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Interoperability in the Amazon region: application of the SAPEVO-M method to select logistical equipment to be used by the Armed Forces

Interoperabilidad en la region amazónica: aplicación del método SAPEVO-M para seleccionar el equipo logístico que utilizarán las Fuerzas Armadas

Abstract: The intermodal transportation is essential to the logistical planner at the Amazon region and, to become accessible, its handling or its transshipping cost cannot be excessively onerous. Along the way, the Armed Forces have opportunities to improve the loading and unloading processes in the Amazon region, which, in 2020, hinder the interoperability and increase their aggregate cost. This research approaches the general context of intermodality context and the integration between the Armed Forces in Brazil, as well as bringing forward the interoperability in the United States and European Union. As a study case, there are some needs that should be solved to improve interoperability in the Amazon region. In this context, the SAPEVO-M method had been applied to select the right equipment to be used in cargo handling and intermodal logistics integration. It is clear from this paper that the equipment selected, through the method applied in the Army, can be extended to the other Forces, so that each one will have the means to solve this logistical problem.

Keywords: Amazonia. Logistics. Interoperability. Intermodality. SAPEVO-M Method.

Resumen: El transporte intermodal es esencial para el planificador logístico en la región del Amazonas y, para que sea posible, el costo de la manipulación o el transbordo no puede ser excesivamente caro. Sin embargo, se observa que las Fuerzas Armadas tienen oportunidades de mejorar los procesos de carga y descarga en la región amazónica, lo que, para 2020, dificulta la interoperabilidad y aumenta el costo agregado. Esta investigación aborda el contexto general de la intermodalidad y de la integración entre las Fuerzas Armadas del Brasil, y presenta la interoperabilidad en los Estados Unidos y la Unión Europea. Como caso de estudio de caso, hay algunas necesidades que deben ser resueltas para mejorar la interoperabilidad en el Amazonas. En este contexto, se aplicó el método SAPEVO-M para la selección del equipo que se utilizaría para la manipulación de la carga y la integración de la logística intermodal. Se llegó a la conclusión de que el equipo seleccionado mediante el método aplicado en el Ejército puede extenderse a las demás Fuerzas, de modo que cada una de ellas disponga de los medios para solucionar este problema logístico.

Palabras clave: Amazonia. Logística. Interoperabilidad. Intermodalidad. Método SAPEVO-M.

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1 Introduction

In Brazil, transportation infrastructure has faced great limitations for decades due to insufficient investment in the sector, a complex tax system, vicious contracts between the public administration and the private sector (generating legal uncertainty), and excessive bureaucracy. These difficulties lead to an increase in the Brazil Cost that, consequently, is added to the value of products for final consumers. A study carried out in 2019 by the Competitive Brazil Movement in partnership with the Special Secretariat for Productivity, Employment and Competitiveness of the Ministry of Economy pointed out that the real impact of this cost on the economy is R$ 1.5 trillion, that is, 22% of the national Gross Domestic Product (MOVIMENTO BRASIL COMPETITIVO, 2019).

In more recent research of the World Economic Forum, Brazil ranks 85th in a list of 141 nations that had their transportation infrastructure evaluated, and ranks last in Latin America, which demonstrates the magnitude of the problem that exists in the country (WORLD ECONOMIC FORUM, 2019).

The Brazilian Amazonia has a number of physiographic factors, characteristic of the region, which make regional and inter-regional transportation even more difficult. In addition to the great distances to be covered, the infrastructure is outdated in relation to other Brazilian regions, due to deficits in the road, waterway, airport and railway – networks, characterizing the region as a real challenge for logistics activities.

The Legal Amazon has an area of approximately 5,217,423 km^2, which corresponds to about 61% of the territory. It is composed of the states of Amazonas, Acre, Roraima, Rondônia, Mato Grosso, Amapá, Pará, Tocantins and the municipalities of the state of Maranhão situated west of the 44th meridian (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2014).

This region is divided into Western and Eastern Amazonia. The Western Amazonia is made up of the states of Amazonas, Acre, Rondônia and Roraima. By exclusion, the Eastern Amazonia is made up of the states of Pará, Amapá, Mato Grosso, Tocantins and the municipalities of the state of Maranhão (BRASIL, 1968, 2007).

The legal definition of the Brazilian Amazonia has always been linked to the implementation of government policies for the integration of the vast region and the creation of public bodies. Thus, the areas established above, as well as the aforementioned divisions, have undergone several changes since they their creation. The last change was when the Superintendence of the Amazon Development (SUDAM) was instituted through Complementary Law No. 124, of January 3, 2007. On that occasion, the limit represented by the 13th parallel south, in force until then, was replaced by the limit between the states of Goiás and Tocantins (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2014).

In the Amazon region, the Armed Forces (FA), in addition to other bodies, such as the Federal Police, the Public Ministry and state governments, safeguard our sovereignty and preserve the rich plant and animal biome, the immeasurable mineral heritage and the world's largest hydrographic basin.

According to Carvalho and Silva Júnior (2019), the development of logistical systems has improved slowly and gradually over centuries, but has been largely improved with military activities. Therefore, the development of the FA logistical system in the region is responsible

for supplying military units with greater efficiency and assisting the country's development by promoting trade in municipalities and places isolated from the rest of the nation.

The region has several rivers with the potential to transform into waterways capable of draining much of the grain production in the Midwest through northern ports (CÂMARA DOS DEPUTADOS, 2016), stimulating economic and social development in that territory.

The Ministry of Infrastructure (BRASIL, 2018) mentions that, in 2016, Brazil had 19,464 kilometers of economically navigable waterways. According to the Bureau of Transportation Statistics (UNITED STATES, 2018) and the United States Army Corps of Engineers (2019), the United States of America (USA), a country with geographic dimension similar to Brazil's, has 40,200 kilometers of waterways, with approximately 19.3 thousand kilometers being shallow water courses (depth from 2.74 to 4.27 meters) and 33.7 thousand kilometers being deep channels with more than 4.27 meters. The comparison showed that the United States, in addition to having almost twice (in kilometers) our economically navigable waterways, has a transportation capacity on these ways much greater than the Brazilian reality.

In Brazil, the inconsistency of the water level, the rainy periods and the lack of adequate signage make traffic intermittent in the Amazon region, which makes logistical planning difficult.

According to Santos (2016), air transportation in this scenario is essential for planning the logistical supply in the Amazonian region due to the great distances to be covered and, mainly, because of the precarious surface connections. This mode of transportation is advantageous since is relatively easy to construct an airstrip (whether paved or not), which brings an almost immediate return for the local population.

However, even if the modes of transportation did not present problems individually, when an Amazonian transport network is composed it has to be capable of integrating these modes, because, currently, highways, waterways and airports do not connect, and, when they do so, often the equipment needed for transshipment does not exist or is inadequate.

McGinnis (1990) found that six variables are fundamental to the choice of transportation services: 1) freight rates; 2) reliability of the service provider; 3) time in transit; 4) losses, damages, claims processing and order traceability; 5) considerations regarding shipper's market; 6) considerations regarding shipping companies. It is noticed that the time and resource optimization indicator permeates all variables directly or indirectly, indicating that they are important logistical factors to be targeted for decision making.

Ballou (2006) reiterates that, although freight rates are usually determining factors for the option of the mode of transportation, the quality of customer service should be the main to be considered, indicating the best cost-benefit ratio option. Transportation in the Armed Forces is no different; it seeks to improve public expenditure efficiency and services.

In this scenario, the increase in logistical interoperability between the Brazilian Army (EB), the Brazilian Navy (MB) and the Brazilian Air Force (FAB) will greatly contribute to simplifying the structure and execution of logistical support, as prescribed in the Manual of Joint Operations Doctrine, Ministry of Defense – MD30-M-01, 3rd Volume (BRASIL, 2011).

In addition to these factors, Ordinance No. 301 – General Staff of the Army, of November 10, 2015, approved the rationalization of positions in the Personnel (QC)

and Expected Personnel (QCP) of the Military Organizations (OM) of the Brazilian Army (BRASIL, 2015b). Besides, the macroeconomic environment overview after the pandemic is not encouraging. The IPEA (INSTITUTO DE PESQUISA ECONÔMICA APLICADA, 2020) established three possible economic scenarios impacted to a lesser or greater degree by the duration of the social isolations established due to the disease. In the best of the economic scenarios, the Gross Domestic Product will fall 0.4% by the end of 2020, which may impact the financial resource allocation to the FA in the short and medium term.

Thus, analyzing the economic situation exposed and meeting the guidelines for rationalizing personnel, unitization[1] of cargoes and improvement of automation in intermodal transfer logistics and in loading and unloading processes at warehouses will help optimize resources and personnel by increasing transport efficiency.

2 Contextualization of the problem

2.1 Interoperability in the Armed Forces

Robbins (2007), through his work *An Essay on the Nature and Significance of Economic Science*, conceptualizes economics as "the science that studies human behavior as a relationship between ends and scarce means," addressing human characteristics in decision-making by economic agents. Thus, for the logistical function to provide lasting operations, costs are essential for planning, given that resources are limited.

The search for cost reduction is sometimes confused with a reduction in fighting power, as it is mistakenly associated with indiscriminate demand for cutting costs. Thus, in order to resolve this paradox, the fundamental foundation to discuss integration between the Singular Forces is emphasized: the excessive search for cost reduction restricts the operational capacity by reducing its core activities, but the cost reduction refers to another concept, and it is fundamental to lasting operations.

For example, if the Frigate *União* in *Operação Líbano XV*, part of the Maritime Task Force of the United Nations Interim Force in Lebanon, suffered damage that needed urgent repairs so that it could proceed with the mission, the cost of shipping parts by air would be much larger than if it were sent by another sea vessel. However, attention should be paid to the customer service level. That is, one of the needs of the frigate is replacement time, regardless of value, since lives can be lost. However, although it is necessary to use a more expensive mode to accomplish this mission of transporting spare parts, planning for hiring the shipping company should not be overlooked, seeking to reduce total costs. In this example, the trade-off[2] for the use of a more costly mode of transportation

1 According to the Council of Supply Chain Management (2020) glossary, unitization can be understood as the consolidation of several units into larger units to improve efficiency in handling and reduce transportation costs.

2 It is a term that defines a situation in which there is a conflict of choice. It occurs when an economic action aimed at solving a problem entails another, and a choice has to be made.

was the maintenance of the lives of the vessel crew, which did not hinder the planning for carrying out the cheaper transportation among the possible options.

Therefore, rather reducing expenses in an indiscriminate manner, what is intended through logistical interoperability is to reduce expenditure in operations, making the aggregate logistical cost lower and increasing the combat and *deterrence* capacity.[3]

According to the Manual of Military Logistics Doctrine of the Ministry of Defense -MD42-M-02, "Logistics Interoperability is the use of skills, capabilities and means between organizations, verified in the ability to exchange services and information, without changing the operational structure itself, to solve a logistical problem" (BRASIL, 2016, our translation).

In order to elucidate the classification of military operations according to the military branches employed and the understanding of sharing and interoperability between them, Table 1 below presents the definition and objectives for each employment situation in a generic and synthesized manner.

Table 1 – Armed Forces X military operation, objectives and demand

Armed forces			
	Singular	**Joint**	**Combined**
Definition of military operation	Singular operations are carried out by only one branch of the Armed Forces (FA). The receipt of small fractions and/or resources from another branch does not change this concept.	Operations involving the coordinated use of elements of more than one branch, with interdependent or complementary purposes, through the constitution of a Joint Command.	Operations carried out by ponderable elements of the Multinational Armed Forces, under the responsibility of a single command.
Objectives	Defense of the State, guarantee of constitutional powers and guarantee of law and order upon the initiative of those powers.	Universality, unity, objectivity, economy of resources, flexibility, versatility, simplicity, and interoperability.	Achievement of common interests among nations within the framework of an alliance or coalition, determined by a military or civilian authority in a war or non-war situation.

Source: Based on FA manuals, Brasil (1988, 2011, 2015a, 2017), Lopes (2013), and Freire (2018).

The mechanisms for more effective global governance, as set out in the Defense White Paper (LBDN), go through the integration of the Brazilian Armed Forces, reaching the capacity for interoperability in joint and combined operations.

> The Armed Forces Joint Staff exercises a fundamental role in the execution of the National Defense Strategy. It is responsible for the coordination of interoperability programs with the purpose of optimizing military resources for national defense, border security as well as rescue and humanitarian operations (BRASIL, 2012, p. 59, our translation).

3 According to Figueiredo and Violante (2019), the objective of deterrence is to reduce and/or inhibit the use of force by an eventual opponent, so that there is no opposition to Brazil's will.

Coordination and integration of the FA logistical systems (modes and capacities) are facilitated by the standardization of materials and processes, favoring the reduction of the diversity of parts, materials and services, with positive effects for the Industrial Defense Base, since it reduces bureaucratic barriers and benefits the predictability of demand.

The binomial feature between the National Defense Strategy and the National Economic and Social Development Strategy refers to the concept of Figueiredo (2015) that national defense and development are inextricably linked, based on state-level documents.

> Power and politics must be linked to national independence, which, in turn, is linked to defense and development, just as it can be said that there is no real development without credible defense systems. Development and defense are concepts that cannot be thought inseparably (FIGUEIREDO, 2015, p. 62, our translation).

Brazil addition to NATO Codification System (NCS), for example, internationalizes and further expands the reach of national agents/stakeholders in the defense area. Embraer is an example of a company that needed to adapt to the requirements contained in that catalogue and to the life cycle of products to materialize the sale of the KC-390 to Portugal (MEDEIROS; MOREIRA, 2018).

The United States of America's support for Brazil to participate as a member in the Organization for Economic Cooperation and Development (OECD) formalized on January 15, 2020 (BRASIL, 2020b) not only demonstrates strengthening of foreign policy, but also accelerates and evidences the need for consolidating standards and metrics in the country. Thus, increasing standardization of modes enables greater integration and joint planning between the Forces, making it a project for improving public expenditure efficiency, which will bring greater efficiency to the Ministry of Defense and expand its operational capacity in view of the savings generated by reduction of duplicate or idle transportation caused by joint planning.

Initially, this article will discuss the development of the Joint and Combined Armed Forces doctrine and present a brief history of interoperability in Brazil. After that, the EB transportation system in the Amazon region will be evaluated for the study on interoperability and intermodality in the FA, seeking to improve the logistics in the region by applying the SAPEVO-M method to support decision making for selection of logistics equipment that meets the peculiarities of the region. Finally, a succinct conclusive analysis will be made.

2.2 Interoperability in the international environment

2.2.1 Combined military operations

The right to collective self-defense is at the heart of several international treaties, uniting its members and committing them to protect each other from external threats,

as we can see in the extract below, for example, of Article 5 of the North Atlantic Treaty, to which Brazil is a signatory.

> The Parties agree that an armed attack against one or more of them in Europe or North America shall be considered an attack against them all and consequently they agree that, if such an armed attack occurs, each of them, in exercise of the right of individual or collective self-defence [sic] recognised [sic] by Article 51 of the Charter of the United Nations, will assist the Party or Parties so attacked (...) (NORTH ATLANTIC TREATY ORGANIZATION, 2019).

Thus, in order for combined military operations to be effective, military logistics among the pacing countries should be aligned with the collaborative reality of the supply chain in all countries, providing greater fluidity to the flow of goods, people and information.

The low incidence of regional armed conflicts in South America, especially in the twentieth century, creates a dangerous feeling of protection and leads to misunderstandings about the elements of security in several national public agents. However, several cross-border tensions demonstrate the importance of integrating and deepening cooperative ties between States through the so-called "new threats": war on drugs, arms and human trafficking, piracy, terrorism, and smuggling. These threats are often generated by financial and humanitarian crises that impact the defense both of the Amazon region and of the South Atlantic (FIGUEIREDO; VIOLANTE, 2019).

In general, security in its expanded concept (political, economic, and social security, considered qualitatively and quantitatively) is one of the aspects that makes States sign international agreements, in order to avoid the erosion of the armed conflict or to create deterrent capacity against an external threat. With this pretext, Europe overcame its historical rivalries to draft a peaceful coexistence treaty that permeates all sectors of the economy of the countries involved.

In Europe, the Movement Coordination Centre Europe (MCCE), established since 2007, aims to manage and use transportation capacities of the 28 member countries jointly, in order to optimize structures and maximize efficiency of military transportation (MOVEMENT COORDINATION CENTER EUROPE, 2018). In times of austerity, the creation of this center reinforces the idea that the union of logistical capacities and the use of strategic cooperation in defense bring positive results for military logistics.

The MCCE remains prepared to guarantee support for the coordination of operations of the European Union (EU), the North Atlantic Treaty Organization (NATO), and the United Nations (UN). For this purpose, it uses several mechanisms and systems that are capable of managing the costs involved and the idle modes in air, sea and land transportation, which include railways, roads and *inland navigable waterway*s.[4]

4 The distinction of understanding inland waterways in Brazil and the European Union is highlighted. In Europe, they are defined as a designation that covers rivers, lakes, canals and navigable estuaries, not limiting to the routes of a single country. Thus, if they form a common border between countries, they should be included in the statistics for each country (UNIÃO EUROPEIA, 2007).

Within air transportation management, for example, the mechanism entitled *Air Transport and Air to Air Refueling and other Exchange of Services* (ATARES) is a system for exchanging air transportation services between member countries, based on the equivalent flight time. That is, taking the cost per flight hour for the C-130 and C-160 aircraft as a reference, the value of the transportation to be performed by another country is calculated and the reimbursement is made without financial compensation, solely and exclusively with the commitment to future transportation. As a result, idleness in air transportation is reduced, which has the highest aggregate cost, benefiting and supporting the nations involved (EUROPEAN AIR TRANSPORT COMMAND, 2017).

The combined Forces' interoperability in the face of scarce strategic modes of transportation is vital for the timely use of the Force and for the success of military operations in the face of the aggressions that NATO and the EU may receive due to the operation global environment covered by these organizations. Therefore, the MCCE enables economic efficiency and the reduction of duplicate transportation with unused capacity, optimizing synergies and each member state's available modes and capacities.

2.2.2 Joint military operations

In the USA, after the World War II, the pressure for more effective inter-force coordination was increasingly evident. Several factors delayed the design of an effective Joint Chiefs of Staff, which became a reality after the Goldwater-Nichols Act, published on October 4, 1986. This reform was quite controversial, because it originated in the US Congress, that is, outside the scope of the Armed Forces, resulting in a costly and constructive legislative debate that altered the highest level of strategic decision-making on matters related to National Defense.

The reform is considered the most important and comprehensive reorganization of that country's Department of Defense (LOCHER III, 1999), and has implemented several important programs or functions for the Armed Forces, including (1) Strengthening the authority of the Chairman of the Joint Chiefs of Staff (2) Acquisition of integrated systems; (3) Policy of valuing and promoting military personnel who act in joint commands; (4) More effective advice to the Joint Chiefs of Staff; (5) Changes in the functions of the Joint Chiefs of Staff; and (6) Dynamics of Commanders in the Theater of Operations (PIRES; HONORATO; COSTA, 2019).

It appears that the logistical integration provided by the reform increased the effectiveness of Combatant Commands, increasing combat capacity. In the First Gulf War (1991), for example, the operation known as "Desert Storm" was preceded by a major six-month logistical mobilization for a 100-hour land campaign, demonstrating the complexity of modern combat and the need for integration to make the clashes more proficient.

Despite the consensus regarding the benefits that the reform brought to the US Department of Defense, McInnis (2016) points to the need for a reformulation, revealing the concern of several US military personnel regarding the lack of interaction between the Armed Forces and the public security agencies.

The analysis regarding interoperability in other countries allows us to compare the current situation of our FA, providing the opportunity for a more balanced and integrated action.

2.3 Brazil's Military Interoperability in the Ministry of Defense

Adhering to the doctrinal evolution, the Ministry of Defense prepared, in 2001, the first publications referring to Combined Command Basic Doctrine and to Combined Operations Logistics, through the manuals MD33-M-03 – Combined Command Basic Doctrine, and MD34- M-01 – Combined Operations Logistics. In 2007, according to Lopes (2013), specific objectives were established regarding interoperability between the Armed Forces, including the integration of military logistics. During this period, the Military Defense Structure – MD35-D-01 (in 2005), the Command and Control Procedures for Combined Operations – MD31-M-04 (in 2007), and the methodology of Combined Employment Strategic Planning of the Armed Forces – MPEECFA – MD33-M-07 (in 2008) were approved

The Armed Forces Joint Staff (EMCFA) was created in 2010 with the mission of promoting and coordinating interoperability between the Single Forces and advising the Minister of Defense. Since then, several manuals and ordinances have been revoked and a new doctrine has been established, through the Manual of Joint Operations Doctrine – MD30-M-01. EMCFA was assigned to plan the joint and integrated employment of personnel from the Singular Forces, optimizing the use of available resources (BRASIL, 2020a).

The migratory movement initiated in 2015 and triggered by the political and economic crisis in Venezuela is a contemporary example of the joint application of the Armed Forces, being the largest displacement of people in the history of Latin America. So far, more than 4 million Venezuelans have left the country (MILLIONS..., 2019). In Brazil, the Humanitarian Logistics Task Force[5] performed and coordinated by the Federal Government with the support of UN agencies and more than 100 civil society entities brought more than 27.2 thousand Venezuelans to 24 Brazilian states by January 2020. According to the Federal Police, from 2017 to November 2019, approximately 6.6% of Venezuelans who left the country (264 thousand immigrants) requested migratory regularization (BRASIL, 2020c).

By restricting interoperability to the logistical aspect, more specifically to the transportation function, the Ministry of Defense (MD), through its Armed Forces Joint Staff, has been improving logistical systems in order to integrate the three military branches. The management of military transportation information is the responsibility of this Central Body, which performs the joint articulation of the Navy, Army and Air Force transportation through the Defense Transportation System (STD) (BRASIL, 2013).

The STD is an integral part of the Defense Logistics System (SISLOGD) (BRASIL, 2013) and works as an integrated agent for the various structures related to the Armed Forces' transportation logistics and resources that can be contracted and/or mobilized.

5 OPERAÇÃO ACOLHIDA. Available at: <https://www.gov.br/acolhida/historico/>. Access on: Feb. 5, 2020.

Although the STD is already in operation, the transportation of military supplies is planned and carried out individually by each Brazilian Armed Force, according to their subsistence needs or in response to the demands of military operations. Only in some more sporadic cases, and for materials (ammunition, for example) or specific mission, there is integration between the military branches, even though there are similar Supply Axes performed by each that could be integrated through a transportation network optimization algorithm.

3 Problem description

3.1 Intermodal efficiency as a key factor for interoperability in the Amazon environment

3.1.1 Problem characterization

According to Orair (1990), the economic and fiscal crises of the 1990s were the turning point in the Brazilian strategic planning for the financing of transportation infrastructure by public resources, with the dismantling of the developmentalist State. During this period, the government no longer had the resources to make new works viable or to increase existing ones. The solution was to start partnerships with the private sector, in order to finance the construction of highways, ports, airports, railway sections, as well as for the maintenance of the roads built.

In the Amazon region, in general, there is a lack of installed logistical infrastructures, mainly in municipalities located in the interior of the states. The river system of the Amazon hydrographic region can be classified, according to Bertani (2015), as a system of predominantly meandering rivers with the presence of flood plains that may contain a complex of several depositional sub-environments. These rivers, influenced by the rain regime, restrict navigation, making it even more imperative to maintain the waterways so that their potential is fully utilized.

The five main waterways are the ones with the highest volume of cargo transported and are shown in Table 2.

Table 2 – Hydrographic regions and their waterways

Hydrographic region	Waterways	Gross weight in tons
Amazon	Of Amazonas, Solimões, Madeira, Tapajós, Pará, Negro, Juruá, Trombetas and Xingu	39,455,613
Tocantins-Araguaia	Of Tocantins and Araguaia	21,871,197
South Atlantic	Of South	4,574,867
Paraná	Of Paraná-Tietê and Paranaíba	2,878,619
Paraguay	Of Paraguay	2,788,405

Source: Based on Brasil (2019).

According to the Institute of Logistics and Supply Chain (2017), the waterway modal has the cost of almost a third of the road modal (predominant in Brazil), in addition to being little explored. The Legal Amazon is the one with the greatest potential for inland water navigation in Brazil, and it is essential that the Armed Forces be equipped with machinery that facilitates the much needed intermodality in that location. According to Hornstra et al. (2020), it is necessary to standardize and organize the cargo of the vehicle for situations in which loading, unloading processes or even cargo transshipment occur, and the costs for handling the cargo have to be considered.

Santos (2016) presented several suggestions for contributing to military logistics in the Eastern Amazonia; among them, he stressed the importance of employing new tools for cargo separation, palletization and unitization, containerization, and intermodal transportation. These factors are fundamental to a sustainable development of logistics in the event of mobilization of large amounts in the region of the Amazon River mouth.

Gansterer and Hartl (2018) present a research on collaborative vehicle routing, analyzing and comparing centralized and decentralized plans, with and without freight auction. As a result, the authors indicate that collaboration between shipping companies minimizes transportation costs. In this sense, the EB could plan the execution of its transportation through the modes that will be available (air, river and road) for its execution in a collaborative way with the other military branches, aiming to reduce costs.

Carvalho and Silva Júnior (2019) point out that the lack of return cargo is one of the logistical problems of the EB in the Eastern Amazonia, which makes the cargo transportation by river more expensive than it should be. However, it is observed that this is a cyclical problem for the Armed Forces and that it could be mitigated with transportation interoperability.

3.1.2 Case study: The Brazilian Army's intermodality in the Amazon region

The bibliographic research carried out from the study of the Structure of the Brazilian Military Logistics, the precept of logistical cooperation of the Movement Coordination Centre Europe and the doctrine of joint operations in the USA composes the prelude to this work. However, in order to measure the logistics of intermodal transportation operations, main fact so that interoperability in the Armed Forces can occur, logistical equipment for transshipment of cargoes that meet the specificities of the Amazon region was identified and parameters were defined (for example, better products in the Brazilian market, prices, technical specifications), and based on which the most appropriate equipment should be selected using the SAPEVO-M method.

In the context of Ground Force logistics, the implantation of the project to incorporate fixed-wing aircraft into the air modal of military logistics in the Amazon region, using the aircraft C-23B + SHERPA, also includes another variable in the EB transportation system, making the processes for intermodal integration in the Amazon region even more essential. In this opportunity, interoperability with the Air Force will only be possible if, from the beginning, logistical obstacles are observed in terms of the means to carry out goods handling and unitization. Figure 1 shows that the cargo handling performed at the Air Force Logistics Center (CTLA) is mechanized and that the handling equipment that will be proposed in this

study is similar to that used. In addition, in Figure 2, the pallets used are aeronautical, showing a problem of cargo unitization that would increase the transshipment time in joint operations.

Figure 1 – Pallet handling equipment

Source: Authors (2020).

Figure 2 – 463L HCU aeronautical pallet

Source: Authors (2020).

Thus, there is a lack of standardized processes, unified and palletized supplies for logistical integration in the transshipment of cargo within interoperability. This is necessary so that there is no increase in the execution time of cargo transposition and neither is there an excessive increase in the total transportation cost for carrying out loading or unloading. In the case it occurs, the entire operation that requires intermodal transportation will have costs increased, reducing the resources destined to the Armed Forces' core activity.

Therefore, the Brazilian Army, observing its logistical chain, approved the Instruction Book for Preparation of Cargoes for Transportation (EB40-CI-10.900) (BRASIL, 2017), 1st Edition, 2017, by means of Ordinance No. 12 – COLOG, of January 31, 2017. It was published as offprint of the Army Bulletin No. 21/2017, on May 26, 2017. It introduced, in the context of the Brazilian Army Transportation System (STEB), the unitization procedures using pallets and containers, mainly by means of the Army Logistics Support Base, located in Rio de Janeiro.

Although these devices for unitizing cargoes in transportation have brought control, operational dexterity and cost reduction, the concept is not yet fully consolidated in the EB. It is still possible to glimpse two obstacles: the unitization at the level of the Ministry of Defense and the other at the regional level of the EB.

Within the scope of the Ministry of Defense, the military branches are seeking to improve in isolation, without synergy. The means for handling and unitizing cargoes are not always the same, which will cause integration difficulties in joint operations.

At the regional level of the EB, it was observed that the Military Organizations are not always prepared to receive the material wrapped in stretch film and palletized. Then, at this level it is possible to observe that what occurs in the Amazon region is the handling of the cargo according to Figure 3 below, although it was unitized and palletized while it was transported by road.

Figure 3 – Transshipment at Madeira River

Source: 17th Jungle Infantry Brigade (2016).

Inefficient cargo transfer between transportation modes increases the time of operations and the total costs, decreasing resources that should be used in the main activity.

As an example, it is possible to mention what was observed in loading and unloading processes in fluvial operations of the EB's 8th Supply Deposit (DSup) in the

Eastern Amazonia (Belém, PA). In its regional delivery routes, the 8th Supply Deposit supplies several garrisons by waterway transportation. The average supply delivered to each garrison is around 20 tons (including refrigerated cargo) and the estimated time for loading and unloading in these garrisons is two days,[6] given that it is carried out as shown in Figure 3 and, generally, in inappropriate places to perform this activity.

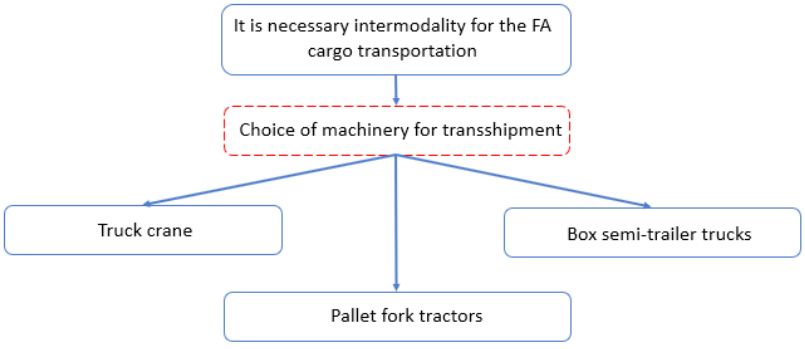
Therefore, the mechanization process through the use of tractors, forklifts and other equipment will continue the development of logistics in the Amazon region. The proposal would be to use equipment designed to carry out cargo transshipment at intermodal points.

However, it is observed that the EB does not have port facility contracts in all garrisons or locations supplied. In other words, it is common for material material unloading to be performed in banks or in rudimentary port facilities, which make it impossible to use common machinery similar to small loaders due to the steep unevenness and irregularity of the terrain. In addition, they increase the risk for container maneuvers by sidelifter due to the total weight of the container and the instability of the terrain.

Therefore, a technical visit was carried out in the city of Belém (PA), from 10 to 15 November, 2019, to verify the suggestions of the logistical staff of the 8th Military Region with regard to more suitable equipment to facilitate cargo transfer in intermodal processes in the Amazonia (considering the procedures and equipment for transshipment adopted by private companies operating in the region), which were: 1) Truck crane with adapter to move pallets; 2) Box semi-trailer truck with truck unraveling at the ferries (dry and refrigerated cargo); 3) Pallet fork tractors. This equipment that does not normally belong to the provision of military units not specialized in logistics.

In view of this equipment, the following question arises: which one would more fully meet the EB' needs for loading and unloading cargo in the Amazon region? In response to this question, the SAPEVO-M method (detailed in item 4) was used to support decision making, which is shown in Figure 4.

Figure 4 – Schematic map



Source: Authors (2020).

6 Average Planning Data obtained from the river transportation executor and head of a vessel from the 8th Supply Deposit, in Belém (PA), Staff Sergeant Mauro Fernando Ramos de Miranda and ratified by the Logistic Staff of the 8th Military Region.

3.1.3 Objectives of machinery selection

In order to support the research, it was sought to establish parameters for the equipment through technical specifications and prices, so that they contemplate technical requirements for the characteristics of the Amazonian environment.

It was also observed the system called man-machine proposed by Fonseca (1975), used in operations in which machines are used in conjunction with human effort. This system needs to be fluid, avoiding operator's physical distress, which would reduce his productivity and quality of work, increasing accident risks at work.

Thus, from the observations of the Logistics Staff of the 8th MR and private companies operating in the Amazon region, mandatory items that the equipment must have were indicated (Table 3), so that its quality does not negatively impact decision makers. From the mandatory items indicated, a new field research was carried out from December 5, 2019 to January 15, 2020 to verify the equipment that will be presented to decision makers and that most fit the logistical needs of the region. Prices are related to equipment manufactured in 2019.

Table 3 – Mandatory criteria

Mandatory criteria	
1	Four-wheel drive for better grip with the ground and better relative drag between the axles.
2-	Air-conditioned cabins, seats with ergonomic adjustments to ensure good posture, viewing, movement and operation conditions.
3	Components such as video monitors, signals and commands should enable clear and precise interaction with the operator in order to reduce the possibility of misinterpretation or feedback error.
4	Engine and body from the same manufacturer, in order to mitigate maintenance logistics costs for eventual breakdowns and equipment defects.
5	Technical assistance for maintenance in Manaus or Belém.
6	Rollover Protective Structures (ROPS).
7	Possibility of coupling back-up alarm to the transmission system.

Source: Authors (2020).

Based on these criteria, the prices for the selected equipment were as follows in Tables 4, 5 and 6:

Table 4 – Truck crane with adapter to move pallets

Machinery	Average price
Truck (6x2 axle configuration)	R$ 340,000.00
Trailer truck	R$ 106,000.00
Crane F20/4H	R$ 47,000.00
Fork adapter for pallets of up to 9 tons	R$ 18,000.00
Amount necessary for Military Organization	R$ 511,000.00
Characteristics	
Crane maximum load capacity	8,700 kg
Maximum lifting height	17.4 m.
Maximum horizontal reach	14.00 m

Source: Authors' images and data (2020).

Table 5 – Pallet shipment with pallet fork tractor

Machinery	Average price
Tractor with breakout force of 9,193 kg	R$ 360,000.00

continue

Table 5 – Continuation

Machinery	Average price
Pallet fork for 7,000 kg	R$ 15,000.00
Amount necessary for Military Organization	R$ 375,000.00
Characteristics	
Average operational capacity	12,400 kg
Lifting height	3.25 m

Spurce: EaeMaquinas magazine images (EAEMAQUINAS, 2016) and authors' data (2020).

Table 6 – Box trailer being transported by ferry

Machinery	Average price
Truck (6x2 axle configuration)	R$ 340,000.00
Semi-trailer van for dry goods	R$ 100,000.00
Semi-trailer van for refrigerated goods	R$ 152,000.00
Refrigerated van cooling motor	R$ 110,000.00
Amount necessary for Military Organization	R$ 1,042,000.00
Characteristics	
Average capacity	15 tons

Source: ANTAQ image (2011) and authors' data (2020).

4 SAPEVO-M method

In complex decision-making, the opinions of the decision-makers' advisors are usually considered. However, this advice on collective decisions in the Armed Forces, due to the peculiarities of a strict hierarchy and discipline, is often distorted in favor of the decision-maker, often leaving relevant technical criteria behind.

Santos (2018) presents a spiral of decision-making made up of eight stages, starting with the perception of the problematic situation until the decision to implement or not the model. Thus, in the course of the process, the decision maker's perception

incorporates new facts from the underlying reality that had not been taken into account before, structuring a new understanding of the problem, which, perhaps, may lead to a new objective, making all the process to be repeated.

Therefore, the SAPEVO-M Method is used when it is not possible to reach a consensus among the advisors to proceed with the application of a certain criteria ordering method. For this reason, Greco et al. (2019) improved the SAPEVO multicriteria assessment method, developed by Gomes et al. (1997). They included the possibility that each decision maker could establish his preferences, generating an ordinal vector for the criteria. Finally, all ordinal vectors are aggregated into a single vector. Similarly, the same concept is used to establish the alternative preferences within each criterion, that is, from the capture of multiple perceptions.

SAPEVO-M Method also has an interesting sociological aspect, since the advisory process is carried out in order to inhibit external factors that significantly influence the opinions of each member. This is because the evaluation is carried out in a secret and individual way, with the vectors being all aggregated into a single final vector, not indicating the military's preferences. In this way, susceptibilities are avoided when a collective decision needs to be taken by members of different ranks in the Force. This makes the process clearer and more efficient, since the decision maker will have higher quality data.

The method has been applied in several areas such as Santos, Oliveira and Lima (2019) in the selection of the best route for a road transportation company, and in Greco et al. (2019) in the selection of a troop landing vessel for the Argentine Navy.

In 2019 a website[7] was developed to data implantation using the SAPEVO-M method, making it easier to be used. The SapevoWeb system was possible to be created through a partnership between the technical staff of the MB's Navy Systems Analysis Center (CASNAV), a research group of the Graduate Program in Production Engineering of the Universidade Federal Fluminense (UFF) and a research group from the Graduate Program in Systems and Computer Engineering at the Instituto Militar de Engenharia (TEIXEIRA; SANTOS; GOMES, 2019).

4.1.1 Solution proposal

In order to determine some evaluation criteria for the selection of the appropriate equipment for the logistical peculiarities in the Amazon region, a senior officer from the Instituto Militar de Engenharia and 3 intermediate officers from a technical and logistical framework who have already served in the Amazon region were interviewed.

The selected criteria were: a) Safety in the use of machinery; b) equipment maintenance ; c) transshipment time; d) possibility of different use, and e) acquisition cost.

Safety in the use of machinery refers to the basic requirement that need to be met in the Amazon region – to carry out transshipment on uneven and uneven terrain

7 The tool can be found at: www.sapevoweb.com. Access on: Feb. 9, 2020.

with low risk for the army officer who is operating the machine, so that there is no cargo and equipment loss.

The "equipment maintenance" criterion is essential, as there are not large numbers of companies capable of supporting equipment maintenance for the public administration in the interior of the states of the Amazon region. Sometimes the cost of maintenance is higher than that of purchasing new equipment. Therefore, the greater the complexity of the machinery, the more difficult its maintenance tends to be.

"Transshipment time" refers to the cargo transfer from the road to the waterway modal or to the air and vice versa.

The more versatile the equipment and the shorter the transposition time of a five-ton vehicle for the SHERPA aircraft, for example, the better it will be for the EB. This criterion is fundamental for interoperability between the Armed Forces, as it will save time in operations, human resources and financial availability.

The "possibility of different use" was a criterion determined to differentiate the equipment that can be used in other daily activities, not only in cargo transfer. The intention is to reduce unused capital and depreciation costs.

The "acquisition cost" will prove to be fundamental for the implementation of this project, in view of the budget restrictions imposed on the Armed Forces. It is important to note that box semi-trailer trucks have to be purchased to separate refrigerated materials, ammunition and the rest of the cargo in the case of choosing the third option, that is, box trailer truck. However, comparing to other handling equipment, this acquisition would not be necessary, since the supported units already have their own cargo transportation vehicles that could be used.

All of these parameters are taken into account when elaborating and presenting the study. In addition, SAPEVO-M method will be used to determine the importance of each criterion in decision making.

The "preferences" are measured from the semantic scale proposed by Gomes, Mury and Gomes (1997), as shown in Table 7.

Table 7 – Table of preferences

Scale 1 (symbol)	Scale 1 (variable/ corresponding linguistic expression)	Scale 2
<<«1	Absolutely worse/ absolutely less important	-3
<«1	Much worse/ much less important	-2
«1	Worse/ less important	-1
1	Equal or equivalent/ as important as	0
»1	Better/ most important	1
>»1	Much better/ much more important	2
>>»1	Absolutely better/ absolutely more important	3

Source: Derived from Greco et al. (2019).

After defining and exposing the criteria to be evaluated, the military make their judgments about the criteria in order of preference and importance, comparing the criteria and the alternatives with each other. Thus, a project was created in the SapevoWeb tool to assist decision making. The data entered are as follows, in Tables 8, 9 and 10.

The decision-making agents are registered one by one, until all are inserted in the system. In this article, the following Decision Makers were used: "Senior logistics officer," "PhD IME's Professor" and two "Technician officer/ IME Engineer", as illustrated in Table 8.

Table 8 – Inclusion of decision makers

Decision Makers	
#	**Decision Makers**
14	Senior logistics officer
15	PhD IME's Teacher
16	Technician officer/ IME Engineer
17	Technician officer/ IME Engineer

Source: Based on SAPEVOWEB online software.

Similarly, information on the names of the alternatives and the criteria analyzed were inserted, as shown in Tables 9 and 10, respectively.

Table 9 – Inclusion of alternatives

Alternatives	
#	**Alternatives**
16	Truck crane
17	Pallet fork tractor
18	Semi-trailer truck

Source: Based on SAPEVOWEB online software.

Table 10 – Inclusion of criteria

Criteria	
#	**Criteria**
14	Safety
15	Maintenance
16	Transshipment time
17	Different use
18	Cost

Source: Based on SAPEVOWEB online software.

When performing the multicriteria analysis, the system returns values related to the criteria analyzed according to the weights given by the decision makers. The result obtained is shown in Table 11:

Table 11 – Weight of each criterion

Weight
Criteria - **Safety** - 4.0
Criteria - **Maintenance** - 3.0950598421186655
Criteria - **Transshipment time** - 2.1475426534250066
Criteria - **Different use** -1.2009931245225363
Criteria - **Cost** - 0.012009931245225364

Source: Based on SAPEVOWEB online software.

From Table 11, it can be seen that the safety criterion was the best evaluated, with the greatest weight. Thus, among the selected factors, this was the most relevant for decision makers, followed by maintenance, transshipment time, different use, and cost.

4.1.2 Results achieved

It can be seen in the results matrix, shown in Table 12 below, that, in view of the selected criteria, the best alternative was to purchase tractors with forks for allocation at cargo transfer points.

Truck crane, the second alternative, has a higher acquisition cost and a relatively higher risk for the operator's safety and cargo loss. In addition, the dual use of the equipment is restricted to transportation in eventual vehicle breakdowns.

The box semi-trailer truck is the one with the easiest maintenance in the Amazon region and also the easiest transfer in the case of changing from road to waterway modal, which is the most common in the region. However, it does not present itself as an optimal solution for logistical use when transportation is by air. Intermodal transfer would be facilitated; however, unloading and loading process through the military would continue to occur. In addition, the acquisition cost proved to be excessively high, since it would be necessary to purchase several box trailer trucks for the transfer to be directly carried out.

Thus, the equipment chosen was the tractor with forks, as shown in Table 12.

Table 12 – Ordering after using SAPEVO-M multicriteria analysis

Ranking
1º -- **Pallet fork tractor** -- 29.4847598675834
2º -- **Truck crane** -- 4.443584151842555
3º -- **Semi-trailer truck** -- 3.22131398013751

Source: Based on SAPEVOWEB online software.

5 Final considerations

The beginning of the decade is marked by an increase in Brazilian leadership in response to the overflow of several regional crises, whether through external relations with Latin American countries, or with the strengthening of public security and the Armed Forces.

At the same time, the country is still in a deep economic crisis, aggravated by the social isolation resulting from the pandemic caused by the SARS-CoV-2 virus (which causes the Covid-19), making scarce financial resources vital to the continuity of basic healthcare and the promotion of education, demanding a reduction in defense expenditure.

Therefore, considering that the variables Security and Defense are closely correlated with the investments made in these areas, there is an urgent need to optimize processes to maintain the levels of service provided with the reduction of financial resources.

In this way, it is possible to infer that the capacity of integrating military logistics is an alternative not only to increase the combat power of the Armed Forces and their deterrent capacity, but also to more efficiently manage the resources destined for National Defense.

Thus, this scientific research sought to analyze military interoperability in developed countries to sustain the Brazilian doctrinal evolution, showing that it is not possible to have logistical interoperability without the Singular Forces being able to integrate quickly and effectively.

In addition, in a country that aims to achieve greater international projection, effective interoperability in its Armed Forces is paramount, with the standardization of processes, modes and systems.

The case study of the EB in the Eastern Amazonia demonstrated that there are precarious means and processes for the transshipment of cargo between modes, revealing an opportunity for improvement that will bring practical results for the optimization of human, financial and interoperability resources.

Therefore, by applying the SAPEVO-M method to support decision-making, it is possible to observe that the best equipment to be acquired by EB in the Amazon region is the pallet fork.

By adopting this machinery: 1) The number of injuries resulting from incorrect cargo handling during loading and unloading processes will decrease. This movement of cargo is carried out, in large part, by the EB temporary personnel; in the case of injuries, after cause and consequence being proved through an administrative process, the EB is obliged to provide an adequate health treatment, increasing the burden of the health system. 2) The transshipment process will be accelerated, increasing the Force's operational logistical capacity, as the mode of transportation used will be available in a shorter time to be used in a new mission. Thus, vehicles need bottleneck is reduced; 3) Direct and indirect costs resulting from this process will be reduced, allowing the supplies to be delivered to the Special Border Platoons, for example, unified and palletized.

In addition, the model observed in the EB should be adopted by other Forces, and this logistical project should have a strategic conception, that is, it is suggested that the Ministry of Defense should be responsible for its management, so that each military branch would have its means to carry out the necessary procedures for intermodal integration.

Finally, as an opportunity for further studies to deepen the theme of this work, the recommendation is that: a) the feasibility of inserting the equipment into other operating environments should be assessed, with special attention to its peculiarities; and b) the strategic transportation axes of each Force should be studied, and they could be unified or integrated.

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