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Positioning of Logistic Resources by the Global Navigation Satellite System (GNSS) for Securing Combat Operations

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Abstract

This publication presents the possible use of the Global Navigation Satellite System (GNSS) for securing logistics supply chains during combat operations. The study's main purpose is to present how positioning conducted by the GNSS can be an element of military logistics assets support in the logistics chain delivery process. To achieve the stated goal of the research, the following research problem has to be defined: How does the positioning of logistics assets by the (GNSS) affect the security of combat operations?

Specific research problems were identified for the research problems:

1. What is the essence of using a satellite GNSS for military logistics?
2. What are the effects of using a satellite GNSS in securing combat operations?

Participants in the research were experts responsible for implementing innovative technologies from the space industry into the GNSS, while the GNSS was the subject of the research. The research hypothesis set in this paper is as follows: *The use of the GNSS as satellite system affects the efficiency of the optimization of the logistics supply chain, increased troop safety and increasing allied forces interoperability.*

An Ishikawa diagram and GNSS system reliability indicators were used to analyze of the specific problem in detail. This publication was based on doctrinal documents such as: *"Doctrine of the Land Forces"* DD-4.2, *"Logistics Doctrine of the Armed Forces of the Republic of Poland"* D-4 (B) version 2.

For the purposes of analyzing the GNSS, information was drawn from *"GNSS Technology and its Application in Implementation and Control Measurements"* and a publication entitled *"Air transport supported by Global Navigation Satellite System (GNSS) in the social security aspect – SARS – Cov-2, Covid-19 pandemic".* An additional analysis and evaluation of the logistics supply chain and making relevant conclusions that can influence the further development of this system.

Keywords: Global Navigation Satellite Systems (GNSS), safety of logistics supply chain, securing operation.

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1. Introduction

At a time when advanced tools are being deployed, there is definite progress is being made in technological advances that impact all sectors of the economy, including the military. Armed forces around the world are competing to introduce new equipment and solutions in the fields of defence, reconnaissance, and logistics. Satellite navigation systems are undoubtedly an integral part of the process of securing combat operations. The evolution of this technology became the premise for the purpose of the work, which is to present the application of technology – Global Navigation Satellite System (GNSS) in the process of positioning logistics assets (Pervan, 2017).

The positioning of logistics assets by the GNSS affects the security of combat operations through its ability to monitor and track assets. Moreover, the use of this system improves the efficiency and accuracy of logistics operations and enables the provision of accurate information on-site by using the available resources. The positioning of logistics assets using GNSS allows the rapid detection of possible attacks or attempts to steal logistics assets (Crandell, 2021).

Using the data obtained from the expert interview, this paper discusses the essence of applying the GNSS for military logistics. It explains the determinants affecting the positioning of logistics assets. In addition, the risks of applying the GNSS and its development trends capable of affecting the security of combat operations are presented (Barker, 2022). Based on an analysis of the Ishikawa diagram of the quality of the transmitted signal by the GNSS transmitter, which affects the decision-making process in the logistics supply chain, dependencies and factors affecting the system are also shown.

2. Analysis of supply chain efficiency by using the GNSS

The systems approach in the GNSS diagnostic testing process is to treat the system as a whole, consisting of various components, modules and interfaces. It is a holistic approach that considers the interactions between the various components of the system and their impact on the quality and reliability of navigation signals. It is important at this point to establish their origins, diagnosis and prognosis.

As part of the systems approach, there are several stages to be distinguished:

1. Requirements analysis: determining the objectives and requirements for the system, considering, among other things, the accuracy, reliability and availability of navigation signals.
2. Identification of system components: identifying all components of the system, including devices, modules, antennas and interfaces that may affect the quality of navigation signals.
3. Parameter analysis: evaluating the parameters of the various components of the system and their impact on the quality of navigation signals.
4. Error analysis: identifying potential sources of errors in the system and determining their impact on the quality of navigation signals.
5. Reliability assessment: evaluating the system's reliability and its components, including identifying critical points that can lead to failure (Lapachelle, 2020).

The GNSS should provide accurate measurements of position, speed and time so that users can effectively navigate and perform precise measurements.

GNSS transmitter failure problems can have various causes, such as hardware failures, software errors, power failures, errors in configuration, etc. Analyzing such causes in detail makes identifying secondary or tertiary causes possible. Based on the analysis of the causes, improvement actions can be developed and implemented to eliminate or reduce the causes of problems using the Ishikawa diagram (Figure 1).

The lessons learned from measuring the quality of GNSS transmitter data transfer are also used to improve logistics processes and customer service. For example, analyzing measurement data can help in determining which factors affect on-time delivery and quality of service logistics, which can lead to a more streamlined supply chain and increased customer satisfaction (Barker, 2022).

Therefore, the measurement branch of the Ishikawa diagram is crucial for the effective management of GNSS transmitter data quality as a blockchain-based GPS for improved data and reliability. It is important to note that the use of the GNSS in securing combat operations is linked to compliance with international humanitarian law and safeguarding sensitive data.

The deployment and use of the GNSS in the context of combat operations requires proper personnel training and adherence to appropriate standards and procedures.

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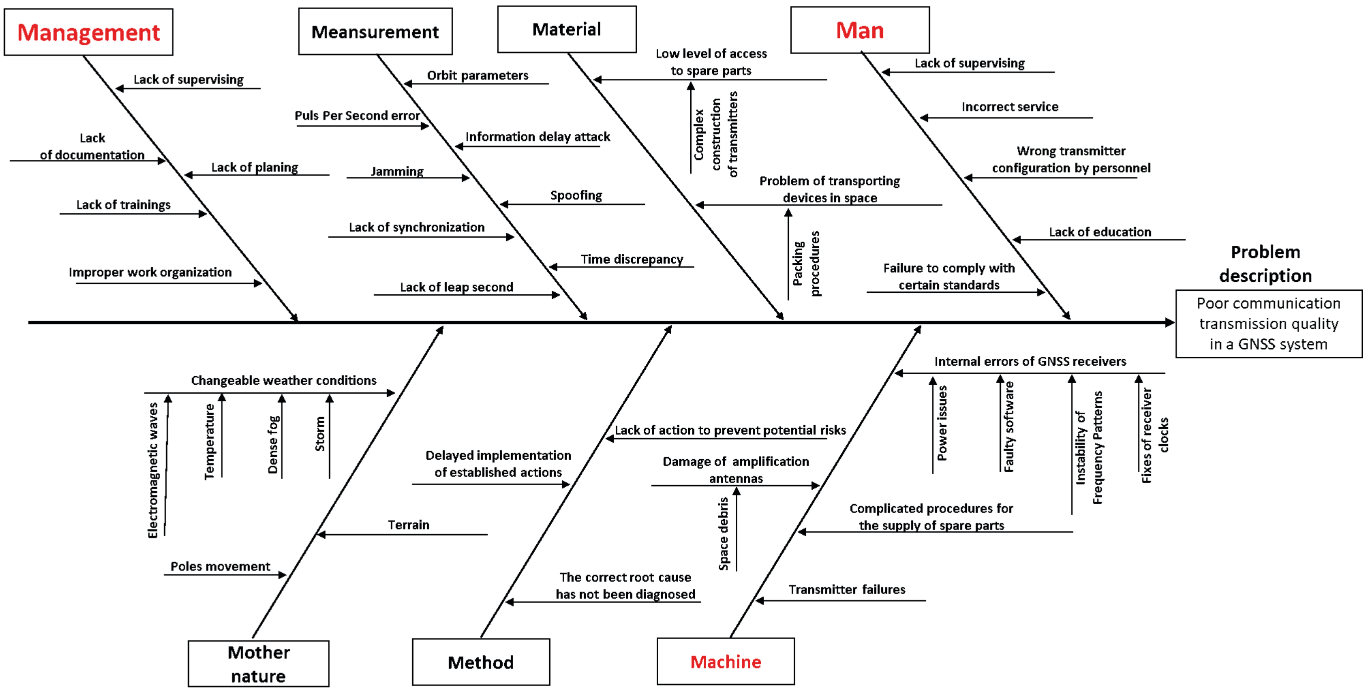

Figure 1. The Ishikawa diagram for the cause of non-compliance, i.e., poor quality of communication transmission GNSS transmitter
Source: Authors' own work.

The benefits of the applied supply chain efficiency analysis by using the GNSS include:
1. Reviewing the existing systems, procedures, organization and responsibilities was made possible.
2. Development of improvement plans is possible.
3. A basis for improving the quality of planning and budgeting has been provided.
4. The basis for cost allocation and process costing was provided.
5. Theoretical labour intensity was lowered by managing cost-creating factors and non-value-added activities.
6. A foundation for continuous improvement has been provided (Lee et al., 2022).

In summary, the GNSS enables military logistics management, including planning supply routes, determining the location of warehouses and supply centers, and managing transportation.

3. Evaluating satellite system GNSS-supported for logistics supply chain

Determining the criteria for assessing the reliability of a system depends on the specifics of this system and the operating environment. The logistics supply chain of the Armed Forces of the Republic of Poland must be taken into account as its characteristics significantly differ from civilian systems, which has been confirmed in the literature. Therefore, when evaluating such system, its specific characteristics should be considered. From the literature review conducted, system reliability in military logistics is defined as the ability to ensure the readiness of all resources. These resources are necessary in the process of carrying out the operational tasks of the military system.

Metrics and indicators are analytical tools used to measure and evaluate the efficiency of processes. The term "yardstick" refers to an economic and logistical category which reflects the actual facts of management in an enterprise, expressed in the corresponding unit of measurement. In other words, "yardsticks" are numbers that characterize a certain phenomenon and enable comparing it with other phenomena. It is important that the metrics reflect the actual status of the processes.

Indicators are an economic category that reflects the actual facts regarding the flow of materials and information in the logistics system. In other words, indicators are relative numbers that express the relationship between different statistical quantities (Barker, 2022).

Evaluation of the quality of the transmitted data through the GNSS can be made based on the following indicators:
1. Positioning accuracy indicator.
2. Time consistency index.

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3. Error indicator.
4. Integrity index.
5. Dilution of Precision (DOP) indicator.
6. Bit Error Rate (BER).
7. Carrier to Noise Ratio (C/N0).

Positioning accuracy can be expressed as the difference between the measured value and the actual value, or position error, as shown in Equation 2.1. This indicator refers to the accuracy of positioning determined by the GNSS. The higher the accuracy, the lower the risk of errors in supply chain management. The total is multiplied by 100 to obtain the result as a percentage.

$$Accuracy\ of\ position\ = \frac{actual\ value}{measured\ value}\ x\ 100 \tag{2.1}$$

The Time Synchronization Accuracy (TSA) indicator is used to assess time synchronization accuracy in the GNSS, Formula 2.2. This indicator refers to the time consistency of the GNSS signal. The higher the consistency, the lower the risk of time synchronization errors in the supply chain. If there is a time lag, the efficiency of the supply chain may decrease.

$$Time\ Synchronization\ Accuracy = time\ consistency\ of\ the\ GNSS\ signal - time\ UTC \tag{2.2}$$

The error rate is the ratio of the number of errors made to the number of days in the study period. The result is a percentage, and the relationship is shown in Equation 2.3.

$$Error\ rate\ = \frac{number\ of\ errors\ in\ year}{lnumber\ of\ days\ in\ year} x\ 100 \tag{2.3}$$

The integrity indicator measures the ease of integrating the GNSS with other elements of the supply chain, such as monitoring or inventory management systems inventory. The relationship is shown in Equation 2.4.

$$Integrity\ indicator\ = \frac{number\ of\ tasks\ completed\ correctly}{number\ of\ all\ completed\ tasks}\ \text{x}\ 100 \tag{2.4}$$

The Dilution of Precision (DOP) indicator determines the extent satellite signals are scattered. The lower the DOP index, the less dispersion and greater positioning accuracy.

$$DOP\ indicator\ = \frac{\sqrt{a^2+b^2+c^2+d^2}}{h}\ x\ 100 \tag{2.5}$$

Where:
a - Position error of the satellite in the north-south plane.
b – Position error of the satellite in the east-west plane.
c – Satellite clock error.
d – Receiver position error.
h – Height of the receiver above the ellipsoid.

The BER (Bit Error Rate) determines the number of bit errors that are transmitted in a signal. The lower the BER, the fewer errors and the higher the data quality.

$$BER\ indicator\ = \frac{number\ of\ bit\ errors}{number\ of\ all\ transmitted\ bits}\ x\ 100 \tag{2.6}$$

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The C/N0 (Carrier to Noise Ratio) determines the ratio of carrier signal power to noise power in a communication channel. The higher the C/N0 ratio, the lower the chance of errors and the higher the data quality.

$$\frac{C}{N0} = \frac{carrier\ signal\ power}{noise\ spectral\ density}\ x\ signal\ amplification\ x\ 100 \quad (2.7)$$

Based on the evaluations of individual experts, it is possible to assess the overall quality of the GNSS transmitter communication transmission. In addition, comparing the experts' ratings for different features can identify any differences in the evaluation of data transmission quality (Tyszko et al., 2007). If there is a large discrepancy in the ratings between the experts, this means that there may be a difference in the perception of the transmission quality of a particular feature. Given the above, based on the evaluations of experts. It is possible to identify the features that are most important for assessing the transmission quality of a communication GNSS transmitter. Consequently, a higher rating indicates better quality (Sharifi & Ghasemi, 2022).

The ratings given by the experts to assess the quality of the GNSS transmitter's communication transmission have been collected and presented in the summary table below (Table 1).

Table 1. *Individual expert ratings assigned for the GNSS transmitter communication quality assessment*

No.	Indicator	Weight (0-5)	GNSS transmitter communication quality rating [%]				
			Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
1.	Positioning accuracy	5	98	97	98	98	99
2.	Temporal consistency	5	100	95	98	98	97
3.	Error indicator	4	2	2	3	2	4
4.	Integrity index	4	100	99	100	95	99
5.	DOP indicator	5	2	4	4	4	3
6.	BER	5	2	4	2	2	1
7.	C/N0 ratio	4	90	90	88	86	90

Source: Authors' own work.

The quality of the GNSS transmitter communication transmission has a major impact on the logistics supply chain of troops. When signal transmission is reliable and of high quality, it enables the rapid and efficient transmission of information about the location of troops, which allows for more efficient planning of logistics activities, such as resupply or movement of forces. On the other hand, when the signal transmission is poor, or there is interference, this can lead to errors in determining the location of troops, making planning logistics operations more difficult and increasing the risk of erroneous decisions. In addition, the quality of the GNSS transmitter's communication transmission also affects the quality of the data that is transmitted in the logistics supply chain. When the signal is reliable and of high quality, it allows the transmission of accurate information about the location of troops and data related to supplies, enabling faster and more effective decision-making (Kanhere et al., 2022).

Satellite technology is constantly improving, and the proposed improvements have already affected every industry. By introducing modern technologies into the army, it is possible to improve the logistics subsystems of the army, whose needs and requirements are increasing. The modern battlefield requires the logistics of the future in order to meet the needs of military units (Siemuri et al., 2021).

In other cases, the indicators provided above are examples. They are taken into account when evaluating the flow quality and reliability of communication GNSS transmitters; however, they do not exhaust the scope of the study. In order to precisely analyze and research the application of the GNSS, experiments and conferences are conducted by world-renowned scientists who have extensive experience and knowledge in this field (Sanz Subirana et al., 2013).

4. Summary

This article's summary confirms the research hypothesis outlined at the beginning of the paper. This hypothesis has been proven by the GNSS, which significantly impacts the positioning of logistics resources and the decision-making process in the logistics supply chain. The research undertaken in this paper does not exhaust the entirety of the issues.

The following conclusions can be drawn based on the use of the GNSS in securing combat operations:

1. The GNSS satellite system can be applied for the needs of military logistics to position logistics assets precisely, optimize supply routes, enhance combat readiness, protect against attacks and theft, and support cooperation and coordination of logistics activities.
2. The effects of using the GNSS in securing combat operations include improved operational and tactical capabilities of troops, increased precision and speed of operations, optimized logistics, increased troop safety, and increased interoperability and cooperation with allies.
3. The development prospects for the GNSS include further improvements in satellite technology, increasing the number and quality of available signals, integration with other military systems, and the development of advanced applications and tools based on GNSS technologies, such as augmented reality, artificial intelligence and data analysis for more effective support in combat operations.
4. In order to design a system for the transmission of data communications, customized parameters are used to meet the needs of the specific elements.

It should be noted that satellite systems, such as the GNSS, will be continuously researched and improved in order to be used for social security purposes. Social security is one of the important aspects of the GNSS's support for safety and security. Rapid technological development and increasing society's dependence on GNSS-based services pose challenges related to potential threats such as signal interference, cyber attacks and unauthorized access. Therefore, the GNSS is continuously being improved to strengthen resilience to such threats and ensure social security while using these technologies.

Declaration of interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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