Multimodal logistics chains for international transportation of dangerous and perishable goods

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Abstract. The overview article delves into the critical area of emergency logistics and supply chain management. Analyzing research conducted by experts in the field, the authors explore the potential benefits and challenges associated with the use of multimodal and intermodal international transportation of dangerous and perishable goods, and assess the potential challenges as well as the importance of emergency logistics for disaster relief and recovery. It is noted that traditional unimodal transport systems may be insufficient for swiftand efficient response to emergency situations, which makes the integration of multimodal and intermodal chains an increasingly attractive alternative. Emergency logistics play a key role in ensuring the uninterrupted flow of goods during crises and disasters, especially when it comes to dangerous and perishable goods. One ofthe purposes of this article is to highlight the importance of vehicle diversification during such disasters. Multimodal transport involves the use of several modes of transport, such as road, rail, sea and air, under the direction of one transport operator or several carriers that cooperate in a coordinated manner. On the other hand,such transportation involves the use of standardized containers that can be easily moved between different modes of transport, offering increased flexibility and cost-effectiveness. The article provides an overview of the challenges faced by emergency logistics and the potential problems when transporting dangerous and perishable goods. It emphasizes the importance of building robust supply chains that can withstand disruptions and provide rapid response to effectively mitigate risks. The need to increase the stability and efficiency of emergency logistics chains is emphasized. The study aims to shed light on which approach offers the best balance between timeliness, adaptability and overall efficiency in the international transport of hazardous materials and perishable goods. The article refers to case studies and real-world cases of emergency logistics operations where multimodal and intermodal transport systems have been successfully applied. These cases highlight their practicality and effectiveness in mitigating potential disasters and minimizing the negative impact of accidents such as spills, explosions or spoilage, and the consequences of war. The authors note the special relevance of multimodal container transportation of dangerous and perishable goods, especially duringthe war that Ukraine is waging against russian aggression, since in these conditions the principle of logistics "just in time" is most in demand, and modern containers allow to ensure complete safety, speed and accuracy,and in necessary cases, the secrecy of the delivery of goods in the conditions of hostilities and other emergency situations.

1. Introduction

In this day and age, the world has become warlike and tempestuous due to numerous military conflicts, crises and natural catastrophes.

Nowadays, undoubtedly, the importance of emergency humanitarian logistics cannot be overestimated. Timely delivery of supplies, when organized and managed correctly, might be able to save numerous lives. Frequently, the account might go on tens of thousands of people. With that being said, the importance of all the conducted researches is quite clear.

Needless to say, on-time delivery of cargo and supplies, sometimes, even of military use or dangerous ones, is crucial to ensure the success of any mission carried out in hostile or extreme environment. All the while being of utmost importance, emergency logistics is undoubtedly a major challenge which subjects the whole supply chain to an immense amount of stress and might even overload it at times.

Avoiding such stress is critical to maintain the transport system not only operational, but also efficient and quick.

Completing this crucial objective is a next-to-impossible task using only one mode of transportation. That is why, the authors deemed necessary to highlight efficiency of multimodal logistics chains in regard to transportation of dangerous goods (weapons, ammunition, toxins, explosives etc.) and perishables as the main problem of this overview article. The goal is to summarize the studies of several researchers and to extract the key theses from their articles/research papers, as well as to present them in an orderly manner in this article.

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2. Emergency logistics – definition and clarification

The concept of emergency logistics was first introduced by researchers in 2004. The definition states the following: logistics activities for the purpose of providing materials needed to deal with natural disasters, public health incidents, major accidents and other emergencies. This definition has been presented by Tomas and Fritz Institute [3].

According to the said scholars, the process of humanitarian (emergency) consists of preparation (risk assessment, scenario planning and gathering required assets for successful execution of the logistical operation), which is the foundation of successful humanitarian logistics. It involves establishing the necessary infrastructure, partnerships, and protocols well before a crisis occurs;

Planning, which is a critical phase in humanitarian logistics as it lays out the blueprint for response activities. It encompasses: resource identification and coordination of the whole process;

Procurement that involves acquiring the necessary resources to meet the needs of affected populations. Key aspects include: establishing relationships with suppliers and getting the paperwork done in a quick, streamlined way.

The main technical aspects of emergency, or, for that matter, any logistical activity, are transportation, which cannot be done without mode selection and route planning, and warehousing, which requires prepositioning of a proper warehouse and inventory management for ensuring the efficient use of the selected warehouse.

Regarding the officialities, often associated with the logistical process, the necessary steps that need to be taken are: tracking and tracing, which may be done using real-time monitoring of the cargo and transparency in the relationships with the stakeholders of the process, and customs clearance, which is sorting all the paperwork out.

Humanitarian logistics encompasses a comprehensive set of stages, each crucial in ensuring the swift and effective delivery of relief materials to crisis-affected areas. From the initial preparation and planning to procurement, transportation, warehousing, tracking, and customs clearance, every stage contributes to minimizing suffering and facilitating recovery for communities facing unexpected challenges.

Effective coordination, utilization of modern technology, and collaboration between various stakeholders are key to ensuring that the principles of efficiency, effectiveness, and transparency are upheld throughout the humanitarian logistics process.

3. Classification and further characteristics of emergency logistics

As it has already been said, emergency (humanitarian) logistics includes urgent planning, allocation of needed resources, selecting the means of transportation and dealing with all the necessary officialities. It is often applied in such emergencies as earthquakes, floods, hurricanes, terrorist attacks etc. Also, it is often involved in various hostilities, such as wars or minor regional armed conflicts. Emergency logistics is not to be confused with regular transport services though.

Emergency logistics and regular logistics are two distinct approaches to managing the movement of goods, resources, and services. They differ primarily in their objectives, processes, and priorities due to the unique nature of emergency situations, as well as the time sensitivity, adaptability and the risks the recipients, stakeholders and the cargo itself may face. Where emergency logistics is employed, the pressure put on those involved in the process is disproportionately more intense than it is in regular non-emergency situations. That is due to the fact that the nature of latter situations allows for much more leeway in terms of time sensitivity: timeframes are usually longer and more predictable, allowing for planning, production scheduling, and delivery optimization, as opposed to crises, in which time is critical and rapid response may save lives.

That constraint brings us to another problem: prioritization, which has to focus on the immediate needs of the affected and timely allocation of the resources required by the latter.

Another difference of humanitarian logistics in comparison to regular logistics is the uttermost importance of flexibility in such logistical activities. Agility and adaptability are key. Plans must be quickly adjusted to respond to changing conditions, needs, and priorities. Supply chain disruptions are common in emergencies. Roads might be blocked, airports closed, and traditional supply routes disrupted, requiring creative and adaptive solutions. That possibility in itself is a valid reason for diversifying the supply chain through employment of multimodal transport, which may greatly help with the overall stress and load on the transport system.

Hongqian Xu, Danhui Fang and Yining Jin, 2018 [3] summarize the differences between humanitarian and regular logistics in the following way: “Compared with conventional commercial logistics activities, the cost and time of emergency logistics are contrary to each other, and time is more dominant in the goal. Therefore, it has the characteristics of sudden and unpredictable, stochastic demand, urgency of time constraints, peak value, weak economy, unconventionality, government and market participation”.

4. Main challenges for emergency logistics

Researchers tend to believe that ensuring stable functioning of emergency supply chains can be done only by solving the following problems [3]:

Location Allocation Problem (LAP) – it mainly refers to determining the number and location of logistical infrastructure units in a given area considering the location of customers, or, in case of humanitarian/emergency logistics – the affected. This problem considers the path

form the logistical hub to the recipients. The main sub-problems of LAP are: site selection and allocation (during emergencies it is often challenging to mathematically calculate the perfect location of an emergency site) and the research on dispatch and allocation problems (supplies usually need to be dispatched and allocated in a reachable and timely manner).

Vehicle Routing Problem (VRP) – a combinatorial optimization and integer programming problem which asks "What is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers?" It first appeared in a paper by George Dantzig and John Ramser in 1959 [3], in which the first algorithmic approach was written and was applied to petrol deliveries. Often, the context is that of delivering goods located at a central depot to customers who have placed orders for such goods. The objective of the VRP is to minimize the total route cost.

Location Routing Problem (LRP) – the following definition was formulated by Rafael D. Tordecilla, Jairo R. Montoya- Torres, Carlos L. Quintero-Araujo, Javier Panadero, Angel A. Juan, 2022 [8] – "a traditional strategic-tactical-operational problem that considers a set of potential facilities and a set of customers with a known demand, whose main decisions are: (I) the number and location of facilities to open, (II) the allocation of customers to open facilities, and (III) the design of routes to serve customers from each facility using a fleet of vehicles. This means that the LRP considers jointly the location allocation problem (LAP) and the vehicle routing problem (VRP)".

5. Integration of multimodal transport in emergency logistics

Emergency logistics is a complex and non-linear problem and therefore, it must be treated as such. For instance, thousands died in 2001 in South Asia during natural disasters due to the lack of proper logistical infrastructure. That is why, integration of multimodal transport is critical and sometimes life-saving during various relief operations [3].

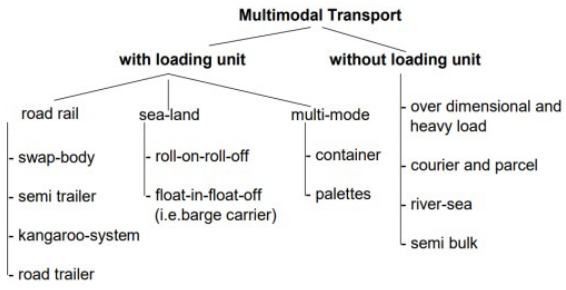

Fig. 1. Classification of multimodal transport by type of loading process

Multimodal transport is an extremely diverse type of transport system. It can be roughly divided in two categories by the type of loading process, as unloading and then loading the supplies on a different mode of transport is sure to be of utmost concern when planning relief operations with the employment of multimodal transport in mind [9].

Regarding Ukraine's regulations on multimodal transport, up until November 2021, when a new Law of Ukraine "On Multimodal Transport" was adopted, it hadn`t really been strongly regulated. The law`s main amendments are:

Multimodal goods transport operations can be carried out under a single agreement between the customer and the operator. It is the operator's responsibility to engage other carriers. The Law establishes material terms that must be included in such agreements.

The operator is directly responsible for the transportation of goods during the entire transportation process. If the transported goods are damaged, the customer does not need to find out and prove which specific carrier was responsible for the damage. The customer instead is able to submit the claims for damage compensation directly to the operator.

Further, the operator is not only responsible for the carriers' actions, but also those of the owners/holders of multimodal terminals as well as of other third parties engaged by the operator to transport the goods.

The responsibility of the operator is limited by an amount calculated under the terms provided by the Law. However, if the value of the goods declared by the customer in the multimodal agreements is higher than the amount of the operator's limited responsibility under the Law, the limitation of the operator's responsibility will be established according to the multimodal transportation agreement [1].

The multimodal goods transportation is to be carried under a single transportation document (multimodal transportation document). The Law establishes material terms that must be included in such a document.

The multimodal goods transportation will be carried out through multimodal terminals.

Multimodal transport systems involve the seamless integration of various transportation modes to efficiently move goods and people from one point to another. [9] There are several types of multimodal transport systems, each focusing on different aspects of transportation and integration. Some of the most common types are:

Intermodal Transportation: This is perhaps the most well-known type of multimodal transport. It involves the use of standardized containers or transport units that can be easily transferred between different modes of transportation such as ships, trains, and trucks.

Combined Transport: Similar to intermodal transportation, combined transport involves the use of multiple modes of transportation but emphasizes the use of a single transport document or contract for the entire journey. It provides a unified approach to booking and documentation.

Integrated Transportation: This involves integrating the various transportation modes and services under a single management system. It focuses on providing a seamless experience for the passengers or shippers, often using modern technology for coordination.

Coordinated Transportation: Coordinated transportation involves collaboration between different transport operators and authorities to optimize routes,

schedules, and other logistics aspects. This coordination can lead to more efficient and reliable transportation systems.

Flexible Transportation: This involves the use of multiple modes of transportation based on the specific needs of the cargo or passengers. It focuses on adaptability and optimizing transportation solutions for different scenarios. This type of multimodality is perhaps the best suited for emergency logistics in disaster situations.

6. Most common challenges during multimodal transportation of dangerous goods

Transportation of dangerous/perishable goods is often connected with various challenges, some of which can be serious obstacles in the way of successful logistics.

First of all, it is critical to classify the goods accordingly. The UN has a pretty clear system of international classification of dangerous goods, which is:
Class 1 –explosives;
Class 2 – gases;
Class 3 – flammable liquids;
Class 4 – flammable solids;
Class 5 – oxidizers;
Class 6 – toxic materials;
Class 7 – radioactive materials;
Class 8 – corrosive materials;
Class 9 – miscellaneous dangerous goods.

Even though the system seems to be quite self-explanatory, there might still be some difficulties, especially when it comes to cross- border transportation of dangerous cargo. For instance, when transporting medical equipment which may contain radioactive material from Europe to the US, the classification must be done according to the US standards, as every type of dangerous cargo is distinguished by its qualities and the national law on dangerous goods of the recipient may differ to a certain degree rather commonly.

Classification challenges unveil another important problem – appropriate packing and marking of dangerous goods. Although the national laws of each country may be different, the Ukrainian marking and classification standards don’t deviate drastically from those set by the UN [2].

The primary objective when it comes to the design of the packaging is to implement measures that effectively minimize the potential occurrence of leakage or any form of damage that might transpire throughout the entirety of the transportation process.

Equally important is the aspect of labeling, which necessitates a concerted effort to ensure that the information conveyed is not only prominently displayed but is also readily comprehensible to all stakeholders who are engaged in the multifaceted shipping process.

It would be quite fitting to consider the scenario of an Australian food exporter [7]. In this context, a lot of attention must be dedicated to guaranteeing that the packaging solutions employed for their perishable goods are not only structurally sound but also labeled in a manner that guarantees the preservation of their optimal quality throughout the journey.

This poses a challenge of incorporating packaging materials and techniques that mitigate the risks of leakage and damage while concurrently implementing labeling strategies that are characterized by their clarity, accuracy, and accessibility. Such a comprehensive approach ensures that the perishable goods, which are of the nature to deteriorate quickly, maintain their inherent freshness and appeal, thus, underscoring the indispensable significance of well thought out and efficient packaging and labeling endeavors in the realm of global shipping.

Shipping hazardous materials can pose significant challenges in terms of the transportation aspect. It's important to select the appropriate mode of transportation in a well-thought-out manner to steer clear of potential dangers. Equally crucial is the need to meticulously chart out the intended route for transport well ahead of time. These considerations help ensure the safe movement of hazardous goods from one point to another.

However, the complexities don't stop there. Language barriers can emerge as a noteworthy struggle in this process. It's critical for all parties engaged in the shipping endeavor to possess a comprehensive understanding of the rules, regulations, specific requirements for labeling, as well as any guidelines or precautions that need to be considered.

In essence, the successful transportation of dangerous materials demands a multifaceted approach that encompasses careful transportation mode selection, strategic route planning, and effective communication across linguistic divides to ensure compliance with the necessary protocols and safety measures.

Regarding the problems caused by multimodality itself, the following challenges may occur:

Intermodal Compatibility. Different modes of transportation have distinct handling and storage requirements. Ensuring that the cargo remains secure and meets the safety criteria of each mode during transfer points can be a logistical puzzle.

Communication and Coordination. Effective communication and coordination among various stakeholders, including carriers, shippers, regulatory agencies, and emergency responders, are crucial to preventing accidents and responding promptly to incidents.

Equipment Compatibility. Different transportation modes may necessitate different types of containers and packaging for dangerous goods. Ensuring compatibility between the cargo and the equipment used in each mode is essential for preventing leaks, contamination, and other safety hazards.

Delays and Disruptions. The disruptions of coordinating multiple transportation modes can lead to delays, disruptions, and unforeseen challenges. These delays can impact the timely delivery of dangerous goods and require agile problem-solving.

7. Further hardships in perishables' transportation

The task of ensuring the secure transfer of perishable goods is a continuous challenge that a majority of freight carriers encounter at some point. With the growing desire from consumers for greater visibility, traceability, and the overall freshness of consumables, these challenges become even more intricate for both transportation providers and sellers.

A leading source of frustration for food and beverage companies is selling the stocks out before they lose the needed freshness that consumers demand. More often than not, this is caused by poor supply chain management efforts.

The following stages make up the modern perishables supply chain [7]:

1. Raw material sourcing;
2. Manufacturing or production of food and beverage products;
3. Packaging and process;
4. Storage of finished products;
5. Distribution to wholesalers;
6. Distribution to the end consumer.

A disruption in any of these links may turn out to be critical and may even compromise the otherwise smooth functioning of the supply chain.

Other problems may occur as consequences of increasing regulatory procedures. While modern technologies surely do make establishing communication between all parties involved in the logistical operation easier, all the necessary officialities still take a toll on the straightforwardness and overall smoothness of logistics. While regulations surely make logistical services vendors` job harder, they are still absolutely critical for ensuring the goods will be meeting all the required quality standards when they arrive to the consumers.

Today`s quality control regulations are one in the same with the threat of product recalls. When they are not met and not maintained properly, it may compromise the freshness of perishable goods, thus rendering selling them impossible.

Another significant trouble in freight of perishables, especially the multimodal freight, is the occurrence of the items which are not controllable by any of the stakeholders involved. Those items impact the perishables` freight process much more so than they do freight of any other cargo. Be it natural disasters, delays in freight caused by poor weather, traffic etc. or just unethical and unprofessional behaviour of individual employees, these mishaps are to be considered when planning freight of perishables.

8. Case studies on multimodal logistics

Case 1. Hub-and-spoke model in COVID-19 related humanitarian logistics:

The "hub and spoke" model is a transportation and distribution system that involves using a central hub or location as a focal point for the movement of goods or passengers.

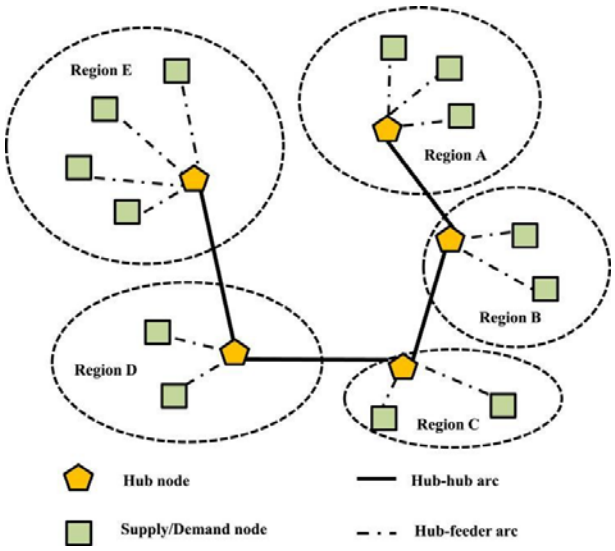

Fig. 2. Hub-and-spoke transportation network model [10]

In a hub and spoke system, the central hub serves as a consolidation point where goods or passengers are collected from various origins (spokes) and then sorted, processed, and redistributed to their respective destinations (other spokes). This model is often used to optimize efficiency, reduce costs, and improve connectivity in transportation networks.

The COVID-19 outbreak was sudden and the response had to be quick. The adequate response to this crisis was to establish a sustainable supply chain in times of global quarantine and total lockdown. To make transportation both time-efficient and cost-effective, a multimodal hub-and-spoke transportation network for emergency relief schedules was considered. Multi-type emergency relief and multimodal transportation were a must in that situation. Also, such mathematical methods as mixed integer nonlinear programming (MINLP) models and Grey Wolf Optimizer (GWO) are of utmost usefulness in such situations.

In disaster-stricken areas, people lack different kinds of help like essential living supplies (food) and personal protective gear (masks). So, it's crucial to efficiently organize the delivery of food and masks from places that have enough stock to help. Creating a good transportation system for this relies on having the right network setup. The hub-and-spoke system is commonly used in a big transportation network to make things more organized and efficient.

Undoubtedly, timely delivery of essentials, which are often perishable, to the affected is of highest priority in such a crisis. However, cost reduction must also be considered due to the finite nature of the resources allocated for organizing and managing the actual relief operation.

Certainly, things get more complex when we consider everything mentioned (different types of relief, using various modes of transport, making both travel time and cost as little as possible). Considering the two goals from the previous paragraph, we can express this tough issue

as an MINLP math problem with two objectives. But it's not easy to solve directly using a common MIP (mixed integer program) solver for this type of math problem. Moreover, because it's really difficult, it can't be perfectly solved using exact methods in a reasonable amount of time, especially for large-scale cases.

So, it's important to create a good method for solving these kinds of problems. One method is the Grey Wolf Optimizer (GWO), which was introduced by Mirjalili in 2014. It's inspired by how grey wolves work together to hunt and by their pack`s leadership structure.

In this case, a custom version of the Grey Wolf Optimizer (GWO) is employed to handle issues related to problems in pickup (from supply nodes to hubs) and delivery processes (from hubs to demand nodes) within a hub-and-spoke transportation system. To confirm that the model and new algorithm work correctly, a real-life situation is used for testing. Two other advanced algorithms, the Firefly Algorithm (FA) and Particle Swarm Optimization (PSO), are also used to compare their efficiency with the customized GWO algorithm. Both FA and PSO are ways to solve tricky problems by having individuals (like fireflies or birds) work together to find the best solutions.

Case 2. The United States' overseas military operations:

Today's realities of Ukraine, a country at war, in the future will provide many examples for studying and improving emergency logistics operations, but for now this is information with limited access, so we will consider foreign experience.

"The United States had been performing large-scale combat operations in the Middle East since Operation Enduring Freedom began in 2001 up until the 2021 Afghanistan withdrawal. As the U.S. Transportation Command's (USTRANSCOM's) representative for Army transportation expertise, the Military Surface Deployment and Distribution Command (SDDC) is at the forefront of sustaining combat readiness in the region" [4].

The initial focus of SDDC's efforts was to manage specific seaports in the Persian Gulf using a single port management approach. However, over the last 16 years, these efforts have expanded by forming diplomatic agreements with host countries and establishing contracts with local shipping companies to provide various port services, known as stevedoring and related terminal services (S&RTS). The 831st Transportation Battalion, situated in Bahrain, had the capability to oversee port management across Saudi Arabia, Qatar, the United Arab Emirates (UAE), and Afghanistan [4].

"Supporting extended combat operations in the Middle East presents several challenges due to the geographical separation between the operations in Iraq and Afghanistan. Nonetheless, transportation experts ensure synchronization of these operations. USTRANSCOM's multimodal contracts allow SDDC to find cost-effective methods of assisting the military through both commercial air and ocean carriers. Through these efforts, SDDC refines well-tested transportation networks that ultimately shape the operational landscape and provide support for combat activities" [4].

The sheer importance of multimodal logistics in the recently finished Afghanistan operation was proven numerous times. Afghanistan is a landlocked country, which is extremely far away from the mainland USA, where all the weapons and munitions come from. The primary transport mode while sustaining such large-scale operations are ground lines of communication (GLOCs). The most viable ground line of supply used to be Pakistan to Afghanistan. However, the hostilities between the two nations used to result in border closures and significant delays in transportation.

Another fitting hub for such logistical operations is the UAE and is ports. The U.S. army established commercial multimodal lift in the UAE in 2010 to ease the logistical process of supplying the military contingent. The UAE has been chosen as the ideal maritime hub because of its developed port infrastructure. Even though the UAE and Afghanistan are 1800 km apart, they are connected by viable air bridges, which explains the US Army's choice.

"Port Jebel Ali is the largest and the busiest seaport in the Middle East with 67 berths. The port … has the capacity to handle more than 22 million 20-foot equivalent unit containers annually." [4]. Furthermore, it is situated near Al Maktoum – a large international airport.

Al Maktoum International Airport is the prime node for multimodal operations and provides a generally clear and secure route to Jebel Ali and the vital link between air and sea transportation. Cargo arrives at Al Maktoum by commercial air carrier. Upon arrival, the cargo is moved to Jebel Ali where it awaits its second leg of conveyance aboard a U.S. flag vessel to its final location.

Additionally, Al Maktoum has been used as a hub to deliver large military equipment such as mine-resistant ambush-protected vehicles (MRAP) and rough-terrain cargo handlers by C-17 Globemaster III aircraft.

While such an example of the hub-and-spoke model used to be quite thought-out in itself, it could surely use a certain degree of improvement. For example, choosing Oman instead of the UAE could potentially minimalize the delays in transportation. Oman has both the maritime and the airfield capabilities for all the potential operations related to military logistics and its infrastructure is advanced enough to have faced all the potential US Army's requirements. The Navy, Marine Corps, and Army already conducted bilateral exercises in Oman yearly. With all of these factors taken into consideration, Oman could have offered many benefits for logistics operations in support of the U.S. objectives.

Case 3. The Ukrainian experience

The Ukrainian experience shows that there are no safe places in this war. Maximum dispersal of people (by means of evacuation) from places that can be affected by the enemy can provide relatively greater security. The legislation of Ukraine determines the procedure for

evacuation [Code] from areas of natural disasters or other emergency situations.

Tent or modular camps can be safer places, a temporary housing for refugees, in places of their evacuation. These camps must be able to be deployed quickly and relocated if needed. Camps must be equipped from the very beginning with everything necessary for the safe stay of people in them. One of the possible solutions is to assemble everything necessary for the deployment of such a camp, starting with the tents themselves and ending with water, food, fuels and hygiene items, in one standard container that can be moved in multimodal logistics chains [12].

Calculations show that all items in the specified kit per 100 evacuees fit into a standard 20-foot container. If necessary, the same containers can later be used to deliver the resources necessary for its residents to the tent city and take away the containers whose contents have been used. The stock of such containers (possibly in several configurations) should be stored in warehouses, it is expedient to create them in the system of the State Emergency Service of Ukraine.

The application of the ISO container described here for logistics and logistical support of internally displaced persons and other victims of war and emergency situations allows to "connect" to any multimodal transport and logistics systems, not only regional, national, but also of an international, global scale.

In this war, there have been both greatly executed emergency, even multimodal, logistical operations, like the delivery of munition, medical supplies and food into Mariupol during the siege of the city, where military helicopters were used at the final stage, as well as the civilian corridors organized by the Ukrainian government.

The destruction of the Kakhovka dam in Kherson region by russian terrorist explosion has caused a massive flood and the disaster-stricken area was a quite sizeable, which led to numerous civilians being affected by the flood. Under those conditions, the relief operations, which included the evacuation of people, animals and delivering the necessary supplies, couldn't certainly be ideal in terms of execution. The relief action had to be conducted predominately by volunteers, as the full-scale effort by the government couldn't be timely undertaken in those circumstances.

Freight of dangerous goods plays a big part in the Ukrainian war effort. It is crucial to supply the army with ammunition and food in a timely manner for any military operation to turn out to be successful and proficient in relation to the overall image of the battle theater. Of course, with the war still going on, most of the information on supply chain management of the army is classified. However, from what we can see now, multimodal transport, such as sea-land (rail and/or road) or air-land solutions, is being actively utilized by the Armed Forces of Ukraine.

Generally, the analyzed articles and cases delve into the problems and challenges of multimodal logistics of different cargo. The information stated in those covers the said problems to a great extent, however, organizing it all in an orderly manner is an important objective, which, eventually, is aimed to be achieved by this overview article.

9. Conclusion

Having considered the challenges and solutions to them in the context of multimodal emergency logistics of dangerous/perishable and other goods needed in situation of disasters of different nature, as well as having analyzed a portion of the studies conducted on appropriate topics, several conclusions are to be made.

Multimodal transportation of goods, especially dangerous and perishable ones, is a challenge to face, especially in the emergency situations. However, logistical services vendors have learned to withstand that pressure and their experience might be really useful in that during the Coronavirus outbreak, when Ukrainian transport companies could learn many valuable lessons from the crisis.

The ongoing Ukraine-russia war, which involves lots of multimodal/intermodal emergency logistics, also shows the crucial importance of multimodal solutions and containerization. Positive experience of multimodal logistic support of US' overseas military operations in cooperation of commercial carriers with Army, Navy and governmental bodies is of great importance for Ukraine and should be implemented in our realities.

The government's part in various relief operations has to be to rationally shared with that of the volunteers, who are active stakeholders in logistic operations. In our opinion, the latter, being in close touch with local final recipients of humanitarian aid and relief items, are the best providers of transport logistics services at the stages of pickup and distribution in the logistics chain, while governmental bodies should focus on coordination and easing of administrative formalities.

Regarding the employment of innovative IT, scientific and technological solutions described in Case 1, following that opportunity would greatly improve the quality of emergency logistics in Ukraine.

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