Improvement of the Integrated Supply Center Functioning Model with the Use of the Agent-Oriented Approach

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Abstract

The experience of using the Security and Defense Forces in the anti-terrorist operation and the Joint Forces operation in deterring armed aggression in eastern Ukraine indicates that under modern conditions the combat capabilities of the Armed Forces of Ukraine depend on timely and comprehensive support of their military units. In order to provide comprehensive support, compact institutions, bodies, structures, and military units of logistical support that respond quickly to the needs of the troops are needed.

The article reveals the concept and purpose of an integrated support center; the main tasks for the logistical support of military units (separate units) during operations (combat actions) have been identified; the basic indicators of efficiency of functioning and the existing model of functioning of the united support center concerning distribution of functional powers between divisions have been determined.

The list of tasks of functioning of the integrated support center where information technologies are applied is defined. The method of solving existing tasks in the process of conducting an operation (combat) is considered to be the use of multi-agent systems. The solution of the issue of integrated automation based on ERP solutions (resources management and planning concept) and WMS (the information system providing warehouse processes management automation) has been offered.

The paper summarizes the conclusions that multi-agent systems allow forecasting the availability of stocks at an integrated supply center, to form a rational model of stock management, which is based on non-stochastic demand and is a combination of known models, that will ensure continuity and completeness of military units of the Armed Forces of Ukraine for their operations (combat actions).

Keywords

Provision of military units, Information Technology, logistics, stock management model, multi-agent systems, integrated support center, stock availability forecasting.

1. Introduction

1.1. Statement of the issue

The experience of implementing logistical support measures in the anti-terrorist operation of the Joint Forces (JF) actions revealed the existence of problematic issues related to the timely, continuous and full provision of military units (separate units) (divisions) in the course of hostilities. Material supplies are delivered to military units from warehouses of higher bodies of logistical support of territorial joint centers of logistical support of the Logistics Forces Command of the Armed forces of Ukraine, realizing models of dispersed/concentrated support. The integrated support center is a warehouse with various material supplies, which serves military units located on the area of approximately 6-7 regions of Ukraine and the operation of which is accompanied by certain problems, issues and difficulties [1] - [2].

The main issues in the functioning of the integrated support center are the automation of the

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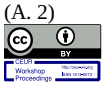

processes of accounting and forecasting the need for material supplies of units (divisions) to form a reasonable need and eliminate the situation of lack of the required volume of material supplies in the warehouse [12]. Thus, in the logistical support organization theory and practice there is an issue of improvement of work of integrated support centers, as the supporting body with use of modern information technologies and tools of construction of agent-oriented systems.

The Objective of the Article is to improve the model of functioning of integrated support centers using the agent-oriented approach.

1.2. Analysis of Recent Research and Publications

The analysis of existing publications on the research topic allows to conditionally divide them into several interrelated groups:

- the first group of sources includes well-known papers in logistics by A.D. Hadzhinskyi, V.S. Lukinskyi, B.A. Anikin, J. Stoke, T.H. Dudara, R.M. Yatsenko where the basic theoretical models and methods of the logistics theory which can be applied and at improvement of work of the integrated support centers are presented
- the second group of sources includes works on modern information technologies (IT) and multi-agent systems (MAS) by authors D.A. Pospelova, V.I. Horodetskyi, M. Wooldridge, E.O. Kharitonov, V.A. Omelianenko; this methodological base allows to improve models of work of integrated support centers [7]
- the third group of sources includes scientific works on modeling business processes at industrial and commercial enterprises by E.M. Mikhailova, S.V. Peterkin, N. Kamran, K.I. Dmytryv, T.V. Marusei. These papers were used to formalize the work of the integrated support center in the form of structural models
- the fourth group of sources includes papers which present the results of research on improvement of systems of logistical support of the Armed Forces of Ukraine and other armed formations held by Kivliuk V.S. [6], Gurina O.M. [9], Trehubenko S.S. [10], Rolina I.F.

Moreover, it can be concluded that the issue of effective functioning of the integrated support centers in the preparation and conduct of operations (combat actions) is considered limited.

The lack of connection between the development of information technology (IT) and multi-agent systems (MAS) to improve the processes in the integrated support centers, determines the relevance of the study.

2. Presentation of the Main Material

The integrated support center is a multifunctional structure which is intended for:

- elaboration of the needs of units (subdivisions) assigned to provide material supplies of current and inviolable stocks for peacetime and a special period according to the relevant nomenclature and classes of supply
- reception, storage and issuance (shipment) of material supplies in accordance with the requirements of the governing documents
- maintenance and accumulation of the established stocks of material supplies of current and inviolable stocks for the provision of military units to be supplied
- timely and uninterrupted provision of units (subdivisions) with material supplies of current and inviolable stocks in peacetime and special periods
- control over the completeness of the accounting of material supplies, their use within the established norms, the legality of use and write-off
- control of timely refilling (renewal) of material supplies of inviolable stocks according to the relevant nomenclature and classes of supply;
- operational accounting of the need, availability, movement and quality (technical) condition of technical means, determining the need for repair of technical means for units (subdivisions)
- keeping records of property in quantitative and qualitative terms
- keeping quantitative records of long-term items of material and technical means by years of commissioning for each separate account
- organization and implementation of centralized transportation of material supplies of a certain nomenclature by road or rail to units (subdivisions)
- implementation of planning of supply and refilling of material supplies of the certain nomenclature and provision of units (subdivisions) to be supported, as well as control over their timely implementation

- implementation of planning of repair of technical means by repair divisions and service, inclusion (removal) of technical means from stocks
- working out of receipt and accounting documents on registration of operations which are connected with movement and changes of qualitative (technical) conditions, writing off, dismantling (division, destruction) of material supplies of a certain nomenclature
- organization of procurement of goods, works and services, their receipt from suppliers in accordance with the legislation of Ukraine on public procurement for the needs of the Central Command, units (subdivisions) and military administration bodies to be supplied
- presence of the right of proportional distribution (redistribution) of the existing material supplies of a certain nomenclature between units (subdivisions)
- regular and unannounced audits of material supplies in units (subdivisions), analysis of the results of audits, inspections, inventory checks and control over the completeness of elimination of deficiencies
- provision of units (subdivisions) that are not to be supported (in a special period) with material supplies of the relevant service on the basis of orders (decrees, instructions) of the military administration [4] - [5].

The main tasks of the integrated support centers are continuous, operational and complete support of units (subdivisions) during operations (combat actions).

The following indicators of efficiency of functioning of the integrated support centers are considered to be the key ones [8,9] - [13]:

- efficiency of implementation of support measures

$$P(t) = \begin{cases} 1, if t \le t_{nec} \\ \lambda e^{-\lambda \frac{t - t_{nec}}{t_{nec}}}, if t \rangle t_{nec} \end{cases}, \quad (1)$$

the ratio λ takes into account the conditions of operations (combat actions), which change the steepness of the characteristics P(t) as shown in Figure 1:

Source: developed by the authors according to [8] - [9].

- completeness of provision of units (subdivisions)

$$K_P = \frac{V_Z}{V_{tr}}, V_Z \le V_{tr}, \quad (2)$$

where V_z is the amount of material assets stored at the integrated support center;

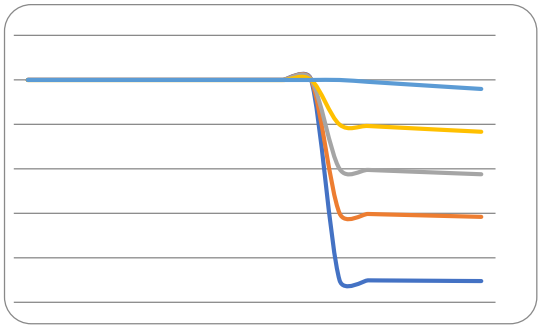

Figure 1: Dependence of the efficiency of support on the time and conditions of operations (combat actions:)

V_{tr} is the amount of need for material resources of units (subdivisions)

- continuity of the process of providing units (subdivisions) with resources.

$$k_{cpi} = \frac{t_{dti}}{t_{dt}}, \quad (3)$$

where, t_{dti} is the duration of time when the ability to perform tasks for the purpose of the i-th part (subdivision) with material supplies, delivered during preparation (provided $t_{dti} \le t_{dt}$);

t_{dt} is designated time of performance of tasks.

The value of this indicator is in the range [0,1], since $t_{dti} \le t_{dt}$.

The general indicator of continuity of designated tasks of units (divisions) is calculated by the formula.

$$k_c = \frac{\sum_{i=1}^{n} k_{ci}}{n} \quad (4)$$

where n is the number of units (subdivisions) of the air forces of the Armed Forces of Ukraine to be supported.

Based on the physical content of the indicator, $k_c \in [0;1]$. The criterion for the effectiveness of functioning of the integrated support centers will be the approximation of this indicator to the unit: $k_c \to 1$.

To date, the activity of integrated support centers is not effective by all these indicators of efficiency (the real time of execution of orders is about 14 hours with the required 12 hours, completeness of supply (no 20% in stock, no required range of stocks) with their urgent need, continuity of operations (combat actions) (under the given conditions of functioning of the integrated support centers, continuity of operations (combat actions) of units (divisions) of the Armed Forces of Ukraine up to 7 days is provided.

The existing model of functioning of integrated support centers concerning distribution of functional powers between divisions, is resulted in figure 2.

According to the results of the analysis, it is determined that IT should be used in the following tasks of the integrated support centers for:

- accounting
- forecasting
- planning
- control.

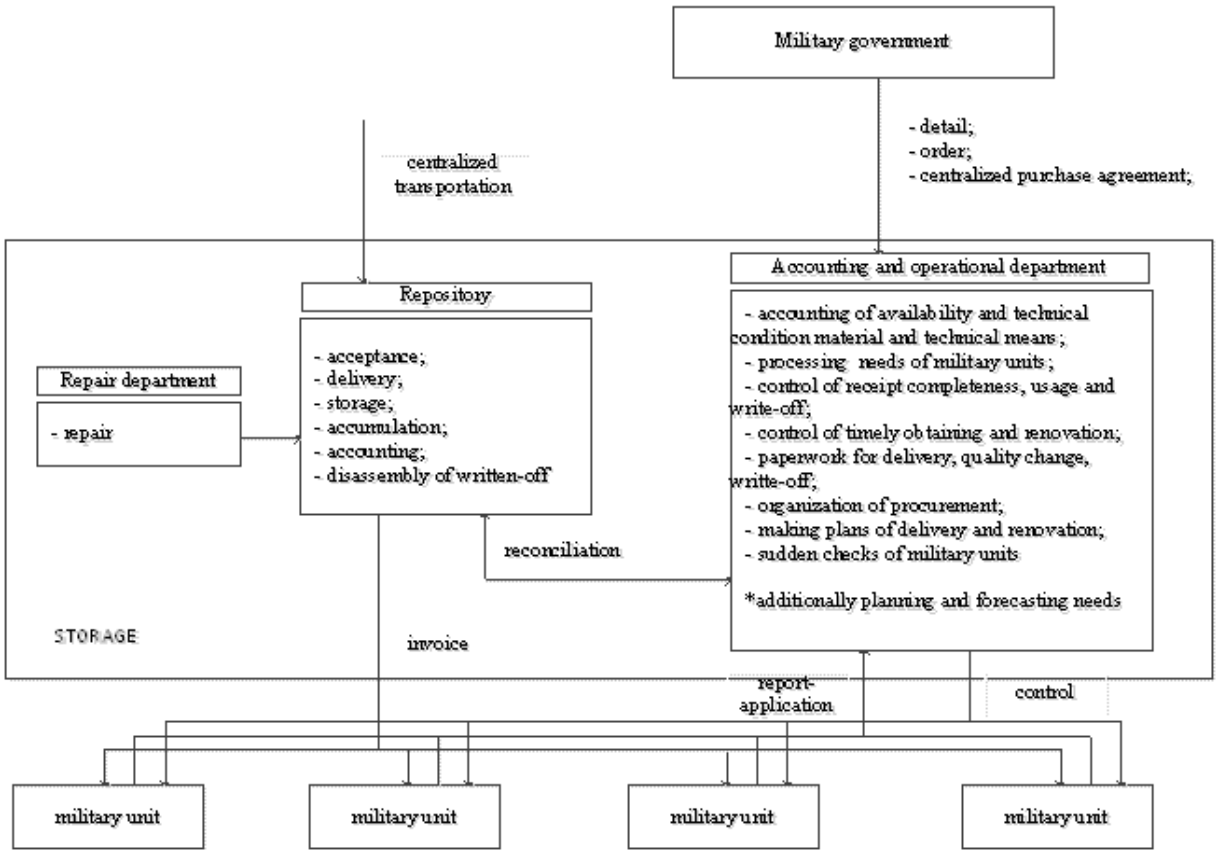

Figure 2: Model of functioning of integrated support center

We will provide a justification that IT should be used in forecasting the need for integrated support centers.

In the theory of logistics, there are a number of models of stock management, which have conditional names:

- fixed order size
- fixed order time
- minimum-maximum
- combined.

These models are effective in performing tasks by the structures of warehouses in terms of projected (uniform demand), or demand, the nature of which is clear. During the operation (combat actions) the nature of the demand for material supplies from the units (divisions) is determined by the conditions of the situation, so the use of classical models [10] - [11] is impossible (limited). Therefore, it is necessary to build adequate forecasting models to ensure the absence of a deficit at the integrated support center (timely orders, deliveries, inventory points, the rate of deficit).

A possible method of solving this issue at the integrated support center in the process of operations (combat actions) is the use of multi-agent systems (MAS). In a distributed environment, complex issues can be solved by interacting agents that act in parallel and asynchronously, jointly developing solutions to complex matters through self-organization. This principle is fundamentally different from the centralized approach and is similar to the processes of self-organization in wildlife.

MAS is a network of agents that interact with each other in a common environment and seek to achieve a common goal for the system.

The interaction of agents in the system occurs either directly through messaging, or indirectly, through the reaction of the external environment to the presence of other agents. The main property of the agent is autonomy, goals and ways to

achieve them, reaction to changes in the environment.

MAS may consist of agents of different types with their own behavior, characteristics, limitations and goals. Agents like software can be written in different languages, run on different platforms and be distributed on a computer network. MAS are usually open and contain a variable number of agents: agents can enter the environment of interaction and leave it [7].

In logistics, order and resource agents are elements of a network of needs and capabilities that interact in the virtual space of the system. They enter into contracts to perform actions, strengthening or weakening connections depending on the situation, where the state and configuration of the network corresponds to a certain dynamic schedule. Agents of needs and opportunities, in turn, if necessary, generate additional agents. The constant search for consensus by mutually acceptable compensation for fluctuations in conditions of uncertainty in the conduct of hostilities, leads to a dynamic equilibrium, organized independently [11]. To date, the automation of processes and their integration with computer systems gives a new impetus to the development of MAS in the direction of logistics, when each object of the system is associated with its corresponding agent. Such systems will operate virtually without external interference.

For complex automation of the integrated support center, ERP-based solutions (resource management and planning concept) and WMS (information system that provides automation of management of warehousing processes of the integrated support centers) are proposed. Logistics concepts allow to determine the properties and characteristics of logistics processes on a single methodological basis.

ERP is the effective planning and management of all the resources needed to produce and sell products. The purpose of the ERP concept is to integrate all departments and functions into a single computer system that can serve all the specific needs of separate departments. It combines all bodies and departments within one integrated program that works with a single database, so that everyone can more easily share information and communicate with each other.

WMS consists in active warehouse management, obtaining accurate information on the location of material supplies in stock, effective management of material supplies, which have a certain shelf life, optimizing the use of storage facilities.

When choosing a program for WMS implementation, it is necessary to take into account the capabilities of software, flexibility in customization, specifics, current and planned tasks performed by the integrated support centers and units to be supported. The advantage of using computer information systems is the formalization of processes (ordering and minimization of errors).

Since WMC is the system, which is an open source system and provides a standard warehouse topology, it is possible to expand its capabilities with MAS. In addition, the introduction of these technologies will increase efficiency (Table 1). Source: developed by the authors according to [8].

Table 1

Comparative table of results

Indicator name	Before storage automation	After storage automation
Efficiency of implementation of support measures	14 hours	12 hours
Completeness of provision of units (subdivisions)	80%	90%
Continuity of the process of providing units (subdivisions) with resources	7 days	10 days

3. Conclusions

The use of MAS allows forecasting the availability of stocks at the Central Command, to form a rational model of stock management, which is based on non-stochastic demand and is a combination of known models that will ensure continuity and completeness of military units (separate divisions) of the Armed Forces of Ukraine.

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