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A POSSIBLE APPROACH TO THE EVALUATION AND CLASSIFICATION OF SUITABLE MATERIALS FOR USING IN MILITARY OPERATIONS

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Abstract: *This article studies an optimal loading of moveable material reserves with the aid of simulation program for loading and cluster analysis. The article clarifies the aspects of material loading. These factors include classification, safety toleration, type of vehicles, type of material and lastly, the methods of palletization. Part of the article is also devoted to a proposal for improvement through cluster analysis simulation. The final result of imaginary 3D picture of all classes of material offers an optimal and safe loading solution of logistic transport and support.*

Keywords: military, material, safe loading, simulation, logistics

1. Introduction

Logistics must support the full range of NATO missions. Logistic support capabilities are critical for many types of operations [1]. Material reserves constitute a significant aspect of logistic support of the Army in the course of operations [2]. The intensity of material consumption increases in direct proportion to the dynamics of various military activities [3].

The high intensity of consumption of material reserves is mainly associated with combat activity, which also require a rapid supply process of restoration to the original state. The process may be viewed as a supply chain management process [4].

The amount and composition of material reserves that will be needed for resupplying combat operations, is only calculated and, in some cases, stored outside the peacetime deployments of units. The standard practice includes the application of draft loading through a sketch, or only rough calculations of vehicles transport capacities.

In the past the military exercises and other forms of training were focused primarily on the security of peacekeeping operations, which were specific. Combat material reserves were not the subject of use or consumption.

At the same time, the peacekeeping operations lack the essential characteristic feature of combat operations which create high consumption requirements for material reserves.

Training of drivers is crucial for safe transport, together with palletization, loading, conditions of transport and acceleration of vehicles [5].

2. Design of material loading optimization

The calculation of combat reserves for the model of a unit on a battalion level includes approximately 3,000 items of material. The basic structure of material is sorted in accordance with the classes of supply. The total sum of all items is presented in the Table 1.

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Table 1 List of main sorts of material [6]

Type of material	Nuber of items *[pieces]*	Total weight *[tonne]*
Ammunition	84	57
Food	35	49
Technical material	2700	67
Medical material	25	8
Chemical material	17	4
Accommodation material	57	7
Fuel and oil	15	3
Other items	150	5
Total	3083	200

3. Cluster analysis

Loading and transport of a broad range of material require a careful planning of the loading process. The material can be classified in groups with regard to their characteristic features. Each group is represented by the feature the similarity of which is either close to or distant from other groups of material. The identification of common material groups can be supported by cluster analysis, which enables us to form similar groups.

With increasing amount of data, cluster algorithms (also known as cluster analysis) have become important tools for analysing such data [7].

The measures of distance (d): They represent the most commonly used measure, based on the presentation of the object (x_1,x_2 … x_n) in space. The most common measure of distance Euclidean distance is also called geometric metric that represents the length of the hypotenuse of a right triangle and its calculation is based on Pythagoras theorem [7].

$$d_E(x_k, x_l) = \sqrt{\sum_{j=1}^{m} \left(x_{kj} - x_{lj}\right)^2} \qquad (1)$$

To avoid the dependence on the choice of measurement unit one has the option to standardize the data [8]. Since the variables are on such different scales, we will standardize them before clustering. The most common standardization way is the use of standard deviations (s).

$$y_{ij} = z = \frac{x_{ij} - \bar{x}_j}{s_{jj}} \qquad (2)$$

The list of standardized data of selected material items is shown in Table 2.

Table 2 List of standardized date

Type of Material	Intensity of consumption of dynamic activity	standardized data of dynamic activity	Intensity of consumption of defence activity	Istandardized data of defence activity	clases of tolerance	standardized data of clases of tolerance
NB 5,56 x 45	0,9	-0,856	0,2	-1,272	1	-0,797
40-SIG	0,4	-1,153	0,1	-1,332	2	-0,202
NB 7,62X51 M69	0,6	-1,034	0,1	-1,332	1	-0,797
NB 30X173 MP-T	0,8	-0,916	0,1	-1,332	2	-0,202
PTŘS SPIKE-LR	0,8	-0,916	0,05	-1,361	4	0,987
Grenade URG-86	0,6	-1,034	0,05	-1,361	3	0,392
Explosive material	0,3	-1,213	0,6	-1,034	5	1,581
Detonator	0,2	-1,272	0,6	-1,034	6	2,176
Exploder B	0,2	-1,272	0,6	-1,034	6	2,176
combat rations I	0,6	-1,034	0,3	-1,213	5	1,581
combat rations II	0,2	-1,272	0,8	-0,916	5	1,581
combat rations III	0,2	-1,272	0,6	-1,034	5	1,581
Tents S 48 m	0,1	-1,332	0,8	-0,916	1	-0,797
Heaters	0,1	-1,332	0,8	-0,916	1	-0,797
Barbed wires	0,1	-1,332	0,8	-0,916	1	-0,797
Defencewall	0,1	-1,332	0,8	-0,916	1	-0,797
Technical material weapons	0,3	-1,213	0,4	-1,153	1	-0,797
Technical material armed vehicle	0,5	-1,094	0,6	-1,034	1	-0,797
Signal material	0,15	-1,302	0,6	-1,034	1	-0,797
POL engine oil	0,2	-1,272	0,2	-1,272	1	-0,797

The application of cluster analysis on the structure of material combat reserves enables graphical presentation of close material groups. It is also possible to identify hazardous material groups.

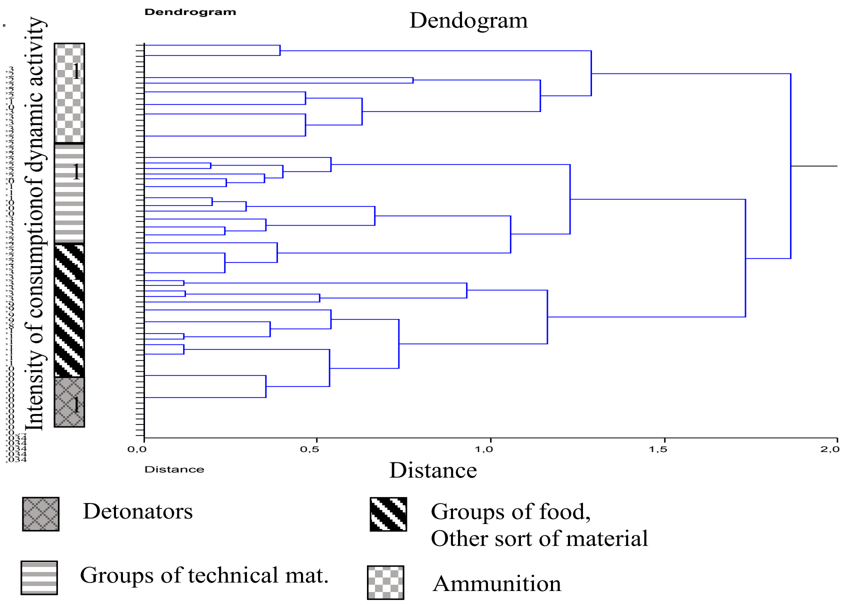

Figure 1: Dendrogram of clustering analysis of defence activities

Transported material has a whole range of properties which can cause dangerous situations when interacting with each other. The results showed the possibilities to combine explosives with technical material. The distance among these items is short. In this case it is possible to create a common palletization segment.

The most dangerous material items are certain types of ammunition, e.g. detonators, explosives and mines. The distance among these items is much bigger. It is strictly forbidden to store and transport such materials together. The outcomes of cluster analysis confirmed dangerous combinations of material in the image of common palletization segment.

The Contour Plot graph is another way of presenting the outcomes of cluster analysis. The graph is presented in Figure 2.

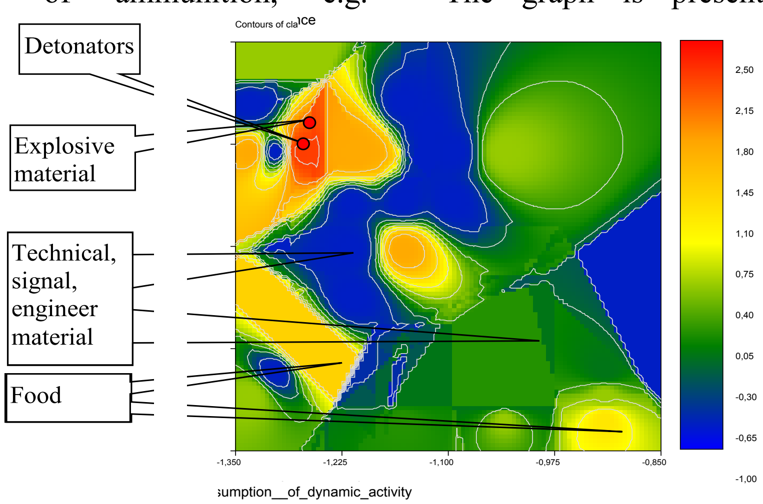

Figure 2: Contour Plot of material groups

Every coloured area represents the ability to combine the groups of material according to their tolerance classes. The material which is located in the blue and green areas is possible to be transported and stored in the common palletization segments. On the other hand, the red area includes the material items that cannot be transported together. This material has to be separated, either on different vehicles or in different warehouses.

4. Palletization of material

Effective utilization of transport capacity can be achieved through a suitable form of material palletization. It is possible to create a common palletizing segment, which may contain many types of material [9].

The palletizing segments are designed (if it is technically and economically feasible) to be transported without special fixation within the supply systems while being compatible with road transportation systems, devices and equipment for material handling [9].

The final content of segments depends on further handling during the operation supply cycle.

It is possible to define a set of vehicles with trailers, as well as specific dimensions of palletizing segments. The optimization loading solution of the material in the program used a unit model structure. The list of specifications and characteristics of vehicles is shown in Table 3.

Table 3 List of vehicles a its capacity [6]

Type of vehicle	Nuber of vehicels	Shipping capacity	Shipping capacity			
		tonnage	Length	Width	Heigth	Total
	[pieces]	*[tone]*	*[mm]*	*[mm]*	*[mm]*	*[m^3]*
Medium truck	22	7	4660	2470	1200	303,9
Heavy truck 6x6	20	10	5360	2410	1200	310,0
Heavy truck 8x8	3	12	6500	2470	1200	57,8
Light trailer	5	4	4400	2480	950	51,8
Heavy trailer	8	11	6960	2420	1000	134,7
Container ISO 1C	8	21	5870	2330	2200	240,7
	66	666				1099,0

Material loading on a vehicle is limited mainly by sidewall heights. Each car has a different loading space and weight capacity. The main limitation values are showed in Figure 3.

It is possible to present a broad range of specific options through software applications offering such loading capacity options.

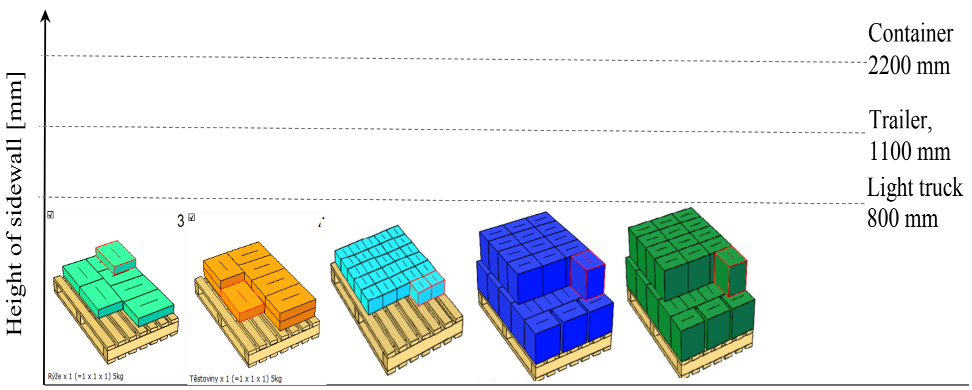

Figure 3: Loading profiles model of palletizing segments

The Figure presents the limited height of sidewalls of the used vehicles, trailers and ISO 1C container. Possibilities of material palletization will be very limited during a dynamic operation in the field conditions [10]. Especially the loading part equipped with tarpaulin canvas is not very convenient for the safety transportation of packages and pallets of material. The 3D graphic presentation creates a real picture and opportunity to combine categories of material in accordance with safety measures and loading capacity.

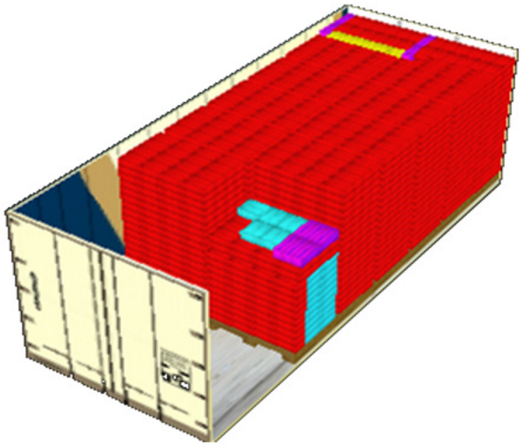

Figure 3: Container palletizing loading model

The optimization software has been tested and it has been confirmed that it is able to plan the loading. The application allows us to determine the optimal load of cargo on a vehicle. Calculating the loading plan follows the rules for stacking the items and their tilt. The division of cargo into different groups allows the items to the same destination (supply points) to be placed together. The order of the groups is then planned in accordance to the sequence of loading and uploading [11].

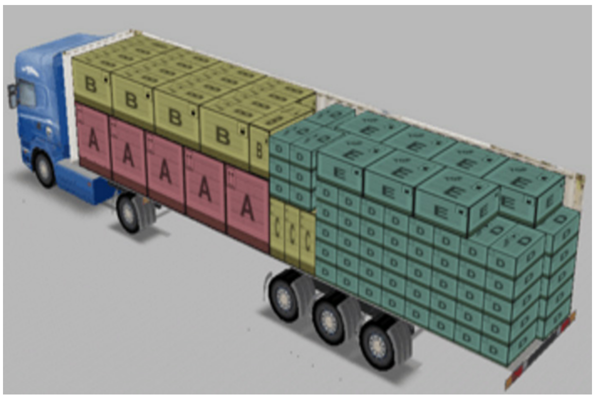

Figure 4: The Sample of vehicle loading options [11]

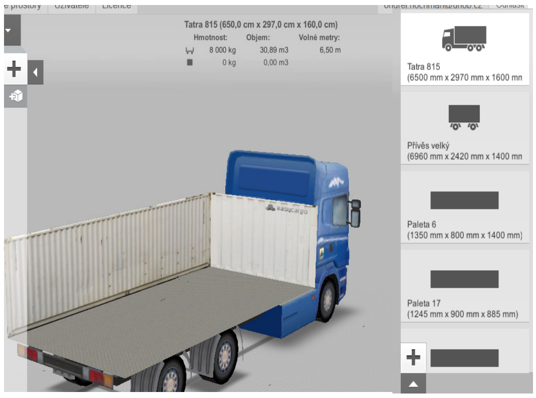

Figure 5: Definition of vehicle parameters [11]

Depending on the composition of transport vehicles, it is possible to define the parameters of vehicles, trailers, pallets and individual items being shipped. The form of setting the required parameters is shown in Figure 5.

Conclusion

The transportation of combat reserves requires a careful planning process of material loading.

Especially in the peace time, material is stored in central warehouses outside the stationary facilities of barracks. In such a case, it is neither possible to train the real loading of material nor to evaluate the alternatives of loading options.

The research outcomes confirm the suitability of clustering analysis for creating the palletizing segments for safe transportation and evaluation of loading options. At the same time, the outcomes reveal the possibility to compare alternative options of loading, which is supported by an effective application of 3D software.

Commanders of logistic units can efficiently simulate material loading. They have the opportunity to prepare a whole convoy of vehicles and propose a save deployment of material without actual presence of vehicles and material.

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