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METHODOLOGICAL APPROACHES TO THE DEVELOPMENT OF AN ELECTRONIC ACCOUNTING AND RANKING MODEL FOR ASSESSING DAMAGE LEVELS OF ARMORED VEHICLES

The paper substantiates the methodological approaches to the creation of an electronic accounting and ranking model for assessing damage levels of armored vehicles based on the concept of a digital twin. The proposed structure includes modules for vehicle identification, technical condition display, recording of damage at the level of replacement end elements, calculation of the combat readiness index, and control of repair and logistics processes. It is shown that the integration of data from various sources and the automation of their processing ensure faster decision-making regarding the evacuation and subsequent restoration of equipment. The use of the proposed approach makes it possible to predict the resource of components, plan spare parts requirements, and quickly make decisions regarding repair and restoration of military equipment samples, which ultimately enhances the efficiency of technical support for the troops.

Keywords: *armored vehicles, damage, electronic accounting, digital twin, combat readiness index, replacement end element, automated data processing.*

Statement of the problem. Modem combat operations are characterised by the intensive use of weapons and military equipment, which results in significant losses of armoured vehicles. Under combat conditions, decisions regarding the evacuation and repair of damaged vehicles must be made as quickly as possible. However, in practice, the processes of accounting, classification, and ranking of armored vehicles by the level of damage are often carried out using fragmented methods based on subjective assessments and paper documentation. This leads to delays in decision-making, irrational allocation of repair resources, time losses, and reduced combat readiness of military units.

An additional complication is that in the combat zone, equipment suffers damage of various kinds, from minor "cosmetic" damage to critical damage that renders it unsuitable for further use. Traditional accounting systems lack integrated tools capable of automatically recording the extent of damage to armored vehicles at the level of individual units and replacement end elements, assessing the criticality of each failure, and predicting the subsequent technical condition. Existing solutions are primarily descriptive and fail to provide a systemic evaluation of combat readiness.

Moreover, modern trends in military resource management require the use of advanced information technologies. Technologies such as digital twins, automated data management systems, and predictive modeling methods have proven their effectiveness in industry and the civil sector, but their adaptation to military logistics and technical support remains in its infancy.

The electronic accounting models used are mainly focused on industrial processes and do not take into account the specifics of combat conditions, the peculiarities of armoured vehicle restoration, the multifactorial nature of damage, and the need for rapid categorization of equipment for real-time decision-making.

Thus, the problem lies in the absence of a unified methodology for the construction of an electronic accounting and ranking system for damaged armored vehicles that would integrate data from various sources [unmanned aerial vehicles (UAVs), crews, and technical reconnaissance, etc.] and would provide automated identification, classification of damage, combat readiness assessment, and real-time management decision-making. Solving this problem is not only of scientific and theoretical importance, but also of critical practical significance, as it directly affects the efficient use of material and technical resources, the pace of combat vehicle restoration, and the effectiveness of military units in performing their combat duties in combat conditions.

Analysis of recent research and publications. Studies by Ukrainian researchers have shown that the foundations for information and technical support of military vehicle operation management have already been formed. These include centralized databases, data collection and processing procedures, and basic decision support algorithms for maintenance and repair [1, 2]. At the same time, article [3] substantiates that optimisation of accounting and automation of processes for recording events/downtime/repairs directly affect the efficiency of armored vehicle model management and the economics of technical support for defence forces. These achievements are a necessary but insufficient basis for solving the tasks of electronic accounting and damage ranking, because in combat conditions, models are needed that are capable not only of storing facts, but also of assessing the combat capability of armored vehicle models at the level of nodes and replacement end element in real time, integrating various data sources (UAVs, crew, technical reconnaissance, information systems). The lack of such automated systems underlines the importance of developing a methodological approach to the creation of an electronic accounting and ranking model for armored vehicles**.**

In recent years, researchers have actively explored the application of the Digital Twin (DT) concept for automating decision-making processes. The ISO 23247 series (Parts 1–4 published in 2021) standardizes the terminology, architecture, data interfaces, and application scenarios of DTs, initially for manufacturing, but with an obvious transfer to military equipment [4–7].

At the same time, existing international approaches to DT are not without their shortcomings. They are primarily focused on industrial and manufacturing processes, where objects operate in controlled environments. This limits their applicability in combat conditions, where equipment is subject to sudden and multifactorial damage, and access to data may be limited. Most of the DT models used also do not take into account the specific requirements for the speed of information processing in tactical operations and do not provide sufficient flexibility in scaling for fleets of different types of military equipment. Therefore, adapting DT standards and developing specialized military-technical models are necessary.

The first step in implementing the DT concept in the military domain is the creation of "digital twins" of the battlefield – situational awareness systems deployed by NATO and partner forces (such as FBCB2/Blue Force Tracking) [8]. The Ukrainian initiative (ICS "IP Delta") confirms the possibility of integrating combat reports, geospatial analytics and UAV streams into a single information environment [9]. At the same time, both international and national examples mostly focus on command-and-control functions and situation analysis, while the formalized modeling of armored vehicle technical condition with standardized damage scales at the replacement end element level and transparent combat readiness categories has received little attention.

Scientific work [10] details the architecture of DT, which is focused on assessing combat damage and testing weapons and equipment, approaches to aggregating sensor streams, hierarchising nodes, and linking to replacement end element.

Economic and management studies on assessing the effectiveness of asset management provide a methodological foundation for the "penalty" interpretation of damage (loss of utility) through weighted sums and standardised coefficients, which allows the DT model to be used for resource planning and repair [11, 12].

Research [13] has shown that the automation of motor resource accounting and maintenance and repaire significantly improves vehicle fleet management and can therefore be integrated into modules for repair monitoring and logistics interaction.

Thus, the analysis showed that the infrastructural and methodological prerequisites for the digitalisation of armoured vehicle accounting have already been created, the first steps have been taken to automate the processes of assessing and forecasting their technical condition in real time, but these processes require further research on the creation of a comprehensive methodological approach to the development and implementation of electronic accounting and ranking by the level of damage to armoured vehicle samples.

The purpose of the article is to develop a comprehensive approach to automating the sorting of damaged armored vehicles after combat for decision-making regarding their recovery (repair, disassembly, or decommissioning), material and spare parts planning, and operational control of restoration processes.

Summary of the main material. The model of electronic accounting and ranking by the level of damage to armored vehicles samples is an integral part of the general information system for managing the operation of military vehicles, which is described in this article [1].The model of electronic accounting and ranking by the level of damage sustained by armored vehicles samples is based on the concept of a digital twin of an object. A digital twin is a comprehensive digital model of an environment or system that combines real-time data, artificial intelligence and modelling technologies. Such digital models are dynamic, interactive and capable of monitoring, analyzing, managing and optimizing their physical counterparts in real time [14].

The conceptual structure of a digital twin is standardised in a series of ISO standards [5–8, 15, 16]. The classic five-dimensional universal model of a digital twin is proposed in [17] and shown in Figure 1. Changes in the state of a real object are reflected in the virtual one, while information or control signals from the virtual object can affect the real one.

The model of electronic accounting and ranking by the level of damage to armored vehicle samples will consist of a unique digital profile for each piece of equipment and will have the following modules:

module 1 – general information about the vehicle;

module 2 – digital twin;

module 3 – technical condition and resources;

module 4 – identification of damage to armored vehicle samples;

module 5 – ranking of armored vehicles by damage level;

module 6 – repair control (logistics and supply), armored vehicles status.

The unique digital profile of each unit of armament and military equipment is a dynamic document that contains a complete history of changes, the date and authorship of the contribution. Figure 2 shows a possible structure of relationships between the main information tables of a unique digital profile of a piece of equipment. The software provides access to this digital profile and data management using appropriate software tools and SQL queries.

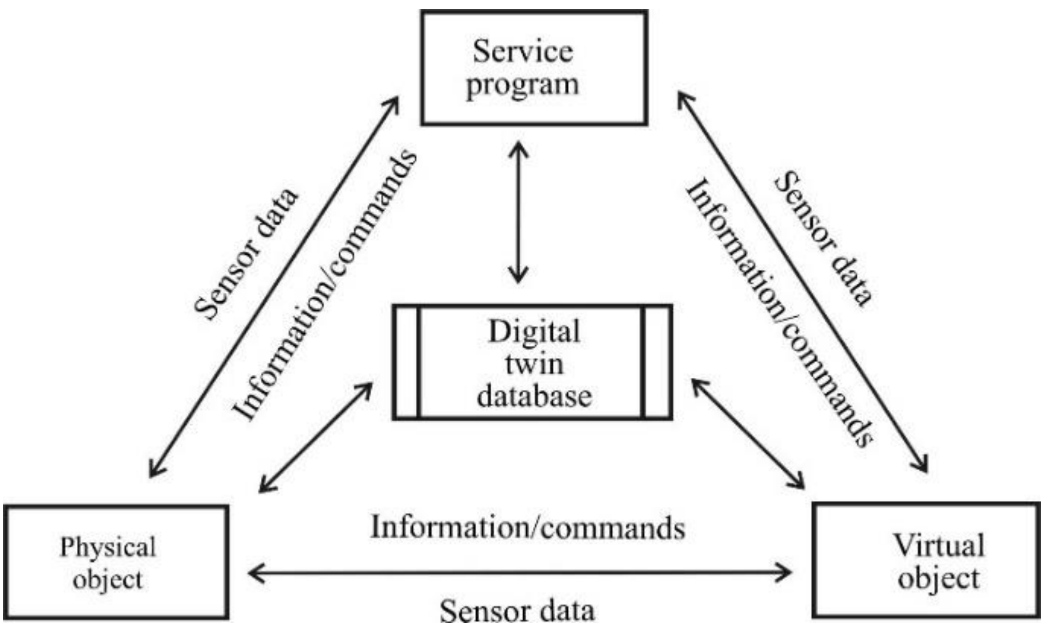


Figure 1 – Conceptual model of a digital twin

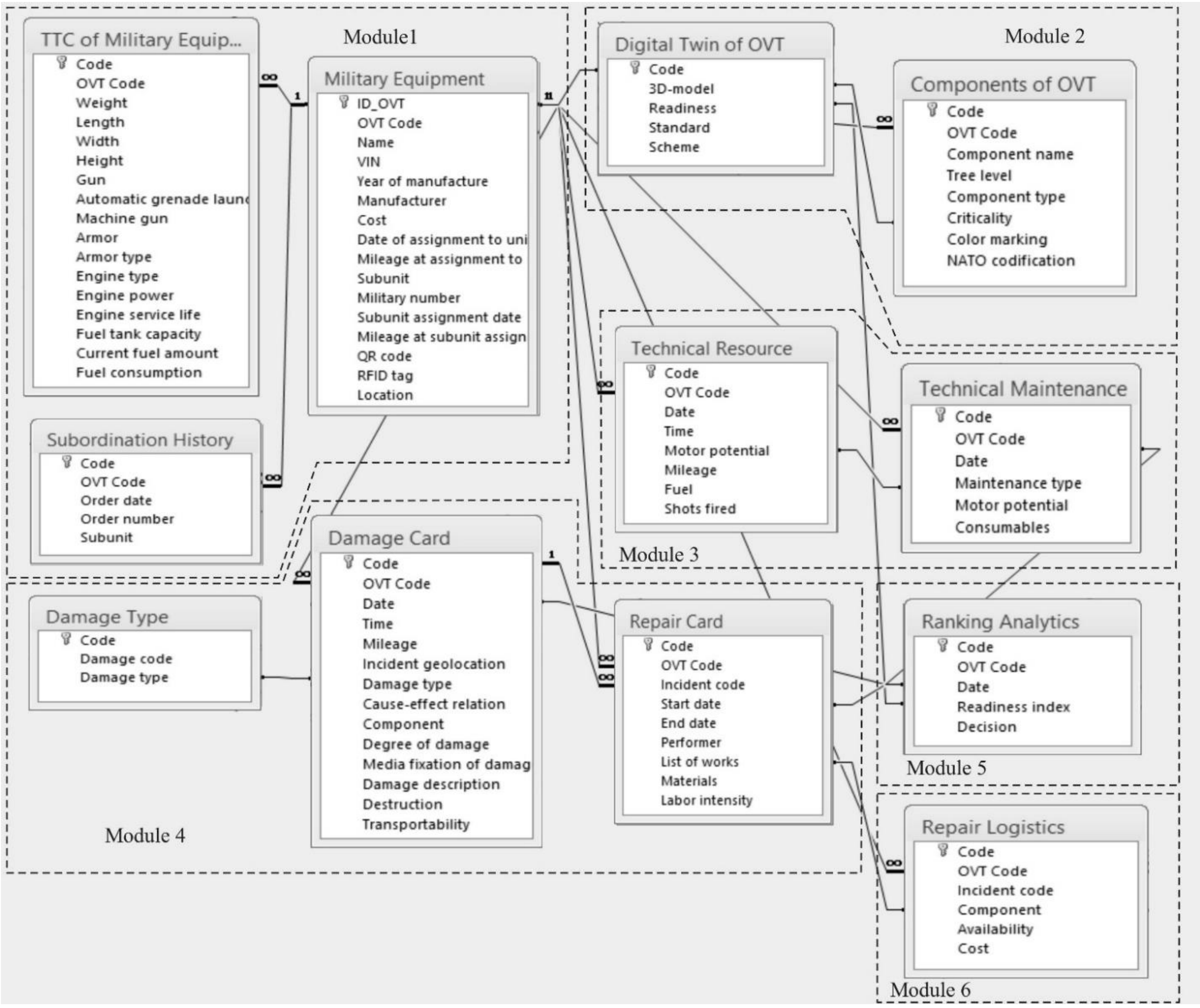


Figure 2 – Structure of relationships between the main information tables of a unique digital profile of a piece of equipment

Let us consider the structure of the given profile in more detail.

Module 1, which focuses on general information about a piece of equipment, consists of three tables: "Military_equipment", "Military_equipment_specifications" and "History_of_subordination". These tables contain information about the identification of military equipment (name, code, military number, current location, etc.), tactical and technical characteristics (TTC) and the configuration of weapons and subordination of the armored vehicle model being described. An important role in this will be played by the remote identification elements of the specified armored vehicle model – a QR code or RFID tag, which are required for quick scanning from a tablet or other detection device. The detection range of an active RFID tag with its own power source can be from 10 cm at low frequencies (LF, 125 kHz) to 100 m at ultra-high frequencies (UHF, 860-960 MHz). The location of the sample can be determined automatically using GPS trackers or by entering data manually.

The main module of the proposed digital profile of the armored vehicle sample (its core) is the digital twin module (module 2).

Module 2 consists of two tables: "Digital_twin_military equipment unit" and "Military equipment unit_components". This module is responsible for the functioning of the interactive 3D model of the military equipment unit sample. It is a highly detailed model, broken down into a hierarchical structure of nodes and aggregates. The digital twin must be detailed to the replacement end element. In this study, replacement end element will be understood as an indivisible element of the technical sample that is subject to replacement from the material and technical supply system.

For example, the component hierarchy may include:

level 1 – main armored vehicle blocks (hull, turret, chassis, etc.);

level 2 – systems (engine, transmission, weaponry, etc.);

level 3 – assemblies/parts (turbocharger, cylinder block, optical sight, etc.).

Each component in the tree will have a link to the spare parts catalogue number [military version of the SAP code, NATO Stock Number (NSN)].

The use of a digital twin will make it possible to quickly track the technical condition of the armored vehicle model, including after combat operations. Each replacement end element will dynamically change colour depending on its technical condition (green will correspond to operational condition, red to completely damaged). In addition, each replacement end element has a criticality indicator (table "Components_military equipment unit" (Figure 2). The criticality indicator ranges from 0 to 1. This value depends on the importance of the impact of the functionality of such a replacement end element on the combat capability of the armored vehicle.

Thus, digital twin technology will enable the technical condition of the armored vehicle sample to be displayed quickly and clearly, as well as the damaged equipment to be ranked.

Module 3 is focused on storing information about the technical condition of a piece of equipment and consists of two tables: "Technical_resource" and "Technical_maintenance". These tables contain information about the current motor resource, mileage and fuel consumption. It also stores a schedule for various types of technical maintenance, plans for replacing oils, filters, etc., linked to the engine resource. One of the functions of this module is to automatically generate a request for technical maintenance and calculate the necessary resources.

An important part is *module* 4, which is responsible for describing, formalising and identifying damage to an armored vehicle unit. This information is collected from various sources, which either confirm this information or not. For example, possible sources may include data from aerial and ground searches (aerial photographs, video streams, damage recorded by an FPV drone operator, descriptions by specialists, etc.), information resources (IKS "IP Delta" or ISTAR tools) and information obtained directly from the crew or command. This module consists of three tables: "Damage_Card", "Repair_Card", "Damage_Type".

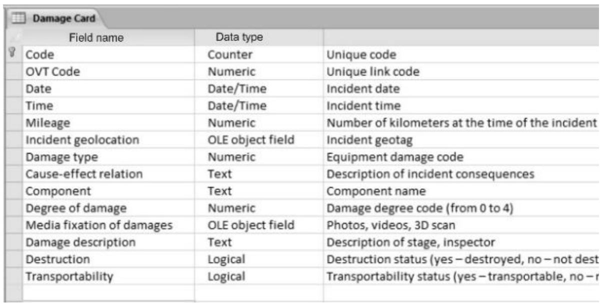
For each damage, the location of the sample, the type of damage, the cause-and- effect relationships of this damage, the list of components and replacement end element that may have been damaged are recorded, and the degree of damage (from 0 to 4) is established. It is also mandatory to state the state of destruction and transportability of the armored vehicle sample itself.

The classification of the degree of damage at the replacement end element (κ^{dd}) level is given in Table 1.

Table 1 – Classification of damage at the replacement end element level

Degree κ^{dd}	Type of Damage	Description of damage type	Example
0	No damage	No damage. Replacement end element is functioning normally	–
1	Minor (moderate)	Superficial damage that does not affect functionality	Dent on the hull, damaged headlight, etc.
2	Moderate	Damage that limits functionality, but the system still works	Damaged sight (difficult aiming), small hole in the body, etc.
3	Severe	The unit is completely out of order, but repair is possible on site or in a workshop	Broken track, crumpled and jammed hatch, punctured engine radiator
4	Critical (irreversible)	The system is destroyed or damaged and cannot be repaired. Replacement is required	Detonation of ammunition, armour penetration with engine destruction, separation of the combat module

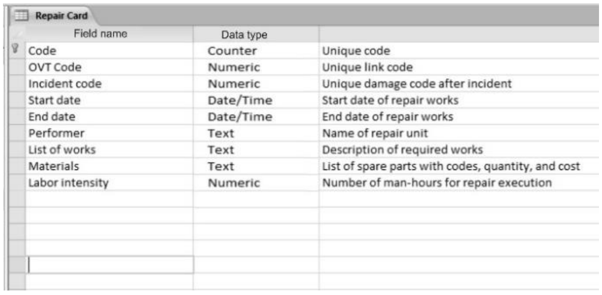
Based on the damage sustained, a repair card is created, which contains data on the necessary resources and means, a list of works and materials is formed, and the labour intensity of repairing the damage is determined. An example of the possible structure of the "Damage Card" and "Repair Card" tables with defined fields is shown in Figure 3.



Damage Card

Field name	Data type	
Code	Counter	Unique code
OVT Code	Numeric	Unique link code
Date	Date/Time	Incident date
Time	Date/Time	Incident time
Mileage	Numeric	Number of kilometers at the time of the incident
Incident geolocation	OLE object field	Incident geotag
Damage type	Numeric	Equipment damage code
Cause-effect relation	Text	Description of incident consequences
Component	Text	Component name
Degree of damage	Numeric	Damage degree code (from 0 to 4)
Media fixation of damages	OLE object field	Photos, videos, 3D scan
Damage description	Text	Description of stage, inspector
Destruction	Logical	Destruction status (yes – destroyed, no – not dest
Transportability	Logical	Transportability status (yes – transportable, no – r

a



Repair Card

Field name	Data type	
Code	Counter	Unique code
OVT Code	Numeric	Unique link code
Incident code	Numeric	Unique damage code after incident
Start date	Date/Time	Start date of repair works
End date	Date/Time	End date of repair works
Performer	Text	Name of repair unit
List of works	Text	Description of required works
Materials	Text	List of spare parts with codes, quantity, and cost
Labor intensity	Numeric	Number of man-hours for repair execution

b

Figure 3 – Possible structure of tables:
a – "Damage Card"; *b* – "Repair Card"

Module 4 is closely connected with Modules 5 and 6. The information from this module serves as input data for calculating the combat readiness index of the armored vehicle sample (K^{cc}) and for generating requests for the required replacement end elements.

In *Module 5*, the result of calculating the combat readiness index (K^{cc}) of the entire armored vehicle sample is stored, based on the totality of the damage levels of each replacement end elements, taking into account such properties as the importance and criticality of each unit for the overall survivability of the vehicle. In addition, this module may store changes in the K^{cc} throughout the entire period of operation. In accordance with the established criteria, based on the values of the K^{cc}, combat readiness index, the readiness levels (RS) of the entire armored vehicle sample are determined.

Let us consider the algorithm for calculating the combat readiness index K^{cc} of the armor vehicle model. Using [18], we propose four levels of combat readiness of the armor vehicle model RS based on the set of K^{dd} of each replacement end element (Table 2).

Let us define the key principles for calculating the combat readiness levels of the armor vehicle sample:

– the need to take into account not only the presence and type of damage to the replacement end element (Table 1), but also its criticality for the viability of the entire vehicle;

– the presence of a cumulative effect, which means that several medium-type damages to different systems can reduce overall combat capability as much as one severe damage to a single system;

– the application of the "weakest link" logic, meaning that the condition of the most critical damaged component determines the minimum level of combat capability.

To develop a flexible and adequate method for calculating the combat capability index K^{cc} of an armor vehicle sample, the following characteristics will be used: the importance and criticality of the replacement end element.

The importance of the replacement end element is a statistical characteristic determined by its design. The importance of the *replacement end element* is characterised by an indicator such as the importance coefficient *W*, which can range from 0 to 1.

Table 2 – Combat readiness levels of the armor vehicle model

RS level	Colour	Name	Description of the armor vehicle sample condition
A	Green	Combat-ready	There are either no damages or they are purely cosmetic and do not affect functionality
B	Yellow	Limited combat readiness	The sample can perform its functions (move and/or shoot), but with limitations
C	Orange	Damaged	Combat capability lost. Requires evacuation and repair in a workshop
D	Red	Criticallv damaged	Restoration is impossible or economically unfeasible

This is a constant that depends on the type of vehicle and the role of the *replacement end element* in the functioning of the entire armored vehicle model. For example, the engine will have a very high importance (W = 0.18), while the track will have a high importance, but lower than that of the engine (W = 0.12), and so on. The sum of the importance coefficients of all REEs in the armored vehicle sample must be equal to 1 (or 100 %):

$$\sum_{i=1}^{M} W_i = 1, \qquad (1)$$

where W_i is the importance coefficient of the i-th *replacement end element*;

M is the total number of *replacement end elements* that make up the armored vehicle sample.

The criticality of *replacement end element* is a dynamic characteristic determined by the type and degree of its damage. As an indicator, we select the criticality coefficient C, which also ranges from 0 to 1. This is a variable value that depends on the consequences of the *replacement end element*'s damage and reflects how dangerous this damage is for the entire armored vehicle sample. For example, consider the *replacement end element* such as "a fuel tank". If the damage is a scratch, then the damage level K^{dd} = 0.1 (non-critical), and the corresponding coefficient C = 0.05. If the damage is a dent, K^{dd} = 2 (potential danger), C = 0.2; if it is a puncture or fuel leak, K^{dd} = 3 (highly critical), C = 0.85; and in the case of detonation, K^{dd} = 4 (catastrophic), C =1.

The value of the criticality coefficient is determined on the basis of statistical data on repairs of various *replacement end elements* and analysis of the consequences of the damage to the considered element for the survivability of the entire vehicle, combined with the method of expert evaluation.

The combat readiness index K^{cc} of the armored vehicle sample is calculated using the following expression*:*

$$K^{cc} = \left(1 - \sum_{i=1}^{N} \frac{K_i^{dd}}{K^{ddD}} \cdot W_i \cdot C_i\right) \cdot 100, \quad (2)$$

where N is the number of damaged *replacement end elements* after combat;

$\frac{K_i^{dd}}{K^{ddD}}$ is the standardised coefficient of the degree of damage to the *replacement end element*ss relative to the degree of damage at level D,

K^{ddD} = 4 (0 – 0; 1 – 0.25; 2 – 0.5; 3 – 0.75; 4 – 1.0);

C_i is the criticality index of the i-th *replacement end elements*.

The combat readiness levels RS, as shown above, depend on the combat readiness index $K^{cc}$of the armpored vehicle model. However, an important issue is to determine the limits of RS levels based on the numerical values of the indicator K^{cc}.

To convert the K^{cc} indicator into a categorical assessment of the state of technology that is understandable for decision-making, the following comprehensive methodological approach was used.

First, the initial setting of the boundaries was carried out using the expert method, which consisted of four stages:

1) formation of an expert group composed of experienced repair specialists, officers with practical experience in operating armored vehicles, and instructors from departments of armored vehicle operation;
2) analysis of scenarios;
3) categorization of scenarios;
4) analysis of the results of mathematical modeling and determination of boundaries (the boundaries were defined as the ranges of K^{cc} values where the degree of expert agreement was the highest).

Second, validation and refinement of the category boundaries were performed using statistical methods based on real operational data.

Finally, testing of boundary cases was conducted through mathematical modeling.

Unfortunately, there are no universal boundaries for all types of armored vehicles. The RS level boundaries must differ depending on the vehicle type due to differences in design features, structural complexity, the number of systems and *replacement end elements*, and functional purpose.

For armored vehicles of the BTR-4E type, the obtained boundaries are shown in Table 3.

It is possible to determine the boundaries of RS levels using a graphical representation. For example, consider an armored vehicle sample consisting of 8 *replacement end elements*. The properties of these *replacement end elements* are presented in Table 4.

Table 3 – RS Category Boundaries for the BTR-4E

RS Level	Range of K^{cc}, %	Criterion Description
A	85–100	All *replacement end element* damages have K^{dd} = 0 or 1
B	60–84	*Replacement end element* damages with K^{dd} = 2 prevail
C	20–59	One or more components have K^{dd} = 3
D	0–19	At least one component has K^{dd} = 4 in a critical unit (e.g., the engine)

Table 4 – Example of *replacement end element* properties of the armored vehicle sample

Replacement end element	W_i	RS				RS			
		A	B	C	D	A (0.25)	B (0.5)	C (0.75)	D (1.0)
		C_i	C_i	C_i	C_i	$W_i \cdot C_i$	$W_i \cdot C_i$	$W_i \cdot C_i$	$W_i \cdot C_i$
1	0.23	0.2	0.5	0.8	1	0.0115	0.0575	0.1380	0.23
2	0.12	0.2	0.5	0.8	1	0.0060	0.0300	0.0720	0.12
3	0.15	0.1	0.3	0.5	1	0.0038	0.0225	0.0563	0.15
4	0.14	0.1	0.4	0.7	1	0.0035	0.028	0.0735	0.14
5	0.11	0.1	0.3	0.5	1	0.0028	0.0165	0.0413	0.11
6	0.10	0.1	0.4	0.6	1	0.0025	0.0200	0.0450	0.10
7	0.08	0.1	0.3	0.5	1	0.0020	0.012	0.0300	0.08
8	0.07	0.1	0.3	0.5	1	0.0018	0.0105	0.0263	0.07
	1.00								

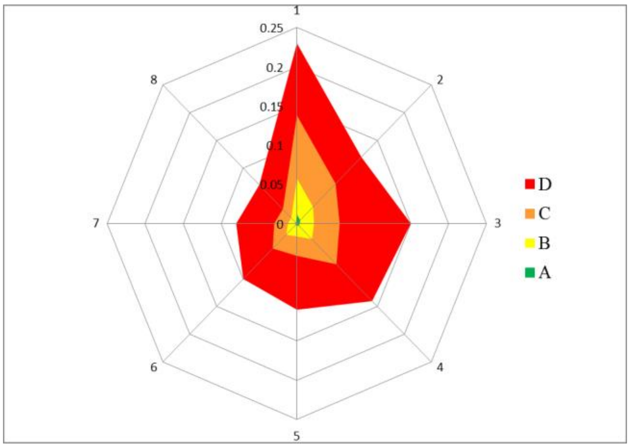


Figure 4 – Graphical representation of RS level zone boundaries

A graphical representation in the form of RS level zones is shown in Figure 4.

Next, according to the obtained values of K^{cc}, all damaged armored vehicle samples on the battlefield are ranked according to a given criterion, for example, from the largest to the smallest ones.

The sum on the right side of expression (2) calculates the amount of combat capability loss from damaged *replacement end element*s (the sum of "penalties" for damage). Initially, the armored vehicle sample consists of undamaged *replacement end element*s, and its technical condition is taken as the initial state of the system (K^{cc} = 100 %), to which only negative penalties are added. The model focuses on assessing losses rather than listing what remains intact. This is a standard and effective approach in asset management and loss assessment systems [11, 12].

The above material forms the basis of the developed method of ranking armored vehicle samples on the battlefield according to the level of damage sustained. The algorithm of the proposed ranking is shown in Figure 5.

The main feature of the developed algorithm (Figure 5) is that it is a combined type algorithm. It combines a logical approach (block 9) and a mathematical approach (blocks 10, 11) when calculating the combat effectiveness coefficient.

The logical approach consists in checking for the presence of a critical condition ($K_i^{dd} = 4$) in any replaceable end element and compiling a list of such components. After that, the importance of the identified *replacement end element*s is verified, and if the specified indicator exceeds the established threshold ($W_i \geq W_{thr}$), the entire armored vehicle sample is immediately assigned the RS = D readiness level.

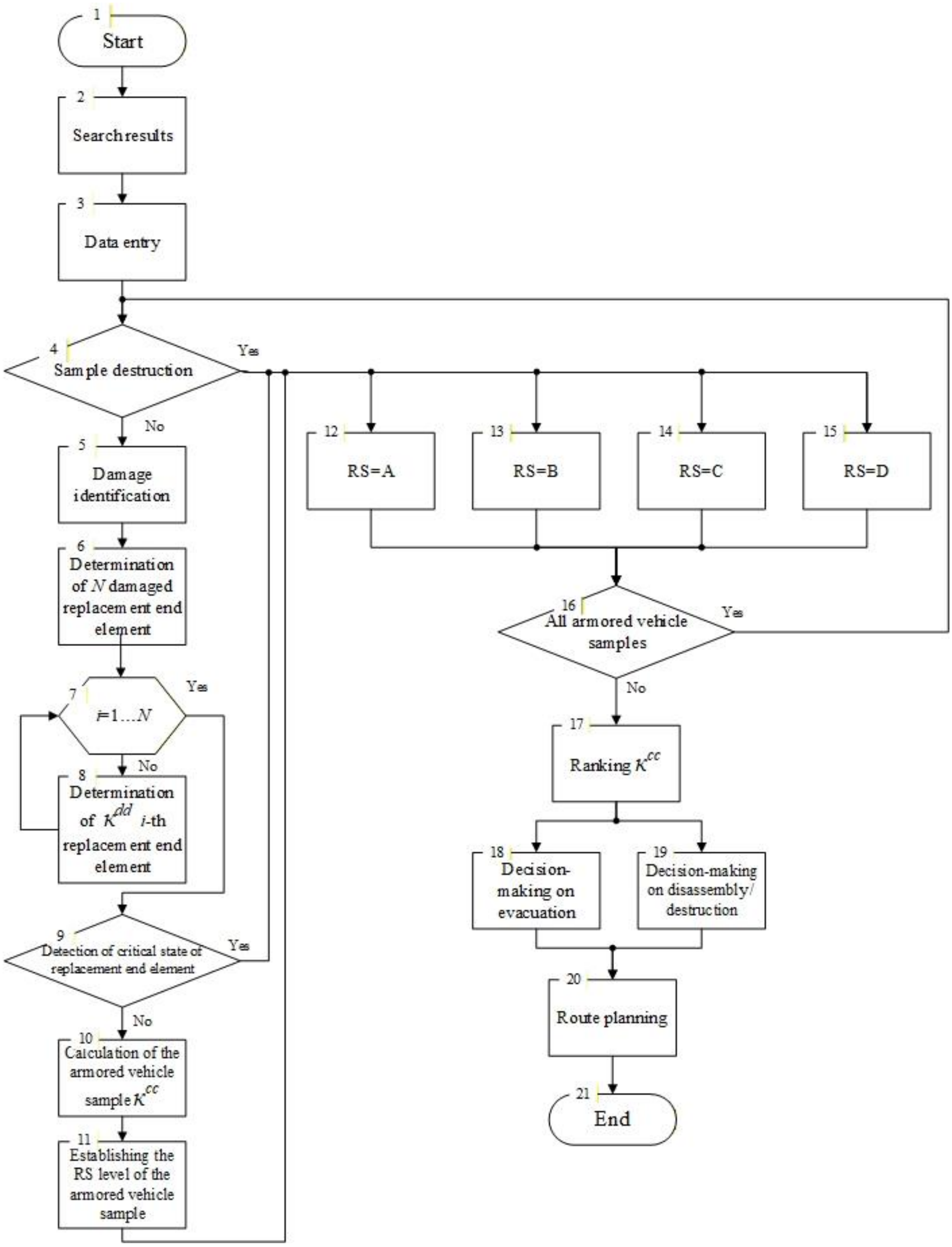


Figure 5 – Algorithm for ranking by level of damage

If the logical approach does not detect any critical situations in the armored vehicle sample, then the calculation of the combat readiness index K^{cc} is performed according to expression (2) in blocks 10 and 11 (an example is given in Table 3).

In block 17, ranking is carried out according to the specified criterion for all armored vehicle samples based on their K^{cc} values. It is proposed to conduct ranking separately for samples with RS levels from A to C, and for samples with RS – D. Next, ranking of the samples with RS levels from A to C is performed to determine the order of current repair on the battlefield or evacuation (block 18). For the samples with D level, a decision is made either on equipment disassembly and destruction, or on evacuation with subsequent recovery procedures.

In block 20, using software applications based on GIS technology (ICS "Delta", NSU GIS "Instrument", etc.), several optimal routes are constructed to carry out the assigned tasks.

Module 6 (Figure 2) defines the relationship with warehouse inventories. When a repair is scheduled, the module automatically checks the availability of the necessary spare parts in the nearest logistics supply warehouse, and if there is a shortage or lack of components, it automatically generates a request. This module stores the current book value of the equipment, taking into account wear and major repairs, as well as the total cost of all restoration repairs over the entire operational period.

The aggregated information from modules 4, 5, and 6 functions as the *sensors* of the physical object and forms an influence on the virtual object, reflecting its current state. Module 2, the *digital twin*, possessing complete information about the condition of each *replacement end element*, performs the following tasks: forecasting the end of life of key components (based on failure statistics for the given vehicle model); planning spare part requirements (based on historical data); and estimating the cost of future repairs (based on repair history and current spare part prices).

In addition, it is possible to simulate future combat engagements on the battlefield and, using statistical data, forecast the most probable combat damages, analyze them, and optimize the placement of protective systems to enhance the survivability of the entire vehicle. This creates a *feedback loop* from the digital twin to the physical object.

In the process of implementing the proposed project, the following requirements must be ensured:

– a unified central database and electronic storage for unstructured information;

– protection against unauthorized interference with the application's functions;

– real-time operation;

– a user-friendly, intuitive interface that is easy to administer and operate;

– scalability in terms of the number of digital twins and the scope of their functions;

– redundancy of critical components and data, enabling database recovery after emergency situations without compromising data integrity;

– access control to software functions;

– capability for integration (information interoperability) with other systems.

However, the proposed model will function correctly only if the data on physical objects are continuously monitored – both automatically and manually by operators. In this case, it is necessary to define at least three vertical access levels for making changes to the model, categorized as: "unit – regional command – main command". This means that the procedure for introducing modifications and updates to the data can be implemented top-down [12].

At the horizontal level within units, user roles can be divided as follows:

1) UAV operator – performs photo and video documentation of damages from various altitudes and angles;

2) Crew members – can upload photos and videos of damages along with detailed descriptions;

3) Technical reconnaissance specialist (inspection engineer) – has the authority to officially classify REE damages;

4) Head of the repair service – develops repair plans and submits requests;

5) Logistics officer – reviews repair request analytics and manages spare parts inventory in the logistics warehouse.

Thus, the approach proposed in this article, based on a combined algorithm that integrates "weakest link" logical rules with weighted aggregation of damage and criticality into a single *combat readiness index*, enables real-time monitoring of the technical condition of armored vehicles, particularly after combat engagement.

Conclusions

Modern combat operations are characterized by the high intensity of weapon and military equipment usage, leading to significant losses of armored vehicle samples. Under combat conditions, it is crucial to make timely decisions regarding the evacuation and repair of damaged vehicles.

This article proposes a methodological approach for creating a model of electronic accounting and ranking of armored vehicle damage using the digital twin concept. The structure includes modules for equipment identification, visualization of technical condition, damage recording at the level of replaceable end elements, calculation of the combat readiness index, and control of repair and logistics processes.

The essence of the proposed ranking method for armored vehicles after combat engagements lies in calculating the extent of combat capability losses resulting from damaged replaceable end elements (the sum of "penalties" for damage) and assessing the final combat readiness level.

The author has proposed four readiness levels and developed criteria for determining the boundary values of combat readiness levels of armored vehicles.

The implementation of the electronic accounting and ranking system provides significant potential for optimizing military operations and resource planning in the long term, ensuring equipment resilience and reducing repair costs.

A promising direction for further research is the integration of the proposed electronic accounting and ranking model with neural networks for remote damage identification, which will optimize the decision-making process and improve the efficiency of technical resource management.

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МЕТОДИЧНІ ПІДХОДИ ДО РОЗРОБЛЕННЯ МОДЕЛІ ЕЛЕКТРОННОГО ОБЛІКУ І РАНЖУВАННЯ ЗА РІВНЕМ ОТРИМАНИХ ПОШКОДЖЕНЬ ЗРАЗКІВ АВТОБРОНЕТАНКОВОЇ ТЕХНІКИ

Обґрунтовано методичні підходи до розроблення моделі електронного обліку і ранжування пошкоджень зразків автобронетанкової техніки із застосуванням концепції цифрового двійника. Актуальність дослідження зумовлена високою інтенсивністю сучасних бойових дій, що призводить до значних втрат і пошкоджень військової техніки, а також потребою у швидкому й обґрунтованому прийнятті рішень щодо її евакуації та подальшого ремонту. Традиційні методи обліку базуються переважно на паперовій документації та суб'єктивних оцінках, що унеможливлює своєчасну класифікацію пошкоджень та ефективне управління ремонтними ресурсами.

Запропонована структура моделі передбачає створення унікального цифрового профілю кожної одиниці техніки, який містить модулі ідентифікації, візуалізації технічного стану, опису пошкоджень на рівні кінцевих елементів заміни, розрахунку індексу боєздатності та контролю ремонтно-логістичних процесів. Інтеграція даних з різних джерел у поєднанні з автоматизацією їх оброблення забезпечує можливість оперативної класифікації пошкоджень, визначення рівнів боєздатності та формування рекомендацій щодо подальших дій.

Особлива увага приділена застосуванню цифрових двійників як динамічних інтерактивних моделей, що відображують поточний технічний стан кожного зразка автобронетанкової техніки і дають змогу проводити прогнозування ресурсу вузлів, моделювати наслідки пошкоджень і формувати потреби у запасних частинах. Завдяки використанню такого підходу можливо оптимізувати процеси ремонту й технічного обслуговування, скоротити час прийняття управлінських рішень, підвищити ефективність логістичного забезпечення та загальний рівень боєготовності підрозділів.

Усе це визначає розроблену модель як стратегічно важливий інструмент для сучасних Збройних Сил України та сил безпеки, зокрема і Національної гвардії України, що забезпечує підвищення стійкості парку військової техніки у довгостроковій перспективі.

Напрямом подальших досліджень є інтеграція запропонованої моделі електронного обліку і ранжування з нейронними мережами, які використовуватимуться для дистанційної ідентифікації пошкоджень, що дасть змогу оптимізувати процес прийняття рішень, підвищуючи ефективність управління технічними ресурсами.

Ключові слова: *автобронетанкова техніка, пошкодження, електронний облік, цифровий двійник, індекс боєздатності, кінцевий елемент заміни, автоматизоване оброблення даних.*

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