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THEORETICAL APPROACHES ON THE MODERNIZATION OF MILITARY EQUIPMENT MAINTENANCE

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ABSTRACT

The article proposes an analysis of the transformation and modernization of the maintenance system of the military equipment together with the adaptation to military technical systems typology existing in equipping Romanian Army. Technological development of weapon systems in recent decades has imposed adjustment of methodologies for repairs and maintenance to obtain some availability coefficients, assumed for technical systems placed in endowment. Although political and economic conditions were hostile at times, the need to align to the geo-strategic reality has led to the remarkable development of military equipment and to improvement of their maintenance. Endowment with complex military equipment including subsystems in various domains (mechatronic, ballistics, information technology, optical, thermal, chemical, hydro-pneumatic and so on) has created prerequisites for the transformation and modernization of operating systems, logistics, maintenance, whose procedures involve optimization methods to meet the requirements of the modern battlefield.

KEYWORDS: transformation; logistics; military equipment; repairs; maintenance

1. Maintenance of Military Equipment in Land Forces Logistics

Maintenance system in land forces logistics operates and is responsible for the maintenance and repair of military or civil equipment used in military operations. The system is organized so as to ensure the timely manner preventive or corrective type maintenance, repairs of small, medium or high complexity, supply and management of spare parts, as well as related tasks assigned to this activity. The importance of the maintenance system in the Romanian Army is greater the higher the equipment share of significant duration in service is. Experience has shown that the frequency of equipment functioning non-conformities occurrence is directly proportional to the increase in length of service.

The typology of the current military equipment of ground forces was conducted by restrictive economic conditions, political and geostrategic conditions that have characterized the period of the last decades and that influenced the directions for action in the field of procurement of military technical systems.

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Long delays in carrying out national programs of investment in modern equipment for ground forces led to the recording of some large amounts of old technical systems and of a large diversity of modern equipment. This reality calls for various maintenance methodologies, with high costs. To maintain the operation of such equipment, it is necessary to implement differentiated maintenance concepts for different technological generations.

Over the past decade, the role of maintenance importance of military equipment has significantly increased, due to the registration of some low levels of availability in all classes of equipment. Degradation of operability state was due to several factors: a poor strategy for transformation of the military system has allowed the elimination of some important production capacities in the field of equipment maintenance (workshops, sections, repairs bases); reducing investment in upgrading the existing maintenance facilities; migration of specialized staff towards civilian industrial sector, due to wage and staff policies and so on.

An important factor which has affected the maintenance field is the disappearance of numerous civilian operators of the defence industry, which ensured the outsourced maintenance, spare parts and materials required in the process of repair/ maintenance and the provision of new equipment to replace those worn out physically/morally. The dramatic fall in investment in procurement of domestic equipment has led to the disappearance of certain economic operators in the national defence industry and has led to increasing obsolescence and physical wear of existing equipment. This has led to the sharp increase in demand of maintenance interventions and drastic decrease in the level of availability of equipment.

In 2007-2008, it was initiated the reorganization of military maintenance system by optimizing on scientific bases of management and performance structures. Reorganization consisted in implementing modern procedures and concepts, taken from similar structures of NATO member states. Reorganization of repair and maintenance field represented one of the measures necessary to achieve an assumed level of availability of equipment within the standardization process and to meet the conditions for achieving interoperability. The necessity of implementing modern concepts was dictated, also, by the technological level of modern equipment, entered in procurement in recent years, and especially by the need for cooperation with NATO partners in multinational operations or in joint training exercises.

2. Modernizing Military Equipment Maintenance System

Technological development of military equipment belonging to ground forces imposed significant transformations in both the operating process, and especially in the repair and maintenance systems, a system responsible for ensuring the functioning in designed parameters of equipment used in missions for a longer period. Maintenance system transformations of the Romanian Army ground forces were dictated by the need to implement NATO's logistic principles and policies (MC 319/3, 2014) in order to meet the conditions of interoperability with similar structures within the Alliance.

In addition to modern concepts of maintenance, another aspect of the transformation of repairs and maintenance system is the change of main assets and resources that depend on this activity: visions, technologies, services, processes, methodologies, data and information and relational systems, material resources, hardware and software resources, human resource. Depending on the requirements of the technological level of the existing equipment and the degree of urgency in obtaining a desired level of availability,

strategic structures in the field of military equipment maintenance set directions for conversion by including maintenance of equipment in integrated logistical support (SLI). This concept represents a technical and managerial process through which financial and logistical support requirements of an equipment shall be identified and integrated for its full life-cycle (from development and design phase until the removal from service of the equipment) (Negrea, 2013).

Integration of maintenance equipment in SLI involves changes in both management area and the area of performance of activities in the maintenance field. Modernization of maintenance activity encompasses equipment maintenance management and the management of equipment during their working life.

Maintenance management aims to optimize the activity by streamlining (human, material, financial and so on and so forth) resource management, associated with the activity of maintenance and monitoring the operation of the equipment through the use of specialized tools and analysis of data supplied by them.

Military equipment management during the life cycle includes the maintenance activity and aims to optimize the use of military techniques based on the analysis of performance, quality, costs, (physical/moral) tear of differences in operational environment, SLI ("*maintenance planning; supply, staff, equipment for testing and support, configuration management, technical data and information, training and support for training, infrastructure facilities, packaging, handling, palletisation, storage and transport*") (Negrea, 2013). Effective management of equipment is obtained through sound planning of SLI before entry into their procurement, the balanced use of the equipment for the entire life duration in relation to targeted operational profile, timely planning and ensuring on time resources intended for SLI to obtain a predictable and assumed level of availability.

Permanent monitoring of the functioning way of constitutive elements of equipment allows for performance of competent analysis on fault development and causes modality of their occurrence with *the failure mode and effect analysis – FMEA* (Certa, A., Enea, M., Galante, G., Lupo, T. (2015). Monitoring is done in order to eliminate the causes that produce breakdowns and runs through the intermediate of sensors and transducers embedded in them, or through periodic checking of the operation parameters with dedicated measuring and control instruments.

Maintenance system transformations from logistics land forces as part of transformational strategy spanned the transition from the systematic maintenance system based on maintenance and repairs scheduled at time intervals or on the basis of technical resource consumption, at the predictive maintenance system based on reliability growth or on monitoring and analysis of the equipment condition. These methodologies are actually modern concepts of maintenance which uses continuous monitoring of the status of equipment and performance of predictive and proactive type. Implementing modern methodologies allows the elimination of a host of redundant interventions, which use ineffectively financial, human and time resources.

The high technological level of modern military equipment, as well as the great diversity of operations that equipment can currently perform necessitated maintenance efficiency of activities specific to maintenance field by developing concepts adapted to the new types of armaments systems: reliability centred maintenance, condition based maintenance, life cycle costs management, total productive maintenance and so on and so forth.

Reliability-centred maintenance – RCM it is the most common maintenance

concept by which one establishes the most efficient maintenance operations for different categories of equipment. The concept was introduced in aviation field in the 1960s to reduce maintenance costs by increasing the reliability of the Boeing aircraft. Very good results obtained by increasing the reliability of technical systems have led to the implementation of this concept in important areas: nuclear power industry, aerospace systems, maintenance systems of military equipments and so on and so forth.

RCM is based upon the analysis of user's tasks and makes a determination of the modality of operation of the equipment. Research in the field of maintenance showed that "only 11 % of the components of a technical system present characteristics of system failure to justify the development of a strict schedule of maintenance or replacement, the other 89 % of components having a failure rate that does not impose such a program" (Ben-Daya, M., Duffuaa, S.O., Raouf, A., Knezevic, J., Ait-Kadi, D., 2009). RCM is based on the detailed analysis of the occurrence of the defect and determines the most appropriate maintenance activities (preventive, corrective, proactive) for each stage of evolution of the defect. In this way, the development of a defect is slowed, and the availability of equipment condition increases significantly. Reducing the speed of evolution of the defect allows safer increase in use, monitoring phases of degradation and optimal timing of execution of maintenance intervention.

RCM principles are:

- RCM is geared towards keeping the functionality of the equipment and less for keeping the level of operability.
- RCM is focused on technical system operation as a whole regardless of the mode of operation of system components. This approach can lead to an increase in the cost per life cycle by increasing the operating cost.
- RCM analyzes faults statistically, by using conditional probability of the occurrence of a breakdown conditioned by the length of use of the equipment.
- RCM allows improving operational equipment design based on the feedback in the maintenance activity.
- RCM is focused on increasing safety in operation and functionality, while simultaneously lowering costs of maintenance.
- RCM allows developing a plot of valid maintenance activities for one category of equipment.

Although RCM ensures increased reliability of equipment and a high economic efficiency, the use of the concept involves a series of conditioning related to the implementation complexity, the high degree of professionalization of operating and maintenance staff, techniques and appropriate monitoring tools. For these reasons and in order to obtain superior actuations in equipment use, RCM is used often in conjunction with other modern concepts of maintenance.

Condition-based maintenance – CBM represents a modern concept in maintenance activity whereby it eliminates a great deal of preventive maintenance activities. The concept uses mainly the monitoring of actual state of equipment at a time, accurate forecasting of the possibilities of occurrence of damage and the establishment of those types of activities strictly necessary for operating parameters. Characteristic for this concept it is the proactive nature whereby, on the basis of equipment operating parameters monitoring one runs a review of maintenance and repair programme, ensuring of spare parts and materials, forecasting the occurrence of a damage.

Specific maintenance activities for maintaining/restoring the functioning of equipment shall be performed as close to the time of the damage occurrence, thus

eliminating a number of expensive maintenance interventions.

CBM is based on non-intrusive inspection and modern diagnostic methods (analysis of vibration or the quality of lubricants, thermography, monitoring of operating parameters and so on and so forth). The advantage of using CBM concept is decreasing of scheduled interventions volume, with implications in reducing maintenance costs. But this methodology calls for major changes in the organization system of maintenance structures, the implementation since the design stage of sensors intended for equipment operation, verifying and monitoring performant tools, increasing the level of staff professional training and maintenance.

Optimization of maintenance equipment through ***life cycle costs (LCC)*** represents a modern concept of equipment management during their life. This concept was developed thanks to the diversification of the types of equipment and performance, but especially because of the difficulties imposed by economic and financial domain conditionings, felt in the current international security environment.

The design of operational requirements of the current generations of military equipment necessitated the framing into the limited budgets of defence, budgets that have lately suffered substantial reductions, decided by the political-economic and geo-strategic reality.

Optimization of maintenance activity through cost management implies detailed analysis of cost component elements. Reducing total costs can be done by identifying and examining specific direct and indirect costs of the production process, but also by tracking the shares of "visible" or "hidden" expenditure.

The development of rigorous planning requirements in the medium and long-term of defence capabilities with strict framing into budgets allocated led to an increase in the importance of maintenance activity costs associated to the projection activity of integrated logistic support. For framing in the allocated resources, the continuous elaboration and updating of cost catalogues is considered a basic support tool in planning future activities of any military capability.

Total productive maintenance – TPM is a Japanese management developed concept in the field of maintenance and which aims to: increase productivity through obtaining maximum efficiency in the use of equipment, involvement in maintenance activity of all departments in the structure composition; designing a programme of preventive maintenance for the entire life-cycle of the equipment, enhancing the action autonomy of the workers organized in small groups.

TPM directly aims at eliminating accidental shutdowns, and as an indirect objective, the suppressing of faulty products and pollution. These objectives shall be pursued in the case of TPM by developing a preventive maintenance plan based on the elements of the monitoring equipment component elements, a monitoring carried out both by the operational staff, and by the maintenance staff.

3. Conclusions

It is obvious that the technological level of current military equipment does no longer allow the continuation of practices used in the past to repair some simplistic technical systems. Monitoring the operation of the equipment and the competent analysis of the occurrence modality of defects by specialized technical and engineering staff represents the basis of any modern maintenance concept.

In the current conditions of security in which the availability of defence capabilities is one of the factors deterring the opponent, the choice of the most suitable maintenance strategy represents

one of the priorities of the military structures of any level (tactical, operative, strategic). According to the categories of equipment of their endowment and the objectives of their utilization in missions, the knowledge and the implementation of the best maintenance practices leads to an increase in the efficiency and effectiveness of the use of equipment placed at one's disposal.

The need for joint use of technical systems and maintenance facilities within the military exercises with multinational participation or in the missions in theatres of operations requires the implementation and adaptation of concepts and methodologies with the aim of achieving the standardisation necessary to satisfy the conditions of interoperability.

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