ANALYSIS AND EVALUATION OF SELECTED TRANSPORT PROCESSES IN THE ARMED FORCES

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Abstract

The article refers to the analysis of selected transport processes based on an example military unit specializing in anti-aircraft defence and destroying enemy firepower, command points, field fortifications and logistics. The first part presents an analysis of the literature on transport processes and specifications of military transport in the Armed Forces. Then, the characteristics of the examined military unit, its structure and the tasks of the fire squadrons and other subunits of the regiment were presented. The next part of the article consists of two subsections and focuses on the task assigned to the studied military unit, i.e. optimization of transport processes. An analysis of the transport of a selected range of munitions was presented, two different transport variants were calculated and conclusions and recommendations were presented.

Keywords:

transport, logistics, Armed Forces, STAR 266, IVECO Eurocargo

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List of abbreviations and symbols:

badow – command battery
bar – rocket artillery battery
blog – logistics battalion
brozp – reconnaissance battalion
das – self-propelled artillery division
dar – rocket artillery division
ddow – command division
DMO – Divisional Fire Module
DOS – Day of Supply
GZM – Medical Security Group
kinż – engineering company
kdow – command company
klog – logistics company
MSD – Place of Permanent Dislocation
P-83 – 9mm gun wz. 1983 P-83
PM-84 – 9mm submachine gun wz. 84P Glauberyt
PM-98 – 9mm submachine gun PM-98 Glauberyt
RM-70 – 122 mm launcher art.? RM-70 on Tatra 815
WR-40 Langusta – 122 mm rocket launcher Langusta WR-40
WZT-2 – Technical Support Vehicle 2
WZT-3 – Technical Support Vehicle 3
UZRGM – Universal Hand Grenade Fuse Modernized
Granat F-1 – F-1 hand grenade with UZRGM fuse

Introduction

The Republic of Poland, as a member of the European Union, NATO and the United Nations, takes an active part in the implementation of tasks, adhering to its international obligations. These tasks also concern the participation of the Armed Forces of the Republic of Poland (AF RP) in the military and non-military activities on the territory of Poland and abroad. An essential element enabling the implementation of all types of operations is the subsystem of transport and movement of troops existing in Poland. It is responsible for all troop movements and transport security of the Polish Armed Forces in times of peace, crisis and war [7, 17].

Transport is a production process whose aim is to change the spatial location of the object of transport in such a way that it meets specific needs [2]. Transport plays a key role in every country in terms of socio-economic life. It allows for the smooth functioning of various sectors of the national economy and is a factor strengthening its development [16].

The most commonly used definition of transport is a set of activities related to the movement of material goods in space using appropriate transport means. This includes a diverse technological process for transporting goods over a certain distance. This article focuses mainly on road transport, which is one of the types of transport. It can be divided into national and international road transport. National road transport means, in accordance with the Road Transport Act, undertaking and conducting business activities in the field of transport of persons or goods using motor vehicles, including vehicle combinations consisting of a motor vehicle and a trailer or semi-trailer. The place of departure and the end of the journey, as well as the entire journey, are located in the Republic of Poland (Act of September 6, 2001 on road transport (Journal of Laws of 2001, No. 125, item 1371). If the journey takes place outside the country, we are talking about international road transport.

The aim of this article is to analyse and evaluate the implementation of the transport processes of combat assets from the combat equipment depot to the examined military unit and the possibilities of their improvement, as well as to compare selected means of transport by which transport processes are performed.

The study covered a military unit specializing in anti-aircraft defence and destruction of firepower, command posts, field fortifications and logistics. Two medium-capacity, high-mobility vehicles operated by the Polish Armed Forces were selected for analysis, as this proved to be sufficient to draw satisfactory conclusions.

1. Transport from the literature perspective

The word “transport” comes from Latin and means “to transport” or “to carry”. It is a set of activities related to the movement of people and goods using appropriate means [21]. One of the purposes of transportation is to change the spatial position of the cargo or passenger, according to specific needs. In the socio-economic sphere, transport plays a key role, enabling the efficient functioning of various branches of the economy and stimulating the country’s development [1].

Transport is a process consisting of many phases, the implementation of which is necessary to achieve the intended objective [20]. It includes forming a cargo unit, loading, moving, unloading and disassembling it.

There are many criteria for classifying transport, but the most common is the division according to the environment in which it takes place. One can distinguish land transport (ground, over-ground, underground, rail and trackless), air transport, water transport (sea and inland) and transmission transport (pipeline, cable and conveyor).

Road transport as one of the types of land transport. It is a type of transport that is used both to transport goods and people, using civilian and military motor vehicles [14]. An extremely important element of the functioning of road transport is road infrastructure, which constitutes the basis for transport and transit companies [8].

Road transport is characterized by a wide selection of different types of transport means and the ability to transport cargo over short and medium

distances. It is used in the process of delivery and evacuation of supplies. To carry out this type of tasks, medium and heavy-duty vehicles with trailers or low-bed units are selected.

The disadvantages of road transport include, among the others, the negative impact on the environment and the high rate of road accidents. Nevertheless, road transport is characterized by general accessibility for people and an extensive road network, enabling comprehensive execution of orders. Additionally, its advantage is the ability to reach the destination directly from the starting point, which certainly increases convenience and saves time.

To sum up, road transport is an important link in the transport system. Its advantages and disadvantages should be taken into account when planning haulage in order to select the appropriate type of transport for a given purpose and ensure maximum comfort and safety of goods and people carried [11].

Rail transport is one of the types of land transport that is characterized by high haulage capacity and allows the transport of people and goods along specially designated railway lines. Therefore, this transport is used in the army as operational transport, used to move troops, military equipment, weapons and supplies over long distances.

To use military rail transport, it is necessary to plan the journey in detail well in advance and include it in civilian train timetables [7]. During peacetime, rail transport is also used to transport troops to training and field exercises, as well as to deliver supplies. In times of crisis and war, rail transport can be used as part of the mobilization and operational deployment of the Polish Armed Forces and to secure operations [7].

Rail transport offers many advantages, including high load capacity, huge space for transporting people and the absence of traffic jams that usually extend travel times. It is also one of the safest forms of travel and has a positive impact on the environment.

However, there are also some disadvantages of rail transport, such as the lack of influence on the established timetable, train delays, lack of available seats in the days leading up to the holiday season and the risk of theft. Despite these disadvantages, rail transport remains one of the best ways to travel over land, especially over long distances.

Inland navigation, or **inland waterway transport**, is the transport of people and cargo on a designated area of inland waterways. Boats, ferries, barges and ships are used for this purpose. This transport can take place in large river ports, but also in small harbours with minimal storage and transport infrastructure. The good condition of waterways is crucial for the proper functioning of this type of transport. Therefore, the existence of Central Waterways, which ensure appropriate navigation conditions, is an important element [7].

Inland transport offers many advantages, such as low costs, the ability to transport heavy equipment, low air pollution emissions and reduced road congestion. Unfortunately, there are also disadvantages of this type of transport, such as limited possibilities of establishing new lines of communication, susceptibility to attack by the enemy, as well as dependence on climatic and atmospheric conditions.

Inland transport is an important element of transport infrastructure and can be used for both civilian and military transport. Thanks to it, it is possible to transport large numbers of people and loads quickly, safely and ecologically.

Maritime transport is an extremely important element of global transport infrastructure, responsible for the transport of large numbers of people, cargo and military equipment over long distances between seaports [5]. Various types of ships and merchant vessels are used for this purpose, and the main transport tool are containers, which facilitate the transportation of large and oversized loads.

In the Polish Army, sea transport is not the primary method of moving soldiers, but it is necessary for the transport of crews and the handling of transported military equipment and weapons. Its implementation depends on the capabilities of the civil market, which provides transport services or means of maritime transport [7]. Containers can be loaded and unloaded in large marine terminals, equipped with appropriate equipment and infrastructure, or in smaller seaports where there is sufficient transhipment equipment.

The advantages of sea transport include: lower storage costs, the ability to transport large and dangerous loads, long-range transport possibilities and lower costs compared to rail and air transport. The disadvantages of sea transport are primarily long transport times, which on average last from 25 to 40 days, the possibility of delays due to weather conditions, problems with clearance or congestion in ports, the need for additional transport to and from the port and high susceptibility to attacks from the enemy.

Air transport is one of the fastest growing branches of the transport industry, enabling movement over very long distances [7]. Aviation is divided into civil and military, and among them there are various types of aircraft being used [5]. Specially designed pallets and containers are used to safely transport cargo [3]. Pallets are adapted to the dimensions of the cargo space of the means of transport, and the load is secured with belts and the containers are almost completely enclosed, which ensures greater cargo safety, and their shape perfectly adapts to the aircraft's cargo space.

Air transport has many advantages, such as speed of movement, the ability to reach places that are difficult to reach by other means of transport, a large operating range and a high level of safety. However, there are also disadvantages, such as the high costs of purchasing and maintaining aircraft, limitations due to weather conditions and the risk of terrorist attacks.

Transmission transport is an extremely effective method of moving energy resources using pipelines, conveyors and other transmission lines. From natural gas to electricity, transmission transport is a key element of modern infrastructure, used in both the civilian and military markets. In the army, transmission transport of liquids is particularly important. It serves as a method of moving fuel and other supplies to designated areas. For this purpose, the army transports fuel along designated lines, using extensive long-distance pipelines, or crossing wide water obstacles using crossing pipelines developed in the Temporary Trans-shipment Areas [7].

Transmission transportation has many advantages, including the ability to transport large volumes of raw materials at a relatively low cost. It is independent of weather conditions or road traffic intensity. Above all, however, transmission transport allows to transfer raw materials without the need for reloading, which increases the efficiency and effectiveness of transport [22].

Unfortunately, there are also drawbacks to transmission transport, including the high cost of pipeline construction, lack of flexibility in the type of cargo transported, and vulnerability to adversary actions. Despite these drawbacks, transmission transport is still an extremely important element of infrastructure, enabling the effective movement of energy resources in various sectors of the economy.

2. Transport needs in the Armed Forces and specifications of troops transport

A requisition is a firm wish or demand for a specific allocation of people, supplies and services, approved but not implemented without the required justification [7]. Looking at the nature of transport needs in the world, we can notice that each transport need generates a decision regarding the selection of a specific mode of transport, carrier, method and route of transport. All this is related to a specific load or batch of cargo that needs to be transported over a given distance.

Transport needs serve the purpose of moving by a specific means of transport and their objective is to change location [19]. They result from the essence of human needs and are related to production activities and human existence [18]. In the Armed Forces, these needs are related to the implementation of specific objectives and assigned tasks. They concern primarily the relocation of military units and institutions, the delivery of supplies and the implementation of evacuations on Polish territory. If necessary, they are met using civilian and military means of transport, mainly by road and rail [10]. Rail transport is characterized by the highest level of transport capacity and readiness for use by the Polish Armed Forces, which is due to the sufficient number of carriages and their diversity that Polish carriers have at their disposal [9].

Road transport is the main means used to carry out tasks related to the movement of supplies according to the needs of units and military

institutions. Medium and large capacity vehicles with trailers, low-bed sets for military tracked vehicles transport and equipment adapted to transport containers are used here. The analysed vehicle fleet for transporting combat assets are two STAR 266 and IVECO Eurocargo vehicles. STAR 266 is a medium-capacity, high-mobility vehicle used in the tactical operations zone. It is used to transport cargo from 3,500 kg to 5,000 kg depending on the terrain conditions, as well as to transport people (maximum 24 people) [13]. The chassis of this car can be used to install special equipment [12]. IVECO Eurocargo is a medium-duty, high-mobility vehicle used in tactical operations. It is used to transport a load weighing 4,800 kg. The vehicle has a classic crate-type structure with a tarpaulin.

Military transport activities employ various types of force movement, including transport to the port of loading, strategic, operational, and tactical ones. This makes it possible to move troops and supplies more efficiently and effectively. Relocation to ports of loading includes the movement of own troops from permanent deployment places (**MSD**) to previously designated ports of loading located within the state territory or abroad [6].

Strategic movement is the process of moving troops and supplies over a significant distance from a port of loading to a developed preparatory base or port of unloading located in or near the theatre of operations. The authority that sets transport priorities is the Strategic Operations Command. The coordinator of the implementation of the tasks of this movement is the Centre for the Coordination of Army Movement (CKRW).

An operational transfer is the transport of troops and supplies in the area of combined operations to the area of destination from the port of discharge. As part of this type of movement, the process of receiving, centering and further movement of troops is carried out. The person responsible for planning and coordinating tasks in cooperation with the host country and other countries is the Joint Force Commander.

Tactical movement is analogous to operational and strategic movement and is defined according to mobility levels [7].

Nowadays, the movement of troops and the tasks related to this undertaking force an increased requirements related to the standardization of cargo. This is to use appropriate packaging and appropriate preparation of the cargo, taking into account the technical parameters of the means of transport and reloading equipment. The article was based on EUR pallets with dimensions of 1200 × 800 × 144 [mm] (length × width × height). They were used in road transport to transport munitions in the examined unit.

It is worth noting that the challenge of modern logistics is to meet the appropriate level of transport of goods formed into container and pallet cargo units of the required size, permissible weight, volume and shape. These activities allow for the rational use of transport means, equipment and devices for handling and transporting loads [6].

3. Transport needs of the examined unit

3.1. The structure of the examined military unit and its tasks

In order to thoroughly analyse and evaluate transport processes in a military unit, it is necessary to familiarize oneself with its structure and the specificity of the tasks it performs. The examined unit is an anti-aircraft unit with specialized equipment. First, the deployment of DOS and the standards of munitions for SpW military equipment used in the subunits of the regiment were described. DOS, i.e. Day of Supply, is a key parameter determining the amount of a given type of supplies necessary to carry out activities [4]. These standards are calculated based on the planned average daily consumption of a given product, expressed in calculation units or pieces.

To calculate the number of ammunition pieces needed to supply a specific number of equipment units or soldiers, a calculation scheme was used based on the number of equipment/soldiers, the DOS deployment by the equipment/soldier and the number of ammunition pieces per DOS. This information is necessary for a thorough analysis of the transport processes of the examined military unit.

The examined unit includes a commander and staff. In addition, it consists of a command unit (ddow), 1st and 2nd self-propelled artillery units (1das and 2das), 3rd and 4th rocket artillery units (3dar and 4dar). The regiment also includes a Medical Security Group (GZM), an engineering company (kinż) and a logistics battalion (blog). Each unit, medical support group, engineering company and logistics battalion is equipped with military equipment.

The self-propelled artillery unit consists of five subunits, including a command battery, three self-propelled artillery batteries and a logistics company. The fire batteries are equipped with a 152 mm self-propelled howitzer "DANA", capable of hitting targets from a distance of up to 18 km. The task of 1das is to destroy enemy targets, including means and fire points, command posts and field fortifications, as well as to destroy forces and logistical means. Each soldier in these subunits has an individual weapon, and other types of weapons are also used.

The self-propelled artillery unit, also known as the Divisional Fire Module (DMO), consists of five subunits: command battery, 1st self-propelled artillery battery, 2nd self-propelled artillery battery, 3rd self-propelled artillery battery and a logistics company.

The single DMO in the Polish Armed Forces includes 24 AHS "KRAB" gun howitzers, 2 command and staff vehicles (WDsz) and 9 command vehicles (WD) built on a tracked LPG chassis, 6 ammunition vehicles (WA) mounted on the Jelcz 882.53 truck chassis in 8 × 8 layout and one weapons and electronics repair workshop (WRUiE) mounted on a Jelcz P662 truck.

The 155 mm "KRAB" gun howitzer has the ability to hit targets at a distance of up to 40 km. The unit's tasks include the destruction of missile systems, artillery batteries and anti-aircraft missiles, command posts, field fortifications and mechanized and motorized units located deep within the enemy group. Each soldier in the above-mentioned subunits is equipped with an individual weapon. Additionally, there is also another type of weaponry.

The rocket artillery unit (3dar) consists of five subunits, including a command battery (badow), the 1st rocket artillery battery (1bar), the 2nd rocket artillery battery (2bar), the 3rd rocket artillery battery (3bar) and a logistics company (klog).

The unit's fire batteries are equipped with 122mm WR-40 "Langusta" rocket launchers, which are capable of hitting targets with standard rockets at a distance of up to 20 km (40 km in the case of Fenix missiles). The ability to direct fire with salvos and cover surface targets means that the unit is intended to destroy and incapacitate human forces, mainly command posts and enemy military equipment in concentration areas. The unit also allows to demolish enemy fortifications and entrenchments as well as destroy logistic facilities in the area where they are developed. Each soldier in the rocket artillery subunits is equipped with an individual weapon.

The rocket artillery unit (4dar) consists of five subunits, including a command battery (badow), the 1st rocket artillery battery (1bar), the 2nd rocket artillery battery (2bar), the 3rd rocket artillery battery (3bar) and a logistics company (klog).

The unit consists of three fire batteries equipped with 122 mm RM-70 rocket launchers on a TATRA 815 vehicle, which enable hitting targets with standard rockets at a distance of up to 20 km (40 km in the case of Fenix missiles). The squadron is used to destroy and incapacitate enemy personnel and military equipment in concentration areas. Thanks to the ability to direct fire with salvos and cover surface targets, the division is capable of incapacitating enemy resistance points on the defence lines and opening preparation fire for an attack by own troops.

Additionally, 4dar allows to demolish enemy fortifications and entrenchments as well as destroy logistic facilities in the area where they are deployed. Each soldier associated with the subunits has an individual weapon, and there are also other types of weapons.

The command unit has several functions. One of them is to ensure the continuity of operation of the command system, including the communication system and protection for the regiment's command. The command unit is also responsible for the operation of the contamination analysis,

reconnaissance and elimination system. The basic tasks of the command unit include preparing and equipping the regiment's command post, protecting and defending the post, and ensuring communication with superiors, subordinates and cooperating subunits. The subunits of the command unit support decision-making processes at the regiment level, using modern communications and IT equipment as well as extensive specialist knowledge.

The command unit consists of three subunits: a command company (kdow), a reconnaissance battalion (brozp) and a logistics company (klog). Each soldier in these subunits has individual weapons and other types of weapons.

The engineering company's task is to strengthen engineering dams, build shelters and prepare hidden firing positions in order to provide engineering protection for the regiment's subunits. Each soldier in this subunit has an individual weapon and additional weapons.

The Medical Support Group provides medical support to the regiment's subunits. Soldiers in this subunit are equipped with individual weapons, but they lack a significant amount of weapons due to the nature of their medical task.

The logistics battalion provides material and technical support for the regiment during long-distance movements and operational deployment of the regiment, as well as during fire support for subunits' operations. Soldiers in this subunit have individual weapons and a significant amount of armament due to the nature of their logistic task.

3.2. Analysis of the transport of selected products

The assumption of the study was that as part of the training to achieve combat readiness, the examined unit was tasked with practicing the transport of ammunition and rockets from the munitions depot to the MSD. This depot is located in a town 80 km away from where the troops are stationed. The unit has STAR 266 and IVECO Eurocargo vehicles that will transport combat assets. The entire undertaking will be based on the road transport.

In order to achieve the adopted objective of the article, which is to analyse and evaluate the implementation of the transport processes of munitions from the munitions depot to the examined military unit and the possibilities of their improvement, as well as to compare selected transport means by which transport processes are performed, the study was conducted in two stages. First, the necessary calculations regarding transport needs were made (number of load units), and then two transport variants were proposed, differing in the transport means used.

Based on the calculations, the number of P-83 ammunition crates needed for the entire regiment is 38, which allows to use two Euro pallets with a total weight of 1178 kg for transport. Based on transport data, calculations were made for three types of ammunition for 7.62 mm AKMS rifles. For each type, the number of ammunition pieces, the number of crates, the total weight of the crates and the number of Euro pallets needed for transport were calculated. In total, twelve Euro pallets with a total weight of 9,698 kg will be needed to transport three types of ammunition.

In order to transport ammunition for BERYL wz. 96 assault rifles, it is necessary to properly pack and use euro pallets. For the 5.56 nb steel bullet ammunition, 7 Euro pallets with a total weight of 4,810 kg should be used, and for the 5.56 nb tracer bullet ammunition with brass cartridges – 4 Euro pallets with a total weight of 2,444 kg. The number of ammunition crates depends on the load capacity of one crate and the amount of ammunition transported.

Analysing the information on the number and weight of individual types of rifle grenades, it can be concluded that the GNPO anti-tank fragmentation grenade should be packed in 212 crates and transported using 8 Euro pallets with a total weight of 3,392 kg.

The NGD-93 smoke grenade should be packed in 124 crates and transported using 5 Euro pallets with a total weight of 1,984 kg. The NGZ-93 incendiary grenade should be packed in 106 crates and transported using 4 Euro pallets with a total weight of 1,696 kg. The NGO-93 illuminating grenade also needs to be packed in 106 crates and transported using 4 Euro pallets with a total weight of 1,696 kg.

In the case of the 9mm PM-98 GLAUBERYT wz. 84P submachine gun, in order to calculate the number of packages, the load capacity of one crat and the total amount of ammunition, which is 74,000 pieces, should be taken into account. Taking into account the weight of one crat, it was determined that 74 crates with a total weight of 2,294 kg should be transported. This way, the type of ammunition being analysed can be transported using three Euro pallets.

The WR-2/WR-2M wind gauge rifle uses three types of ammunition for which calculations were performed. The first is the NSD-1 day probing cartridge, for which 28 crates must be used and transported on one Euro pallet with a total weight of 420 kg. Ammunition is transported in full packages, and the load capacity of one crat is 240 pieces. Based on transport data, it can be calculated that 6,300 rounds of ammunition are needed. The second type of cartridges are NSD-2 day probing cartridges used in WR-2/WR-2M air rifles. It was estimated that 6,720 rounds of ammunition should be transported, packed in 28 crates. The load capacity of one crat is 240 pieces and the total weight of the crates is 420 kg. The last type of cartridges are NSN night probing cartridges, the number of cases will be 31 and the total weight of the cases will be 434 kg. The analysed type of ammunition should be packed in 31 crates and transported using two Euro pallets with a total weight of 434 kg.

The RPG-7 grenade launcher uses three types of ammunition, which are transported in full packages, which means that it is to be transported in the number of full packages. Therefore, to transport 180 rounds of ammunition, 30 crates are needed, assuming that one crate can hold 6 rounds of ammunition. The total weight of 30 crates is 900 kg. To transport ammunition, one needs to use four Euro pallets.

The PKM, PKMN 7.62mm machine gun uses three types of ammunition. For each type of ammunition, the crat weight, packaging dimensions, number of pieces in the crat and the number of crates on the pallet are given. Calculations were then made regarding the number of crates and the total weight to be transported for each type of ammunition. As a result of these calculations, it turned out that the first type of ammunition should be packed in 56 crates and transported using two Euro pallets with a total weight of 1,568 kg. The second and third types of ammunition should be packed in 25 crates and transported using one Euro pallet with a total weight of 748 kg and 700 kg respectively.

The 26 mm flare gun uses two types of ammunition. The first type of ammunition, the 26 mm signal cartridge, must be packed in crates weighing 55 kg and packaging dimensions of 730 × 550 × 250 mm. One crat can accommodate 56 rounds of ammunition, and one pallet can transport 6 crates. In turn, the second type of ammunition, the 26mm lighting cartridge with a parachute, must be packed in crates weighing 50 kg and packaging dimensions of 840 × 650 × 500 mm. One crat can hold 300 rounds of ammunition, and one pallet can transport 2 crates. In order to transport 1,960 rounds of the first type of ammunition, they must be packed in 35 crates and transported on six Euro pallets with a total weight of 1,925 kg. However, in order to transport 4,200 rounds of the second type of ammunition, they must be packed in 14 crates and transported on seven Euro pallets with a total weight of 700 kg.

The 155 mm "KRAB" self-propelled howitzer uses five types of ammunition. The first type of ammunition is a 155 mm high-explosive cartridge with a gas generator and a modular charge. There is only one piece of ammunition in the crat, and the whole amount must be packed in 672 crates and transported using 42 Euro pallets with a total weight of 39,648 kg. The second type of ammunition is a 155 mm high-explosive cartridge with a modular charge. As in the case of the previous ammunition, there is only one piece in the crat, and the whole amount must be packed in 1,344 crates and transported using 84 Euro pallets with a total weight of 79,296 kg. The third type of ammunition is a 155 mm precision shot round, which should also be packed in 672 crates and transported using 42 Euro pallets with a total weight of 39,648 kg. The fourth type of ammunition is a 12.7 × 99 round with an MP NM-140 functional turret round, which should be transported in 60 crates on two pallets with a total weight of 1,500 kg. The fifth type of ammunition is a 12.7 × 99 round

with a spherical bullet, which should be packed in 168 crates and transported using 6 Euro pallets with a total weight of 2,856 kg.

122mm "LANGUSTA" WR-40 Rocket Launcher and 122mm RM-70 Artillery Launcher on TATRA 815, which use the same types of rockets and ammunition.

In order to transport 6,720 122mm M-21 high-explosive rounds, they must be packed in 6,720 crates, each weighing 100 kg, and transported on 560 pallets with a total weight of 672,000 kg. Large and small braking rings? for M-21 missiles should be packed in 21 and 42 crates, respectively, each of which will weigh 30 kg. Transporting the first type of ammunition requires two Euro pallets with a total weight of 630 kg, and the second – four Euro pallets with a total weight of 1,260 kg. The MRW--U fuses should be packed in 672 crates, each weighing 30 kg, and transported on 68 pallets with a total weight of 20,160 kg. To sum up, in order to transport the above-mentioned types of rockets and ammunition, it is necessary to pack them in an appropriate number of crates and pallets and transport them using 560 pallets, 2 Euro pallets, 4 Euro pallets and 68 pallets, respectively. The total weight of the transported materials will be 897,050 kg.

The "LANGUSTA" WR-40 122 mm rocket launchers and the RM-70 122 mm artillery launcher on TATRA 815 use the same types of rockets and ammunition. The types of ammunition are (M-21 missile, large braking ring for the M-21 missile, small braking ring for the M-21 missile and MRW-U fuse). The number of cases containing 122 M-21 high-explosive missiles is 6,720, and the total weight of these cases is 672,000 kg. The rockets are transported individually and on special pallets with 12 pieces each.

WZT-2 and WZT-3 ammunition are: 12.7 mm rounds with the B-32 projectile and 12.7 mm rounds with the BZT projectile. For each type of ammunition, the number of pieces that could be transported in full packages was calculated, and then the number of crates and the total weight of the crates were determined. For 12.7 mm rounds of B-32 ammunition, 6,290 pieces should be packed into 37 crates with a total weight of 1,036 kg and transported on two Euro pallets. For 12.7mm ammunition with BZT projectile there should be 17 crates packed with a total weight of 1,036 kg and transported on one Euro pallet.

Describing the transport requirements for an artillery command vehicle on a tracked and wheeled chassis, information on six types of ammunition was presented. Calculations were made for each type of ammunition to determine the number of ammunition crates and their total weight. It transpires that each type of ammunition should be packed in a certain number of crates and transported using one Euro pallet with a total weight not exceeding 102 kg. The gr. GAK-81 81mm ammunition has the smallest weight (15 kg), and the remaining types of ammunition weigh 17 kg each. The number of ammunition pieces in the crate is 500 for each type of ammo.

To transport an RG-42 hand grenades with a UZRGM fuse, one crate can contain 32 pieces of grenades with a total weight of 16.5 kg. Assuming that the grenades are transported in full packages, it can be calculated that there will be 3,264 pieces of grenades in the transport, which requires 102 crates. The total weight of the crates will be 1,683 kg, and four Euro pallets will be used to transport grenades.

For F-1 hand grenades with a UZRGM fuse, one crate holds 20 pieces of grenades weighing 19.5 kg, and one pallet can accommodate 30 crates, which gives a total of 600 pieces of grenades on one pallet. Assuming that the grenades are transported in full packages, the calculations show that 3,260 pieces of F-1 should be transported, which requires 163 boxes with a total weight of 3,178.5 kg and six Euro pallets.

To sum up, after the analyses carried out, it was calculated that the transport of all combat assets of the examined unit requires the use of 15,313 transport crates and 1,364 pallets with a total weight of 1,139.921 tons. Due to the large number of munitions being transported, it was decided to use medium-capacity, high-mobility vehicles. Two different vehicles were selected (STAR 266 and IVECO Eurocargo), which were analysed as part of the task of practicing the transport of ammunition and missiles from the munitions depot to the MSD. Its purpose is to identify the best car to perform this task. Therefore, the analysis was conducted in two variants, presented below, in each of them analysing one type of transport.

3.3. Variants of transport of munitions

I. Variant – Transport of munitions using the STAR 266 vehicle:

The STAR 266 vehicle has a cargo bed with dimensions of 3900 × 2200 × 1600 [mm] (length x width x height) and a capacity of 3,500 kg off road. This vehicle allows to transport 6 Euro pallets of combat ammunition, i.e. 180 crates. When transporting rockets, the car can transport 3 pallets, but only up to 35 boxes.

The course of transport processes in this variant is as follows. Each subunit in the deployment area will be supplied with combat equipment transported using forces and resources allocated from the logistics battalion. It is capable to assign 100 STAR 266 vehicles for this task, which will cover the route from the combat assets depot to the MSD.

Rockets Calculations:

First, the number of cars needed to transport all the rockets was calculated by dividing the number of rockets requiring transport by the number of rockets that could fit on STAR 266:

$$6720 \div 35 = 192$$

To be able to transport all the missiles at once, the regiment would have to use 192 vehicles. Due to the fact that the number of rockets is 6,720 pieces, the weight of one rocket is 100 kg, and the capacity of the STAR 266 cargo box is 3,500 kg, to confirm and ensure transport safety, the weight of the transported munitions was checked against the permissible load capacity of the selected vehicle off road:

$$6720 \times 100 \text{ kg} = 672000 \text{ kg}$$
$$672000 \text{ kg} \div 3500 \text{ kg} = 192$$

The average speed of the vehicle column is 40 km/h and the distance to be covered is 80 km. One needs to calculate how long it will take for one car to transport the load using formula (1):

$$v = \frac{s}{t}$$

Where:

v – speed

s – distance

t – time

By transforming formula (1), it can be determined that the travel time t is:

$$t = \frac{s}{v}$$

So from the calculations it follows

$$t = \frac{80km}{40km/h} = 2h$$

The time of loading and unloading munitions on STAR 266 should also be taken into account. This vehicle has a cargo box without the possibility of unfolding the side walls. Loading and unloading takes place only using the physical strength of soldiers, through the rear side of the car. It takes at least 2 to 4 soldiers to lift a crate of ammunition or rockets. For this reason, the entire process of transporting combat assets is very time-consuming and this is a definite disadvantage of this variant.

It is assumed that loading 1 rocket takes 2 minutes[1], and loading the entire vehicle takes 70 minutes, i.e. 1 hour 10 minutes. The combat assets depot

[1] Based on the information obtained from JW

is capable of loading 4 vehicles at the time, so there will be 48 such loading turns. The loading time for all rockets will be 56 hours.

35 × 2 min = 70 min
70 min × 48 = 3360 min = 56 h
120 min + 70 min + 120 min + 70 min = 380 min = 6 h 20 min

The combat assets depot operates 12 hours a day, during which it is capable of accepting and conducting 10 loading rounds, i.e. a maximum of 40 STAR 266 vehicles in 11 hours 40 minutes. Table 1 below shows the implementation of the entire task.

Table 1. Sequence schedule of loading rockets on the STAR 266

Days/Rounds	1. Round	2. Round	3. Round	4. Round	5. Round	6. Round	7. Round	8. Round	9. Round	10. Round	Number of STARs 266	Time
1.	x	x	x	x	x	x	x	x	x	x	40 pcs.	11h 40 min
2.	x	x	x	x	x	x	x	x	x	x	40 pcs.	11h 40 min
3.	x	x	x	x	x	x	x	x	x	x	40 pcs.	11h 40 min
4.	x	x	x	x	x	x	x	x	x	x	40 pcs.	11h 40 min
5.	x	x	x	x	x	x	x	x			32 pcs.	9h 20 min
Total											192 pcs.	56 h

Source: own study

From Table 1 above, it can be seen that the transportation of all the missiles can be accomplished with a maximum of 40 STAR 266 vehicles in five days. The total time of the transport process for one round of cars was 6 h 20 min. It consists of a 2-hour journey to the munitions depot, then 1 hour 10 minutes of loading the missiles, a 2-hour return to the MSD and 1 hour 10 minutes of unloading.

Ammunition calculations:

In order to transport remaining munitions, the number of remaining pallets of ammunition to be transported was calculated by subtracting the number of pallets with rockets from the number of all pallets:

1364 - 560 = 804

Then, the number of vehicles needed to complete the transport was calculated by dividing the number of remaining pallets by the number of pallets that could fit on the STAR 266 vehicle:

804 ÷ 6 = 134

The result obtained showed that the transport requires 134 cars. Due to the fact that the total weight of all munitions is 1,139,921 kg, the weight of rockets is 672,000 kg, and the capacity of the STAR 266 cargo box is 3,500 kg, for the sake of transport safety, the weight of the transported munitions was checked with the permissible load capacity of STAR 266 off road:

1139921 kg - 672000 kg = 467921 kg
467921 kg ÷ 3500 kg = 133,69 ≈ 134

Additionally, the time needed to complete this task is calculated below:

STAR 266 allows to transport 6 Euro pallets of combat ammunition, i.e. 180 boxes. In this case, it is assumed that loading one box takes 1 minute. The loading time of one STAR 266 vehicle is 180 minutes, or 3 hours. During this time, the combat assets depot is able to load 4 cars at the same time. The loading time for all cars with all ammunition will be 102 hours.

180 × 1 min = 180 min = 3 h
180 min × 4 = 720 min = 12 h

The munitions depot works 12 hours a day. During this time, it is capable of accepting and conducting 4 loading rounds of vehicles, i.e. 16 STAR 266 cars, which takes 12 hours. This schedule is presented in Table 2.

Table 2. Schedule for loading ammunition onto STAR 266

Days/Rounds	1. Round	2. Round	3. Round	4. Round	Number of STARs 266	Time
1.	x	x	x	x	16 pcs.	12 h
2.	x	x	x	x	16 pcs.	12 h
3.	x	x	x	x	16 pcs.	12 h
4.	x	x	x	x	16 pcs.	12 h
5.	x	x	x	x	16 pcs.	12 h
6.	x	x	x	x	16 pcs.	12 h
7.	x	x	x	x	16 pcs.	12 h
8.	x	x	x	x	16 pcs.	12 h
9.	x	x			6 pcs.	6 h
Total					134 pcs.	102 h

Source: own study

From the table above, it can be seen that loading all the ammunition can be accomplished with a maximum of 16 STAR 266 cars in nine days. The total time of the transport process for four cars was 10 hours. This consists of a 2-hour journey to the munitions depot, then 3 hours of loading ammunition, a 2-hour return to the MSD and a 3-hour unloading.

II. Variant – Transport of munitions using an IVECO Eurocargo vehicle:

The IVECO Eurocargo vehicle has a cargo box with dimensions of 5790 × 2330 × 1990 (length x width x height) and a capacity of 4,800 kg. This vehicle allows to transport 8 Euro pallets of combat ammunition, i.e. 240 boxes. When transporting rockets, the car can transport 4 pallets with 48 rockets.

The course of transport processes is as follows. Each subunit will be supplied with combat assets transported using forces and resources allocated from the logistics battalion. It is cap able to assign 100 IVECO Eurocargo vehicles for this task, which will cover the route from the combat assets depot from town of Zieleniec to MSD.

Rockets Calculations:

First, the number of cars needed to transport all the rockets was calculated by dividing the number of rockets requiring transport by the number of rockets that could fit on the IVECO Eurocargo:

$$6720 \div 48 = 140$$

To transport all the missiles, the regiment would have to use 140 vehicles. To confirm and ensure transport safety, the weight of the transported munitions was checked with the permissible load capacity of IVECO Eurocargo:

$$6720 \times 100\ kg = 672000\ kg$$
$$672000\ kg \div 4800\ kg = 140$$

The average speed of the vehicle column is 40 km/h and the distance to be covered is 80 km. One needs to calculate how long it takes for one car to transport the load using formula (3):

$$t = \frac{80km}{\frac{40km}{h}} = 2h$$

The time of loading and unloading munitions onto the IVECO Eurocargo should also be taken into account. This vehicle has a cargo box with the possibility of folding out the side walls, thanks to which loading and unloading can be carried out using a forklift. It is assumed that loading the entire IVECO Eurocargo car takes 30 minutes[2]. The loading time of all 560 pallets of rockets would therefore be 70 hours.

$$560 \div 4 = 140$$
$$140 \times 30\ min = 4200\ min = 70\ h$$

The munitions depot works 12 hours a day. During this time, it is capable to accept and load 48 vehicles, as two vehicles are handled simultaneously every 30 minutes using two forklifts.

Fig. 1. Schedule for loading rockets onto IVECO Eurocargo

1. day	2. day	3. day
1.2xIVECO in 30 min	1.2xIVECO in 30 min	1.2xIVECO in 30 min
2.2xIVECO in 30 min	2.2xIVECO in 30 min	2.2xIVECO in 30 min
–	–	–
24.2xIVECO in 30 min	24.2xIVECO in 30 min	16.1xIVECO in 30 min
Number of the cars used – 48	Number of the cars used – 48	Number of the cars used – 44
Total in 12 hours	Total in 12 hours	Total in 8 hours

Source: own study

[2] Based on the information obtained from JW

Fig. 2. Loading rockets onto IVECO Eurocargo

Source: From private archive, photo: Konrad Łojanowski

The above analysis shows that the rockets can be loaded in 32 hours using a maximum of 48 IVECO Eurocargo cars. The total time of the transport process for two vehicles will be 5 hours. It consists of a 2-hour journey to the munitions depot, then 30 minutes of loading the missiles, a 2-hour return to the MSD and a 30-minute unloading time.

Ammunition calculations:

In order to transport remaining munitions, the number of remaining pallets of ammunition to be transported was calculated by subtracting the number of pallets with rockets from the number of all pallets to be transported:

1364 - 560 = 804

Then, the number of vehicles needed to complete the transport was calculated by dividing the number of remaining pallets by the number of pallets that could fit on the IVECO Eurocargo vehicle:

804 ÷ 8 = 100,5 ≈ 101

Thanks to the result obtained determining the number of vehicles, it was found that it would be sufficient to carry out the transport using 101 cars. For transport safety, the weight of the transported munitions was checked

$$t = \frac{80km}{40km/h} = 2h$$

with the permissible load capacity of IVECO Eurocargo off road:

1139921 kg - 672000 kg = 467921 kg
467921 kg ÷ 4800 kg ~ 98

Additionally, the time needed to complete this task is calculated below:

In the case of ammunition, it is assumed that loading 240 crates, i.e. 8 pallets with ammunition onto an IVECO Eurocargo vehicle takes 30 minutes[3]. During this time, the combat assets depot is capable to load 2 vehicles at the time. The loading time for all 101 cars would be 50 h 30 min.

101 × 30 min = 3030 min = 50 h 30 min

Fig. 3. Schedule for loading ammunition onto IVECO Eurocargo

1. day	2. day	3. day
1.2xIVECO in 30 min	1.2xIVECO in 30 min	1.2xIVECO in 30 min
2.2xIVECO in 30 min	2.2xIVECO in 30 min	2.2xIVECO in 30 min
–	–	3.1xIVECO in 30 min
24.2xIVECO in 30 min	24.2xIVECO in 30 min	–
Number of the cars used – 48	Number of the cars used – 48	Number of the cars used – 5
Total in 12 hours	Total in 12 hours	Total in 1,5 hours

Source: own study

The above calculations show that ammunition loading can be carried out in 25 h 30 min using a maximum of 48 IVECO Eurocargo cars. The total time of the transport process for two vehicles was 5 hours. It consists of a 2-hour journey to the munitions depot, then 30 minutes of loading the missiles, a 2-hour return to the MSD and a 30-minute unloading time.

The analysis of the transport of the selected goods allowed for the identification of differences between variant I and variant II used as part of the combat readiness training of the examined military unit.

Summary and Conclusions

Analysing the transport capabilities of both vehicles, significant differences were found between the use of STAR 266 and IVECO Eurocargo vehicles. The capacity of the cargo box of both cars is the main factor influencing the differences in the transport processes of munitions. The column speed of vehicles is the same for both variants, and it is 40 km/h. At the beginning, for each variant, calculations were made related to the required number of

[3] Based on the information obtained from JW

cars that would be needed to transport missiles and other combat assets at one time. In further calculations, the maximum number of cars that was used to transport missiles and other combat assets was determined.

Taking into account the rockets, it can be noticed that the maximum number of STAR 266 cars used is smaller, despite the smaller cargo bed capacity, than the maximum number of IVECO Eurocargo cars used. This is determined by the loading time, the method of loading the vehicles and the processing capacity of the munitions depot. This depot works on a 12-hour basis. The total loading time of all rockets is so time-consuming that it takes 56 hours, i.e. less than 5 working days using the STAR 266 truck. In the case of IVECO Eurocargo, the total loading time of all rockets is 32 hours, i.e. less than 3 working days.

With the remaining combat assets, the total loading time in the case of STAR 266 is 102 hours, and in the case of the IVECO Eurocargo car – 25 h 30 min. This huge difference is due to several factors. As previously noted, the first of them is the capacity of the vehicle's cargo bed. Another is way of loading the cars. In the case of STAR 266, it is "manual" loading using soldiers. This is caused by the unfolding of only the rear side of a cargo bed. This is the factor that slows down the entire transport process the most, and has a direct impact on the time needed to complete the task. In the IVECO Eurocargo, the loading method uses forklifts, which carry out loading after unfolding the side walls. The possibility of using them significantly speeds up the entire transport process, allowing more cars to be loaded on the same day.

The total time to transport the missiles is slightly longer when STAR 266 vehicles are used, as it is 6 h 20 min. In IVECO Eurocargo it is 5 hours. The difference is 1 h 20 min, or almost 27% longer.

The total time to transport other munitions in the case of STAR 266 vehicles is 10 hours, while in IVECO Eurocargo it is 5 hours. The difference is 5 hours, i.e. 50% longer.

To sum up, the use of IVECO Eurocargo vehicles is more advantageous than the STAR 266 type in terms of transport capabilities, especially in the case of missiles and other combat assets. However, the use of half-measures, such as the use of both vehicles, to optimize transport processes would also be useful. It is worth noting that not every unit or combat assets depot may have forklifts, or using them to achieve combat readiness will not always be possible.

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