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DOI 10. 52781/cmm.a131

Lean Manufacturing in the context of National Defense applied in defense industries and the Armed Forces: an integrative review

La manufactura esbelta en el contexto de la defensa nacional aplicada en las industrias de defensa y las fuerzas armadas: una revisión integradora

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Abstract: This paper aims to present the contributions of lean manufacturing in the context of National Defense, via an integrative literature review focused on applications in defense industries and Armed Forces, and identify opportunities to integrate the lean manufacturing to the Brazilian Army. The integrative literature review highlighted 27 articles, in which military organizations and defense industries around the world have benefited from the application of lean principles and tools, as it eliminates or reduces process waste, mainly related to waiting between activities and unnecessary processing, achieving better results in the delivery of their goods and services. Value Stream Mapping (VSM) stands out as the main lean manufacturing tool for process improvement and efficient application of resources. The opportunities to integrate lean manufacturing into the Brazilian Army are primarily identified in the processes of maintenance, repair, and overhaul of Military Employment Systems and Materials (SMEM), and can be applied in other environments such as health management, military works management, organizational management, project management, SMEM life cycle management, and supply logistics management.

Keywords: Lean Manufacturing. Brazilian Army. Integrative Review. Systems and Materials for Military Use.

Resumen: Este trabajo tiene como objetivo presentar las contribuciones de la manufactura esbelta en el contexto de la defensa nacional, a partir de una revisión integradora de la literatura centrada en aplicaciones en las industrias de defensa y las Fuerzas Armadas, e identificar oportunidades para integrarla en el Ejército Brasileño. La revisión integradora de la literatura destacó 27 artículos, en los que organizaciones militares e industrias de defensa de todo el mundo se han beneficiado de la aplicación de los principios y herramientas de la manufactura esbelta, en la medida en que elimina o reduce desperdicios de procesos, principalmente relacionados con la espera entre actividades y procesamientos innecesarios, logrando mejores resultados en la entrega de sus bienes y servicios. El Mapeo del Flujo de Valor (MFV) se destaca como la principal herramienta de manufactura esbelta para la mejora de procesos y la aplicación eficiente de recursos. Las oportunidades para integrarlo al Ejército Brasileño se identifican principalmente en los procesos de mantenimiento, modernización y revitalización de los Sistemas y Materiales de Empleo Militar (SMEM), y pueden ser aplicadas en otros ambientes como gestión hospitalaria, obras militares, gestión organizacional, de proyectos, ciclo de vida de las PYMES y logística de suministro.

Palabras clave: Manufactura Esbelta. Ejército Brasileño. Revisión Integradora. Sistemas y Materiales de Empleo Militar.

Received: Out 24, 2023
Accepted: Jun 24, 2024

COLEÇÃO MEIRA MATTOS
ISSN on-line 2316-4891 / ISSN print 2316-4833
http://ebrevistas.eb.mil.br/index.php/RMM/index

1 INTRODUCTION

The Brazilian Army, in its transformation process, has been seeking to improve the Land Military Logistic System by modernizing the existing maintenance lines in maintenance parks and war arsenals, which conduct maintenance services on Military Employment Systems and Materials (SMEM). Aligned with this, the Science, Technology, and Innovation System of the Brazilian Army has been working to enhance the management of the manufacturing system, which includes activities related to the modernization and/or revitalization of SMEM developed in the Brazilian Army's manufacturing structures.

Among the aspects observed in the management of maintenance, modernization, and/or revitalization processes of SMEM, the use of modern operations management systems points to a better utilization of employed resources, be they financial, human, physical infrastructure, or others. Lean manufacturing is characterized as the standard operations management model for the 21st century (Rinehart; Huxley; Robertson, 1997 apud Shah; Ward, 2007).

One of the main objectives of lean manufacturing is to apply a philosophy that allows organizations to increase efficiency and enhance processes through continuous improvement, reducing and eliminating waste (Womack; Jones, 2004). Thus, lean manufacturing relates to superior performance and the ability to provide competitive advantages to organizations (Shah; Ward, 2003 apud Shah; Ward, 2007).

This study investigates the contribution of lean manufacturing in the context of national defense, focusing on studies and applications in the Armed Forces and defense industries. From these contributions, it identifies opportunities to integrate the lean manufacturing philosophy into the Brazilian Army. Given this aim, the following research questions are presented:

- How has lean manufacturing contributed to improve the performance of defense industries and the Armed Forces?
- Which lean manufacturing tools have already been applied to defense industries and the Armed Forces?
- What are the opportunities to integrate the lean manufacturing philosophy into the Brazilian Army?

1.1 Brazilian Army Transformation Context

Significant changes have occurred in all sectors of Brazil since the emergence of new business models to the reshaping of production systems. In recent years, the Brazilian Army has been undergoing a transformation process to acquire capabilities compatible with the rapid evolution of humanity.

The Brazilian Army's transformation process is aligned with the policies and guidelines in the national defense sphere, which are established by the National Defense Policy (PND) and the National Defense Strategy (END). Brazil's defense structure includes:

studies regarding threats to sovereignty and national interests; the development of the potential of all sectors of the country; modernization of equipment and the qualification of the Armed Forces' human capital. Additionally, discussions are held on concepts, doctrines, guidelines, and procedures for preparing and employing the military expression of national power (Brasil, 2020b).

The *Livro Branco de Defesa Nacional* (LBDN), based on the PND and END, defines defense transformation as a consequence of the need to improve the Armed Forces, equipping them with the appropriate capabilities to fulfill their constitutional mandate. In Brazil, defense transformation occurs through three pillars: the Defense Articulation and Equipment Plan (PAED), the modernization of national defense system management, and the reorganization of the Defense Industrial Base (BID) (Brasil, 2020a).

In this context, the PAED consolidates the Armed Forces' strategic projects aimed at meeting the articulation and equipment needs required to fulfill their constitutional mission, as outlined in the END. One of the priority projects is called Achieving Full Operational Capacity (OCOP). OCOP refers to achieving high availability and reliability of equipment, encompassing the recovery of existing assets, their revitalization and modernization, and even their replacement due to obsolescence (Brasil, 2020a).

Strategic programs and projects act as drivers of the transformation process underway in the Brazilian Army (Brasil, 2020b). The direction of investment efforts is guided by the Army Strategic Plan (PEEx) (Brasil, 2019), based on the capabilities of interest to the Army. Finally, relating the objectives proposed in the PEEx to the central theme of this study, the following strategic objectives of the Army (OEE) are highlighted

- OEE8 – Improve the Land Military Logistic System: establishes the modernization of production and maintenance lines in the war plants and arsenals.
- OEE9 – Improve the Science, Technology, and Innovation System: establishes the enhancement of the manufacturing system management through the mapping of processes related to the modernization of SMEM developed in the manufacturing structures of the Brazilian Army.

It is important to highlight that the Brazilian Army's transformation process, under the science and technology vector, must be capable of achieving the necessary paradigm shift in all its systems and functions to reach the Army of the Future (Prado Filho, 2014). The importance of scientific-technological capacity in the expression of national military power, manifested in research and development, production, and SMEM modernization activities, which are conducted by military organizations and companies within the Defense Industrial Base (BID), is a central element in the development and sustainability of military power (Galdino; Schons, 2022).

In light of the presented situation, public and private organizations, both civilian and military, have been striving to acquire capabilities compatible with the rapid evolution of humanity. In the wake of development and the profound changes occurring in all sectors of nations, in the pursuit of a production management system capable of adapting to new scenarios and demands, lean manufacturing is seen as a suitable solution for organizations to work by eliminating or avoiding waste, in search of high productivity with quality, agility, and flexibility.

1.2 Lean manufacturing

The history of lean manufacturing dates back to the 1950s, after World War II, when Japanese engineers Eiji Toyoda and Taiichi Ohno, from the Toyota Motor Company, an automobile manufacturing company founded in 1937, believed it was possible to improve the production system. In 1949, Toyota faced major problems, undergoing a collapse in sales and mass layoffs of its employees. Notably, by 1950, Toyota had produced 2,685 automobiles, while Ford's Rouge factory in Detroit, United States (USA), produced 7,000 units of automobiles per day (Womack; Jones; Roos, 1990).

In this scenario, after a visit by Eiji Toyoda to Ford's Rouge factory, the engineers improved the Ford production model and began, experimentally, what came to be known as the Toyota Production System (TPS) at Toyota, which eventually became lean production (Womack; Jones; Roos, 1990).

The emergence of TPS aimed to create a more flexible and faster production system in response to market changes. These characteristics would become an important strategic differentiator, as the prompt response to constant market variations was aligned with achieving effective results in the main dimensions of competitiveness: innovation, flexibility, quality, cost, and service (Shingo, 1996).

The term "lean production" or "lean manufacturing" was coined in the late 1980s by researchers from the International Motor Vehicle Program (IMVP), a research program linked to the Massachusetts Institute of Technology (MIT). They aimed at understanding the challenges faced by the global automotive industry, which at the time was undergoing a paradigm shift in the production system, from mass production to a flexible, efficient, and innovative production system (Womack; Jones; Roos, 1990).

Krafcik (1988), a researcher associated with MIT's IMVP research program, was the first to use the term "lean." However, the popularization of the term "lean manufacturing" occurred with Womack et al. (1990), who described the manufacturing practices of TPS, developed to adapt to the scarce resources of the Japanese economy after World War II.

According to Ohno (1997), the foundation of TPS is the elimination of waste with the integration of principles and tools that drive the pursuit of excellence. Lean manufacturing is based on five principles, which provide a better understanding of its foundations and lean thinking perspectives: d*efine value,* by determining the precise added value of each specific product; *map value stream*, by studying the value chain for each product; *create flow*, by making the value flow without interruptions; *establish pull*, allowing customers to pull value from the product; and *pursue perfection*, continuously seeking improvement. Based on these principles, industries become flexible and capable of effectively responding to market needs (Womack; Jones, 2004).

Shingo (1996) states that the main feature of TPS is waste reduction, as previously waste was considered part of the job. Eliminating waste means analyzing all activities and processes in a production system and suppressing those that do not add value to the final product (Womack; Jones, 2004). Ohno (1997) identifies production waste based on theories and principles of Henry Ford.

According to Ohno (1997) and Shingo (1996), wastes in lean manufacturing can be classified into seven categories, as follows. *Overproduction*, or producing more than necessary; *waiting*, or idle time of people and equipment; *transportation*, or unnecessary movement of materials; *processing*, of unnecessary work and improper material processing; *inventory*, or excessive quantity of available material; *movement*, or unnecessary movement of personnel; and *defects*, or products with lower quality than desired by the customer, requiring rework.

Thus, lean manufacturing seeks production excellence by integrating principles and tools, all through continuous improvements. Additionally, it aims to reduce and eliminate waste, allowing organizations to lower costs, increase profit margins, and improve processes.

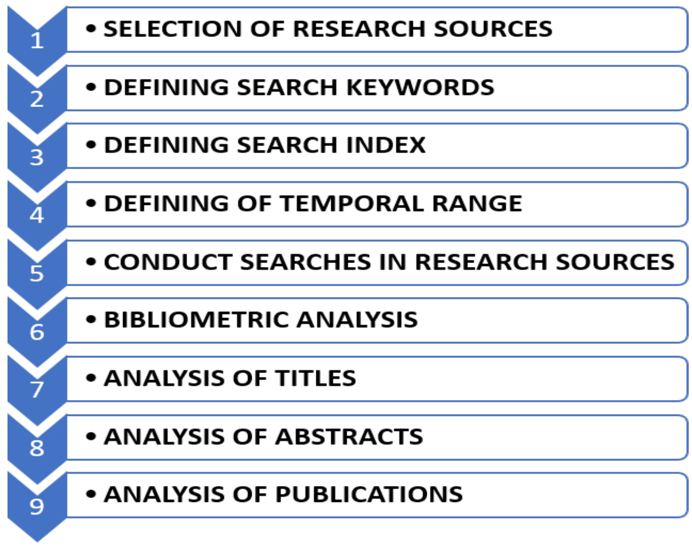
This work is structured as follows. The introduction presents the context of the Brazilian Army's transformation and the historical evolution of lean manufacturing. The methodology section outlines the research design as an integrative literature review, identifying works that address contributions of lean manufacturing to defense industries and Armed Forces. The results and discussions section analyzes the works found in the literature review, identifying performance gains achieved through the application of the lean philosophy and its tools. Finally, the conclusion offers insights on the topic focused on applications in the Armed Forces, as well as opportunities to integrate lean manufacturing into the Brazilian Army.

2 METODOLOGY

Literature reviews aim to map a research field and its development, as well as to identify existing gaps (Chen, 2017). Thus, in this study, a literature review was conducted aimed at identifying and mapping national and international works relating lean manufacturing to Brazilian national defense, focusing on defense industries and the Armed Forces. Snyder (2019) states that the main types of reviews are: systematic, semi-systematic, and integrative.

In this study, an integrative review was adopted to evaluate and synthesize knowledge on the research topic and uncover new contributions that can fill existing gaps. The integrative review should result in an advancement of knowledge, rather than simply describing and providing an overview of the research area (Snyder, 2019). The systematic process used to develop this review was adapted from a systematic method for conducting research in journal databases (Lacerda, 2009). Figure 1 presents the steps used.

Figure 1. Steps for the literature review



Source: the authors

The selected information sources were national and international studies, considering works published in journals (articles and reviews) and papers from conferences or congresses (conference paper and proceedings paper), found in the following databases: SCOPUS and Web of Science (WOB). These databases contain important information for bibliometric analysis, including abstracts, references, citation indices, authors, institutions, affiliations, countries, impact factor, and other details (Carvalho; Fleury; Lopes, 2013). The keywords were defined based on the application environment of lean manufacturing: defense industries and Armed Forces (Army, Navy, and Air Force). Table 1 presents the search strings used in the respective databases.

Table 1. Search string for literature review

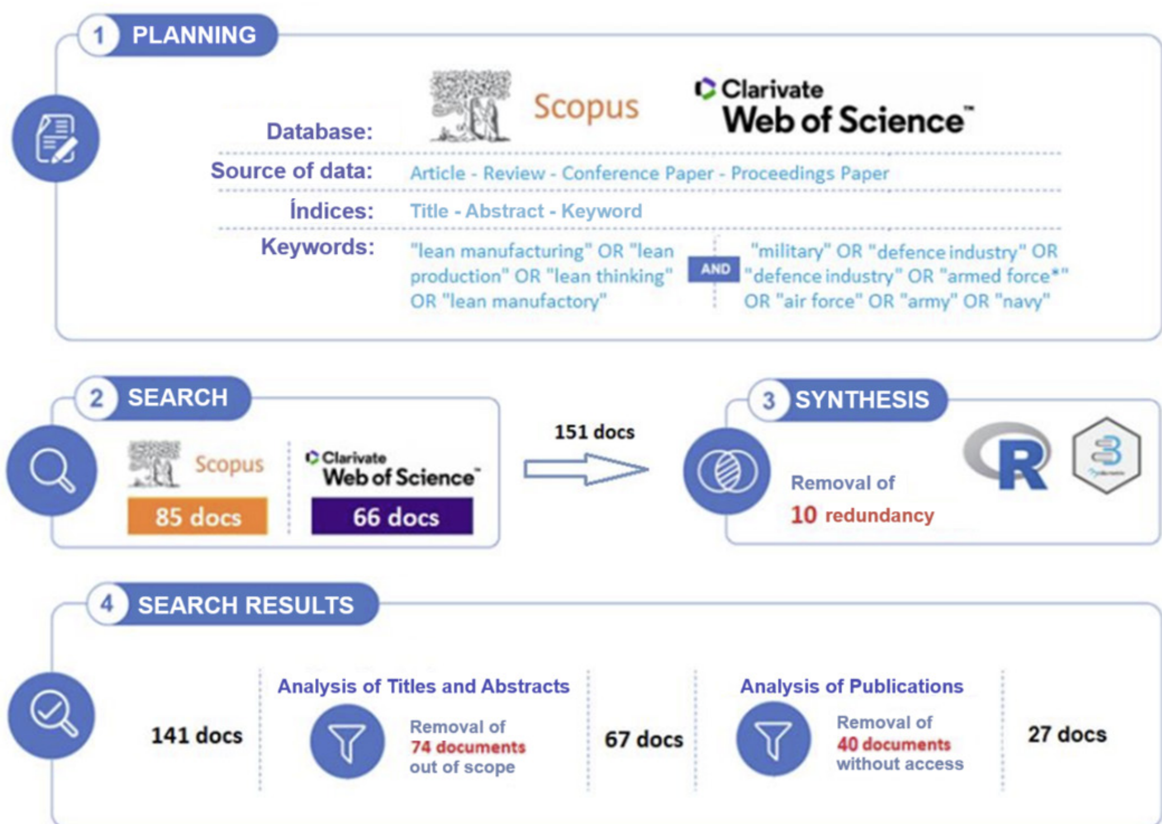
Database	Search string
SCOPUS	TITLE-ABS-KEY ((“lean manufacturing” OR “lean production” OR “lean thinking” OR “lean manufactory”) AND (“military” OR “industry defence” OR “industry defense” OR “armed force*” OR “air force” OR “army” OR “navy”))
Web of Science	TS=(((lean manufacturing) OR (lean production) OR (lean thinking) OR (lean manufactory)) AND ((military) OR (industry defence) OR (industry defense) OR (armed force*) OR (air force) OR (army) OR (navy)))

Source: the authors.

The title, abstract, and keywords were defined as search indexes as these are the first components of an article that readers keep contact, playing a role in their decision-making process on whether or not to read a text (Garcia; Gattaz; Gattaz, 2019). Regarding the time range defined for the research, no specific period was established, aiming to capture the largest possible number of publications.

Figure 2 presents the outlined research procedure based on the sequence of steps proposed for the review. After collecting and importing data from the SCOPUS and Web of Science databases in BibTeX format using RStudio software, a duplicate check filter was applied to avoid redundant documents. During the analysis of titles and abstracts, 74 studies deemed outside the research scope were excluded. Finally, in the publication analysis phase, the full content of 27 papers was reviewed.

Figure 2. Procedure of the search on lean manufacturing and defense (armed forces and defense industries)



Source: the authors.

3 RESULTS AND DISCUSSIONS

This study investigated the contributions of lean manufacturing in defense industries and Armed Forces. Its findings allowed the identification of opportunities to integrate lean manufacturing into the Brazilian Army, addressing the research questions outlined in the introduction of this work:

- How has lean manufacturing contributed to improve the performance of defense industries and the Armed Forces?
- Which lean manufacturing tools have already been applied to defense industries and the Armed Forces?
- What are the opportunities to integrate the lean manufacturing philosophy into the Brazilian Army?

Initially, the analysis of the 27 selected documents permitted to draw a relationship regarding global scientific production on the topic of lean manufacturing and defense. Table 2 presents the distribution of scientific production by country.

Table 2. Scientific production worldwide on lean manufacturing and defense (armed forces and defense industries)

País	Qty
USA	13
Italy	3
United Kingdom	2
Spain	2
Belgium	1
Brazil	1
Singapore	1
China	1
India	1
Malaysia	1
Norway	1

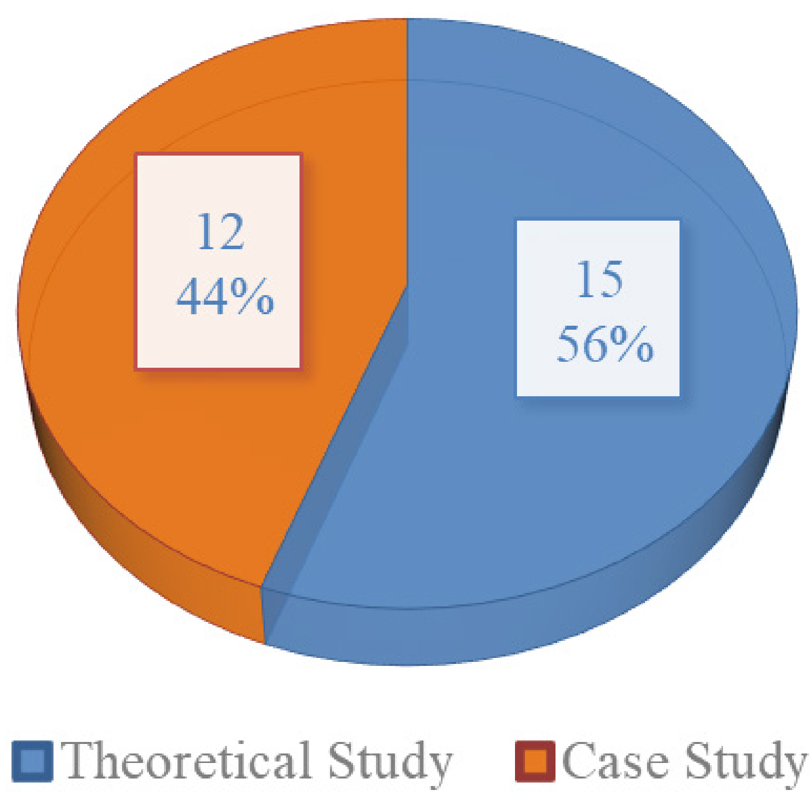
Source: the authors.

Given the distribution presented in Table 2, a higher number of U.S. publications are observed, which may be due to several factors. First, it is worth noting that studies aimed at understanding the challenges faced by the global automotive industry in the 1980s spread to the aerospace and defense industries, with the direct influence of lean manufacturing in the U.S. Armed Forces (Womack; Jones; Roos, 1990; Mathaisel; Comm, 2000).

Additionally, the support provided by the U.S. Department of Defense since 1988 is highlighted, promoting a continuous improvement strategy at all levels and areas of operation (DoD, 1988). This reflects the size and power of the U.S. Armed Forces, considered the largest in the world (Global Firepower, 2023).

The synthesis of knowledge was achieved through the reading and classification of the articles selected in the literature review into several categories. The works classified as theoretical studies presented only relationships between the benefits of lean manufacturing in the studied environment without measuring performance improvements. In contrast, the works classified as case studies showed effective applications of lean manufacturing principles and tools, demonstrating and measuring the gains obtained. Figure 3 presents the distribution of the 27 studies by type of research.

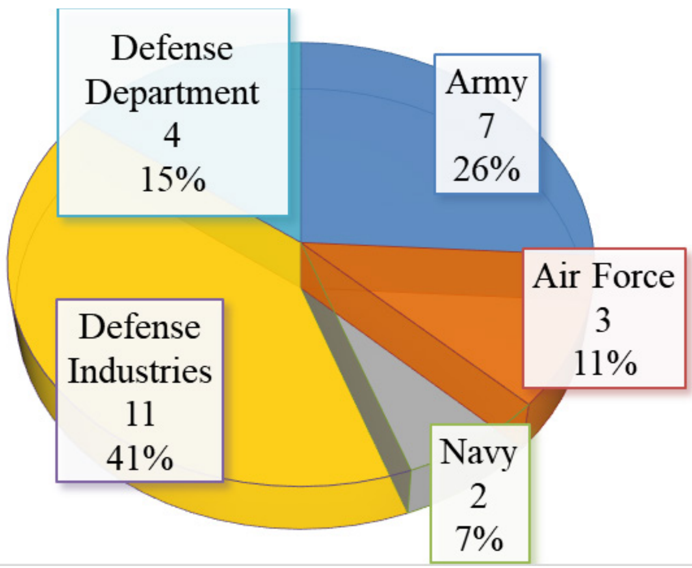
Figure 3. Distribution of the works of the literature review by type of research



Source: the authors.

A second classification of the works was generated based on the analysis of application areas of the research topic. Figure 4 shows the division of works according to each applied area. In Table 3, the works from each application area are related to the type of research conducted. Figure 5 presents the 12 articles considered case studies, classified according to the frequency of application of lean manufacturing tools.

Figure 4. Distribution of the works of the literature review by area of application/study



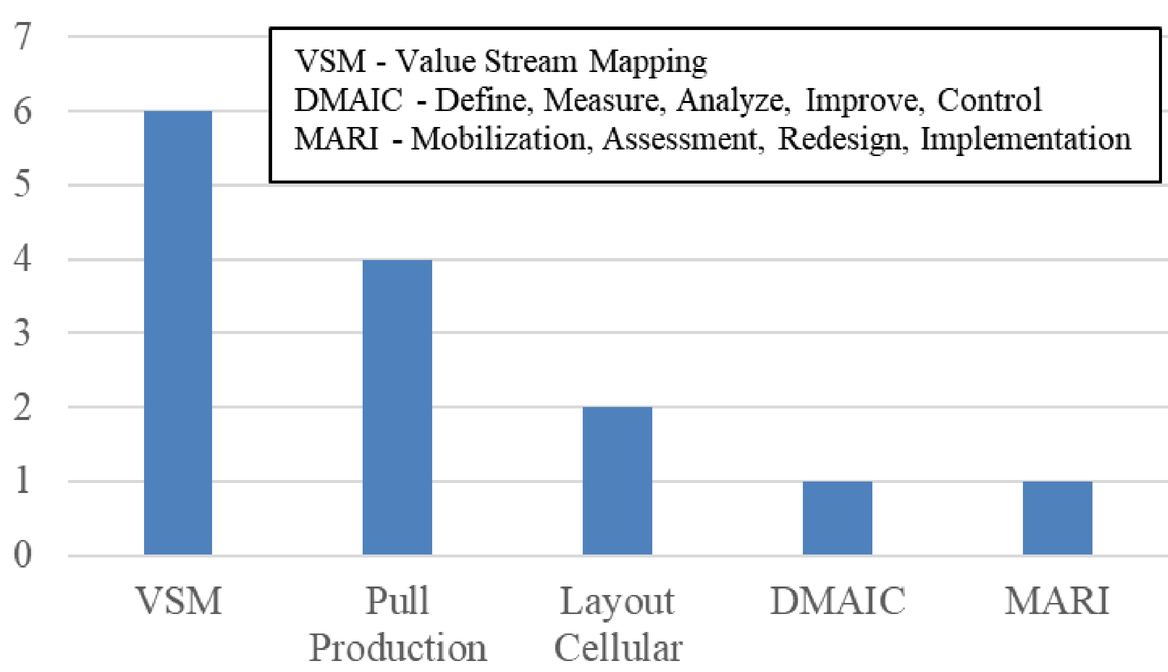
Source: the authors.

Table 3. Distribution of literature review works by area of application/study and type of research

Área of application/study	Case study	Theoretical study
Defense industries	4	7
Air Force	2	1
Army	4	3
Navy	1	1
Department of Defense	1	3

Source: the authors.

Figura 5. Frequency of application of lean manufacturing tools in the literature review works



Source: the authors.

Among the 27 articles reviewed, it is important to highlight the contributions of the authors, particularly focusing on case studies, which somehow measure the benefits of from the application of lean manufacturing principles and tools. Based on the results presented in Table 3, the discussion initially addresses studies applied in defense industries.

The case study in a defense company[1], by Pattanaik and Sharma (2009) identified the benefits of lean manufacturing through the application of a cellular manufacturing system, also known as a cellular layout, in which machines in the production cell were grouped according to the characteristics of each part produced. The new cellular production layout, combining some production operations and relocating machines into production cells, increased value-added activities from 44% to 54%, while reducing non-value-added activities, such as waiting and setup time (Pattanaik & Sharma, 2009).

The benefits of applying lean manufacturing, presented by Pickrell, Lyons, and Shaver (2005), resulted from case studies in a U.S. defense industry manufacturing controls and electrical, electro-hydraulic, and hydraulic systems for aerospace and defense applications. The first case study showed substantial improvements in cost reductions, cycle time, customer returns to inventory, and increased production capacity. In the second case study, an automated document

1 ALCAST, the studied company, is located in India and is a supplier of parts and components for missiles and other military materials to the Indian government.

control system was implemented, reducing customer rejections and manufacturing delays due to documentation and revision errors during production (Pickrell, Lyons & Shaver, 2005).

The aerospace industry has greatly benefited from the lean manufacturing philosophy. In the late 1980s, a research group associated with MIT sought to understand the challenges faced by the global automotive industry (Womack; Jones; Roos, 1990). In 1993, a similar program was created with representatives from the U.S. government, industry, and academia (MIT) to promote changes in the aerospace and defense industry, based on systematic knowledge of the lean manufacturing philosophy. These changes aimed to achieve significant advances in efficiency and quality in the following decades (Mathaisel; Comm, 2000).

Fleishman's (2002) work demonstrates the advantages gained from incorporating lean manufacturing principles in the assembly of the fuel system for the C-17 military transport aircraft, manufactured by Boeing Company. By using lean manufacturing principles and tools, the project team found the necessary adjustments to adapt the aircraft's fuel system, improving assembly efficiency while maintaining performance. Still within the aerospace industry, Kinard (2018) highlights that the F-35 aircraft program, manufactured by Lockheed Martin, found lean manufacturing to be a key strategy as part of the production system, adopting just-in-time (JIT), standardized work, and pull production.

The application of lean manufacturing principles and tools in both defense industries and the Armed Forces is observed in the work of Mathaisel (2005). The model developed by the author, called Lean Enterprise Architecture (LEA), was initially designed for use in an aerospace defense industry, but its application expanded to military organizations in the U.S. Air Force. The results achieved with the application of the LEA model include: improving the quality of goods and services by up to 85%; increasing productivity by up to 30% per year; enhancing customer satisfaction by delivering goods and services on time; reducing operating costs by eliminating waste; and improving workflow efficiency (Mathaisel, 2005).

Other applications identified in the context of the U.S. Air Force were in the areas of logistics and personnel management. The work of Berry and Akhbari (2000), developed within the context of the United States Air Force (USAF), presents the integration of lean manufacturing into the supply chain logistics for the C-17 military transport aircraft. This integration helped reduce project costs, making the C-17 program more competitive and ensuring that a project with its first delivery in 1991 would remain viable into the 21st century.

In both civilian and military environments, the application of lean manufacturing focuses on processes related to the manufacturing, maintenance, or acquisition of military equipment and materials. Differently, Valencia and Rusnock (2018) applied lean manufacturing principles to understand and improve the productivity of emergency response aviators in the U.S. Air Force, using the Value Stream Mapping (VSM) tool.

Moving on to applications found in armies, ranging from supply chain logistics to healthcare management, lean manufacturing principles and tools have improved performance in the environments where they were applied, enhancing processes and achieving greater efficiency. The case study of lean manufacturing application in improving military logistics presented by Acero and collaborators (2019) shows that the strategic approach to military logistics should focus on process improvements to meet the Armed Forces' requirements for efficient supply delivery in the theater of operations.

Lean manufacturing was implemented in the supply chain management of military organizations to improve response times and ensure the necessary flexibility while avoiding waste. The results showed an increase from 44% to 70% in added value activities in the logistics process and a 69.6% reduction in the logistics process lead time (Acero et al., 2020). In this regard, Carier (2007) proposed alternatives to improve battlefield supply logistics, applying lean manufacturing tools and decision-making techniques based on value-focused thinking (VFT), to enhance the process of material and equipment distribution to soldiers in the theater of operations.

It is also important to note that lean manufacturing principles and tools can be applied to organizational process management. Another application was identified in improving the pilot training process for the U.S. Army. Enos (2011) proposed a lean organization concept for the U.S. Army Aviation Center of Excellence (USAACE), based on lean manufacturing principles and tools to improve the U.S. Army's pilot training process.

As seen in Table 2, a publication related to Brazil presents a case study on the application of lean office[2]. It is an adaptation of lean manufacturing to administrative processes and management in a healthcare organization of the Brazilian Army, located in the Campinas garrison, in the state of São Paulo. (Silva et al., 2015). The research aimed to answer the question: Is it possible to reduce lead time in administrative processes by applying lean office? As a result, outpatient care was improved by eliminating non-value-added activities, increasing value-added activities from 1.7% to 8.2% in the process (Silva et al., 2015).

The work of Mayer, Irani, and Adra (2008) evaluated the feasibility of applying a cellular manufacturing system, also known as cellular layout, in a U.S. Navy maintenance organization[3]. The new proposal considered grouping similar processes for each type of material or product family (vessel). Based on the current structure, it was possible to simulate the new layout model, resulting in better response times, meaning reduced repair times for vessels, thereby increasing the availability of resources (Mayer; Irani; Adra, 2008).

In the United Kingdom, the Ministry of Defense found an opportunity in lean manufacturing principles and tools to reduce the maintenance demand for one of

2 The concept of lean office concept emerged from the application of lean manufacturing principles and tools in management environments (management processes) (Silva *et al*., 2015).

3 The ship maintenance organization, known as the Southeast Regional Maintenance Center (SERMC), is structured by specific jobs (welding, machining, assembly, etc.) and not by product families.

its helicopter fleets, such as the Chinook Mk2/2A, manufactured by Boeing Company (Cook, 2007). A prognostic analysis mathematical model based on real-time information on the mechanical condition of the aircraft, as well as a lean supply chain, were identified as possible solutions to reduce maintenance queues for grounded aircraft due to a lack of spare parts.

From the content analysis of the 27 papers, it was observed that among those classified as case studies (12 articles), six articles used the Value Stream Mapping (VSM) tool as the main lean tool to analyze the current state and propose the necessary modifications for improving the process toward the desired future state. These results reinforce that VSM is an essential tool, as it not only enables the visualization of the flow but also helps identify waste (Rother; Shook, 2003).

In light of the above, the literature review revealed various applications of lean manufacturing in the context of defense industries and Armed Forces, presenting the advantages that can arise from adopting the lean manufacturing philosophy. The use of lean manufacturing in the Brazilian Army is an opportunity to be explored by applying its principles and tools in the modernization of maintenance lines in war parks and arsenals, contributing to the improvement of the Brazilian Army's manufacturing system.

When we observe the maintenance activities carried out by Military Maintenance Organizations (MMOs), which can be divided according to the type of material, we can see, for example, in Class V materials (weaponry), an opportunity to integrate the lean manufacturing philosophy into the 3rd-level maintenance process of light weapons. Regarding Class IX materials (motor-mechanization), which include wheeled and tracked armored and non-armored vehicles, lean manufacturing principles and tools can be applied to the processes of maintenance, modernization, and/or revitalization of these SMEMs.

Although the lean manufacturing philosophy originated on the factory floor of Japanese automotive industries, its expansion has reached various areas of knowledge, such as healthcare (lean health), construction (lean construction), and administration (lean office and lean enterprises). In other words, beyond production environments, other areas can also benefit from lean principles and tools, such as hospital management, military construction, organizational management, project management, the life cycle of SMEMs, and supply chain logistics. As found in the literature review, the improvement of Land Military Logistic System can leverage lean manufacturing principles and tools to develop efficient management of the supply chain logistics.

It is worth noting that the application of a new process management model may encounter some barriers and challenges to be overcome. The success of integrating lean manufacturing into any process is not limited to the application of the tools. According to Pereira, Anholon, and Batocchio (2017), it is a collective result achieved through the dedication of the entire work team, from the strategic level to the operational, putting into practice the essence of the lean philosophy, its principles, and tools. For example, the challenges of implementing a new model in the maintenance, modernization, and/or revitalization processes of SMEMs can be overcome through the precise application of lean manufacturing principles and tools.

4 CONCLUSIONS

The relevance of this research lies in investigating lean manufacturing in the context of national defense and its applications in defense industries and the Armed Forces. This study initially presented the importance of the topic in the transformation process of the Brazilian Army, from the perspective of modernizing the Land Military Logistic System and improving Science, Technology, and Innovation System.

The integrative literature review highlighted works already conducted in defense industries and Armed Forces, allowing to answer the research questions. Initially, it was observed that lean manufacturing has contributed to improving the performance of these organizations by eliminating or reducing process waste, particularly related to waiting times between activities and unnecessary processes.

Regarding lean tools used, a variety of applications were observed, such as pull production, cellular production layouts, and JIT, with Value Stream Mapping (VSM) standing out as the main lean manufacturing tool to analyze the current state and propose necessary changes to improve processes in the desired future state.

Finally, opportunities to integrate lean manufacturing into the Brazilian Army are primarily identified in the processes of maintenance, modernization, and/or revitalization of SMEM. The application of lean manufacturing in maintenance processes, such as light weaponry highlight best practices and adaptation challenges to the new maintenance management model.

In addition to production environments, other areas may also benefit from lean principles and tools, as observed in the literature review. The development of work in areas such as hospital management, military construction, organizational management, project management, SMEM lifecycle, and supply chain logistics align with the Brazilian Army's transformation process, modernizing existing management tools and contributing to the efficient use of available resources.

5 AUTHORS' COLLABORATION

Hanameel Carlos Vieira Gomes – conceptualization, methodology, and writing (draft, manuscript, revision, and editing).

Giuseppe Miceli Junior – methodology and writing (revision and editing).

Antonio Eduardo Carrilho da Cunha – conceptualization and writing (revision and editing).

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