topics, available in the last column of Chart 6, express the researcher's perception of the research questions identified as the most promising gaps to be explored in future studies, in contribution to the academic environment.

Therefore, through this analysis based on a rigorous scientific procedure, the researcher could propose innovative and relevant research topics for the literature.

6. Conclusions

Equipment used by the Defense sector, due to the specific nature of the military activity, requires low failure rates, high reliability, and consequently, approval in quality tests standardized by MIL-STD standards. That said, it is of great importance to choose an adequate method for conducting the evaluation and selection of COTS (products and components), to mitigate the risks associated with the acquisition of non-compliant equipment concerning the customer's needs. An appropriate method contributes to the good use of public resources, as a good acquisition represents less costs with maintenance and acquisition of parts throughout the product's life cycle, and is aligned with the prerogative of safeguarding people's lives.

In this article, a Systematic Review and Morphological Analysis of more than three decades of scientific studies on "*COTS Selection and Evaluation for the Defense Sector"* was performed. The examination revealed that the Literature is dispersed in several journals related to management and optimization.

In addition, it was possible to observe the evolution of the research literature and identify many unexplored areas that may motivate future research, as indicated in the CCM by the blue color (Chart 4).

An analysis of research gaps arising from the intersection of relevant variants was performed in Chart 5 and materialized through research questions in Chart 6. Potential research topics were presented to compose future studies on the subject. Thus, the Morphological Analysis of the theme ends: Evaluation and Selection of COTS equipment for use in the Defense sector.

In this way, the present work contributes to the identification of innovative research themes based on Morphological Analysis, a scientific method recognized and accepted in the academic environment. Therefore, it acts as a methodological guide for scientific research.

Given the above, as already mentioned in this work, the modular character of the Morphological Structure allows adding new dimensions and variants to the existing ones, which facilitates the researcher's work in the future updating of this scientific analysis, being able to expand it shortly.

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