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## **Adaptation of selected digital solutions in the field of military logistics**

## **Adaptacja wybranych rozwiązań cyfrowych w obszarze logistyki wojskowej**

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**Abstract.** The fourth industrial revolution is especially present in manufacturing processes. However, many technological solutions used in this area can also be successfully used on other levels. One of them is the armed forces. In the article, the authors analysed a process of the soldiers functioning in the course of the daily routine to indicate that it is possible to apply simple solutions in the field of electronic data collection and obtain measurable benefits. This is also how the main aim of the study was defined. The authors made a detailed analysis and evaluation of the selected process, pointing to its imperfections and proposing a solution that would optimize its most important parameters (time, reliability). The proposed solution, involving the use of proximity recorders made it possible to solve the research problem, i.e. to answer the question: is it possible and justified to support selected processes of the functioning of soldiers in a sub-unit with the use of modern logistics 4.0 tools? This allowed to verify the research hypothesis that the use of simple tools using new technologies can significantly improve the functioning of the examined process. The following research methods, tools and techniques were used: literature analysis, synthesis, observational method, statistical analysis, comparison and inference. The article consists of an introduction and then a review of the literature. The main part is a statistical study. Based on this, a possible solution to the identified shortcomings was proposed. The article ends with a summary and final conclusions.

**Keywords:** industrial revolution, logistics, armed forces, proximity recorders, record keeping in a sub-unit

**Abstrakt.** Czwarta rewolucja przemysłowa i związana z nią transformacja cyfrowa rozwijając się niezwykle dynamicznie, wprowadzając istotne ulepszenia w przemyśle. Szczególnie obecna jest w procesach wytwórczych, zmieniając w sposób fundamentalny funkcjonowanie przedsiębiorstw. Jednak wiele rozwiązań technologicznych stosowanych w tym obszarze może być z powodzeniem wykorzystane również na innych płaszczyznach. Jedną z nich są siły zbrojne. W artykule autorzy dokonali analizy przykładowego procesu funkcjonowania żołnierzy w toku codziennego porządku dnia, aby wskazać, że możliwe jest zastosowanie prostych rozwiązań z zakresu elektronicznego zbierania danych i uzyskanie wymiernych korzyści. Tak też określono główny cel badania. Chcąc go zrealizować, autorzy dokonali szczegółowej analizy i oceny wybranego procesu (ewidencjonowanie faktu opuszczania pododdziału przez podchorążych), wskazując jego niedoskonałości. Na tej podstawie zaproponowali rozwiązanie optymalizujące jego najważniejsze parametry (czas, niezawodność). Zaproponowane rozwiązanie, polegające na wykorzystaniu rejestratorów zbliżeniowych i błyskawicznym odczycie danych wychodzącego żołnierza pozwoliło na rozwiązanie problemu badawczego, tj. odpowiedzi na pytanie: czy możliwe i zasadne jest wsparcie wybranych procesów funkcjonowania żołnierzy na pododdziale z wykorzystaniem nowoczesnych narzędzi przemysłu 4.0? Pozwoliło to zweryfikować hipotezę badawczą zakładającą, iż zastosowanie prostych narzędzi wykorzystujących nowe technologie może w istotny sposób usprawnić funkcjonowanie badanego procesu. Osiągnięcie założonego celu badania było możliwe dzięki wykorzystaniu takich metod, narzędzi i technik badawczych jak: analiza literatury, synteza, metoda obserwacyjna, analiza statystyczna, porównanie i wnioskowanie. Artykuł składa się ze wstępu, a następnie z przeglądu literatury z obszaru zarówno rewolucji przemysłowej, jak i modernizacji sił zbrojnych. Zasadniczą część stanowi badanie statystyczne czasów trwania procesu wypisywania się podchorążych w niezbędnej dokumentacji podczas opuszczania miejsca zakwaterowania, jego charakterystyka i ocena. Na tej podstawie zaproponowano możliwe rozwiązanie stwierdzonych niedociągnięć. Artykuł wieńczy podsumowanie przeprowadzonych analiz i wnioski końcowe, a także rekomendacje w zakresie dalszych analiz.

**Słowa kluczowe:** logistyka, siły zbrojne, rewolucja przemysłowa, rejestratory zbliżeniowe, ewidencjonowanie na pododdziale

## Introduction

Technological progress accompanies all areas of human functioning, but it is particularly dynamic in business, where creativity and innovation are the greatest. Modern solutions are also used in matters related to state defence and in the defence industry. Modern technologies used in the military are a fundamental pillar of

every army in the world. Over the centuries, the desire to increase the technological advantage among countries has resulted in enormous economic, social and cultural development. In the era of the fourth industrial revolution, modern technologies are an extremely important part of the armed forces. They ensure the stabilization of the state and increase the sense of security of the society. In a situation where the existing technologies are not modernized, it causes the necessity to use older equivalents, which are often unable to meet the requirements of the 21st century.

The aim of this article is to present the possibilities of both applying simple solutions in the field of electronic data collection and obtaining potential benefits in the functioning of selected processes in the army. In order to implement it, the authors have conducted a detailed analysis and evaluation of the selected process, pointing to its imperfections.

The above allowed to formulate a research problem in the form of a question: is it possible and justified to support selected processes of the functioning of soldiers in a sub-unit with the use of modern logistics 4.0 tools?

On this basis, a solution was proposed to optimize the most important parameters (time, reliability) of the selected process.

It was assumed (research hypothesis) that the use of simple tools using new technologies can significantly improve the functioning of the examined process.

Achieving the assumed research objective was possible thanks to the use of such research methods, tools and techniques as literature analysis, synthesis, observational method, statistical analysis, comparison and inference.

The article consists of an introduction which defines its most important assumptions, and then an analysis of the selected literature, focusing in particular on the genesis and essence of the arms race. It also describes the most important reasons for the modernization of the military technology of countries and presents the key inventions for the development of the arms industry, from the first industrial revolution to the present. In addition, selected modern technologies were presented, along with the benefits of their use in the Polish Armed Forces and the potential they contain. The article ends with a summary of the analyses and final conclusions, as well as recommendations for further analyses.

## **Review of the literature**

### **The industrial revolution and its features**

Rapid technological advancement spurs on changes in all areas of life, and the revolutions accompanying this phenomenon include, among the others, widely understood computerization and automation, which contributes to the

implementation of new solutions [15], [20]. Technological achievements, resulting from the intensive development of industry, introduced revolutionary changes in the functioning of the current logistics [1], [29]. First of all, they caused radical changes in the method of industrial production [6], [11], [23]. Many new concepts also emerged, and with them the possible amenities that later became known as the “industrial revolution”. Currently, we are dealing with the fourth industrial revolution, the mainstream of which is autonomization and digitalization [1], [17], [12]. Autonomization means a situation in which the machine does not require direct human participation in the implementation of the tasks for which it was intended (most often the manufacture of products) [13], [32], transport [7], [30]. It is characterized by the independence of the right decisions making process, which is associated with the dynamic development of enterprises [2], [11], [13]. Moreover, autonomous solutions are characterized by extremely precise accuracy, which is the basis for the development of the industry of the future [14], [26]. Similarly to digitalization, which is a tool to increase market efficiency by improving the capacity of communication channels [2]. Developing communication, sharing data, integrating people and processes in the intra-organizational and non-organizational networks are the features of modern enterprises that can also be successfully implemented in non-business structures, such as the military. They can be used both on a macro and micro scale, improving everyday activities and functioning. Such a concept, applied to simple activities of daily living, is presented in this article.

### **Modern technical thought and the army**

Over the centuries, technological changes have pushed humanity significantly towards development. Progress was also made in the field of defence and in the arms industry [[33], [25]]. Strategic and operational changes, as well as the tactics of individual countries, have constantly evolved due to the desire to increase national security [3], [9]. A necessary step in the further expansion of the modernization of the army was the initiation of investment in a new technical thought. Countries that did not support this idea exposed their citizens to the dangers of the technological advantage of foreign countries, which in the long run meant the country's weakening or even its annihilation. The main reasons for the modernization of the military technology of countries include [16], [20], [31]:

- the potential possibility of a war between states. Neither side intends to turn out to be weaker than the other, and therefore these countries seek to gain a military advantage over the alleged adversary;
- shaken military potential between superpowers and countries with weaker military potential. Countries with lower armaments modernization strive to catch up with states with greater military status, while stronger states try to maintain their imperial status in the international arena;

- competition between defensive and offensive weapons. Each new type of offensive weapon introduced into the operation sooner or later meets a counterpart in the form of a defensive weapon to prevent future attacks.

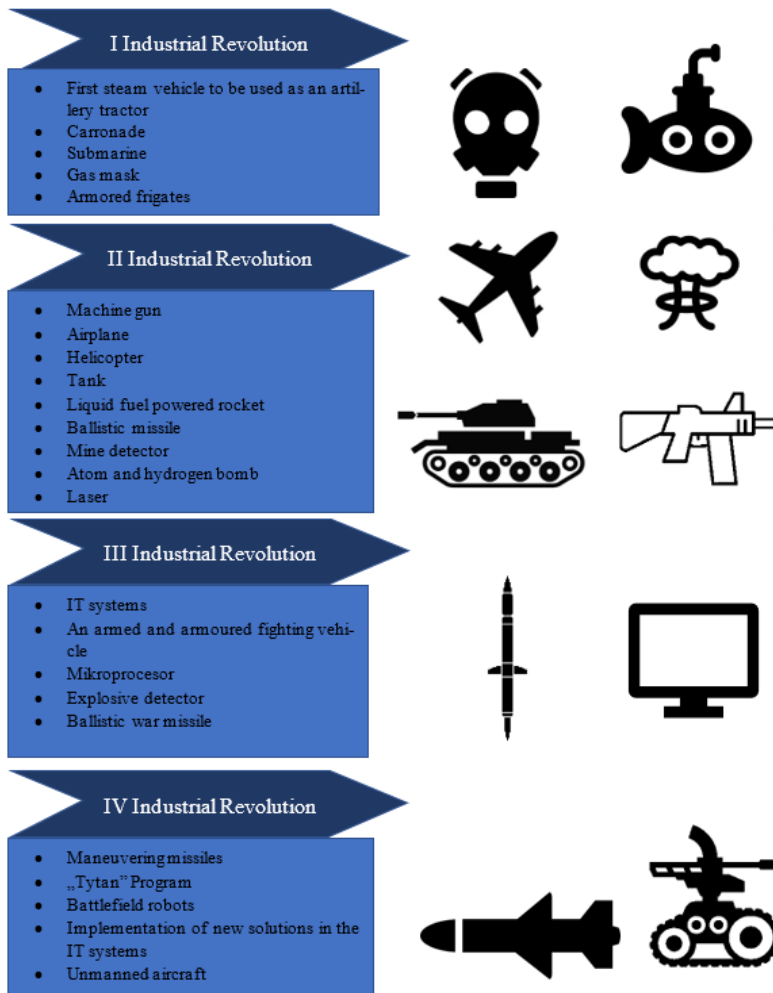


Fig. 1. Selected military inventions during industrial revolutions  
Source: Own study

The period of special technological changes in the army was the end of the 18th century, when the famous scientist, Adam Smith, ended a long period of economic downturn in Europe by introducing his idea of liberalism in Great Britain [[1], [9]]. Economic liberalization contributed to economic development across the continent, which also had an impact on the modernization of the armed forces.

The then superpowers began to develop armies on a massive scale, the weapons of which became widely available and cheaper to make, thanks to the use of modern production techniques. The most popular modern weapons technologies introduced at that time include:

- firearm;
- improved artillery;
- innovative ships in the navy;
- frigates;
- submarine.

Over time, further expansion of military development turned out to be necessary, especially during the First and Second World Wars. At that time, once again, a significant acceleration of the development of military potential was observed, e.g. the construction of the first rocket and the atomic bomb in the USA [7]. The post-war period is the time when the world, divided into two main camps, experienced a slowdown in inventiveness. Only the 70's and 80's introduced significant innovations. Most of them are constantly modernized and used to this day. The most important inventions from the period of the first industrial revolution till the present times used in the army are presented in Fig. 1.

### **Characteristics of selected modern technologies present in the Polish Armed Forces**

In recent years, the IT revolution has accelerated even more along with the advancement of knowledge in the field of technology and military production. The result of military development are modern technologies used in the military and advanced information systems. Some of them are presented below.

#### ***Tytan* Program**

The *Tytan* program, or *Advanced Individual Combat System*, is a Polish project aimed at “creating” a soldier for the 21st century. In its assumption, a soldier of the Polish Army will be equipped with weapons, uniforms and the latest generation communication equipment, which consists of as many as 27 modern elements of armament. The photo below (Fig. 2) shows a prototype of the *Tytan* project, presenting the most modern individual soldier equipment.



Fig. 2. Polish soldier of the future - „Tytan” Project

Source: <https://www.komputerswiat.pl/artykuly/redakcyjne/tytan-polski-zolnierz-przyszlosci/86w-cq98>, [data accessed: 12.03.2022]

The *Tytan* project is not only about the most modern weapons, communication equipment and uniforms for a soldier of the future [[15], [24]]. The work on the *Integrated Individual Combat System* has been underway since 2007, and intensive operations carried out by Polish companies guarantee a number of other amenities. The most important of these include the ability to monitor the condition of a wounded soldier or the level of fatigue on the battlefield. Such improvements will be possible thanks to the use of innovative electronic sensors monitoring vital functions. IT systems enable constant contact with superiors as well as processing and sending the collected data to the commander. On the other hand, the use of

modern SCT Rubin thermal imaging sights gives a chance to detect and destroy the target in all conditions [1], [15], [24]. All these innovations are aimed at creating the most modern equipment for a Polish Army soldier as well as building Polish scientific and industrial potential, because only Polish companies and research institutes work on the project.

The benefits of using the *Tytan* program in the Polish Army include, above all, increasing the safety of soldiers and their combat capabilities due to the use of modern technologies. The implementation of such a large program requires a significant budget (over PLN 4 billion), however, it gives the opportunity to strengthen the position of the Polish scientific and industrial potential in the international arena.

### Unmanned aircraft

In recent years, the world's largest armies have put more and more emphasis on the development of unmanned aircraft. It is believed that drones are one of the most effective and dangerous weapons of the modern battlefield due to being totally unmanned. Thanks to this application, the equipment is capable of performing difficult tasks without endangering human life and health. The machine itself is piloted remotely or autonomously. Current drones used by military forces are mainly used for surveillance and reconnaissance. These devices are usually equipped with optoelectronic heads, i.e. the most modern optoelectronic equipment that integrates passive sensors. The head enables observation of the object on the TV or thermal imaging displayed on a digital indicator, ensuring the measurement of the distance to the target within the range of 100 - 30,000 meters.

The Polish armed forces are also in possession of unmanned aircraft. These are among the others:

- Aeronautics Orbiter;
- ScanEagle;
- WB Electronics FlyEye.

The first of them, the tactical unmanned aircraft- *Aeronautics Orbiter* of the Israeli construction, has been used mainly for missions in Afghanistan. Developed by the United States, the *ScanEagle* tactical reconnaissance unmanned aircraft is used by the Special Forces. *WB Electronics FlyEye* is the only unmanned aircraft that Polish Army is equipped with, constructed entirely by the Polish company *WB Electronics*. Intended mainly for close reconnaissance, *FlyEye* has recently proved itself perfectly well as part of the "Strong Support" operation carried out by the Territorial Defense Forces at the Polish-Belarusian border.



## Combat robots of the battlefield

The modern battlefield is a huge testing ground for modern technologies. The goal of every army in the world is to modernize military equipment and guarantee the safety of its soldiers. One of the ways to meet the above assumptions is to introduce robots on the battlefield, which are able to perform unmanned engineering, transport and special operations, etc.

There are currently over a dozen centres in Poland that are constantly working on the development of machines intended for operations on land. In the context of combat robots on the battlefield, it is worth mentioning the Polish project *Autonomous Air Defense Combat System ASBOP-PERKUN*. This device, just after its premiere at the MPSO trade fair in Kielce in 2019, won a number of international awards due to the extremely modern network of applications and solutions contained in the robot. *ASBOP-PERKUN* is an unmanned aerial defence robot, equipped with a self-propelled, six-wheeled, mobile platform in which each wheel works separately. Thanks to the independent drive, the vehicle is able to move in very difficult and demanding conditions and reach speeds of up to 10 km/h, and the suspension structure ensures maximum stability of the wheels with the ground. The system used in the combat robot enables an immediate reaction to the threat from the air, neutralizing, for example, other unmanned aircraft, rockets or combat aircraft. *The Autonomous Air Defense Combat System ASBOP Perkun* is presented in Fig. 3.



Fig. 3. Autonomous Air Defense Combat System ASBOP Perkun

Source: <https://piap.lukasiewicz.gov.pl/2020/03/18/kolejna-nagroda-dla-systemu-aspob-perkun/>  
[data accessed: 12.12. 2022]

Very fast technological development has significantly improved the functioning and operation of military entities, ensuring, above all, the safety and protection of the life of the soldier and the entire nation. In recent years, an increase in the improvement of communication between the supervisor and the subordinate has also been noticed, due to modern solutions in information systems.

## **Application of modern methods of data recording in the functioning of the military sub-unit - a case study**

### **Characteristics and evaluation of the tested process**

The technologies presented in the previous chapter are large investment projects, constituting a milestone in the functioning of the army. However, according to the authors, minor changes are equally important, improving the functioning of the army to a small but significant extent, in this case military logistics. One of the key elements of the proper functioning of soldiers in both peace and war is quick access to reliable information, and just this area of acquiring reliable knowledge is discussed in this article, using a selected element of the daily process of functioning of soldiers in a military unit (specifically, students of a military university). The process of recording the activities of leaving the sub-unit by cadets was examined. This is an extremely important part of the agenda as it provides the commander with information about the current state of the forces in his possession. Therefore, it is required that this information be up-to-date at all times of the day. In the examined unit, the act of leaving the unit is entered manually in two books, i.e. the Book of leaving the accommodation area and the Name Combat Register. In the presented study, empirical measurements of the duration of these activities were made for various compositions of duty services, and on this basis, their characteristics and evaluation were presented. The measurements concerned the duration of the process of writing out the data of each soldier leaving the sub-unit in the book leaving the place of stay and in the personal combat register. The research sample consisted of 200 observations obtained on random days of the week. First, the measurements of the times of “checking out” in the book of leaving the accommodation area, were analysed. The calculated values of basic measures of the descriptive statistics are presented in Tab. 1.

Table 1. Basic measures of descriptive statistics of measurements of times of “checking out” in the book of leaving the place of stay

Min.	1st Qu	Median	Mean	3rd Qu	Max	SD
25.37	30.28	32.11	32.08	33.85	39.47	2.78

Source: Own study

The value of the mean and the median is the same, which proves the high symmetry of the distribution. Particular attention should be paid to the minimum and maximum value, which are the two extreme results of the cadets' "check-out" times. They are respectively 25.37 and 39.47 seconds. The difference between the borderline results is 14.10 seconds, which indicates a significant variation in the rate of writing an entry by the cadets. This discrepancy - the range - shows precisely the disproportions between the extreme measurements. It is relatively large taking into account the specificity of the activity itself, which makes it possible to improve this system through the implementation of modern technologies. As a result, the times obtained could be close to the minimum value. The list of all measurements, along with marking the minimum and maximum values, is presented in Fig. 4.

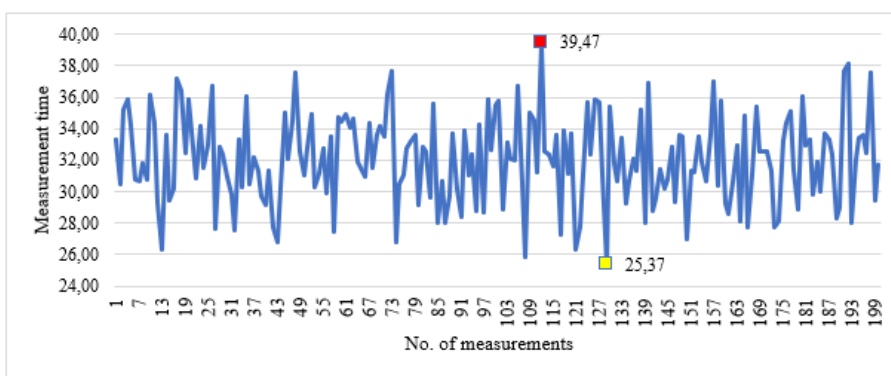


Fig. 4. Linear graph of the measurements of the "checking out" times of soldiers in the book of leaving the place of stay

Source: Own study

The symmetry of the distribution and its compliance with the normal distribution was confirmed using the Lilliefors test. The value of the test statistic was  $D = 0.0284$ ,  $p\text{-value} = 0.9586$ , which means that there is no reason to reject the null hypothesis of the normality of the distribution. The histogram of the analysed measurements is presented in Fig. 5.

The graph is unimodal. The largest number of observations is within the 30-32 second interval, because at that time the number of collected observations (checking out persons) is the largest and amounts to 43. Most of the results oscillate in the values of 30-35 seconds, which makes over 59% of all measurements. The smallest number of people was recorded with time between 38-39 seconds.

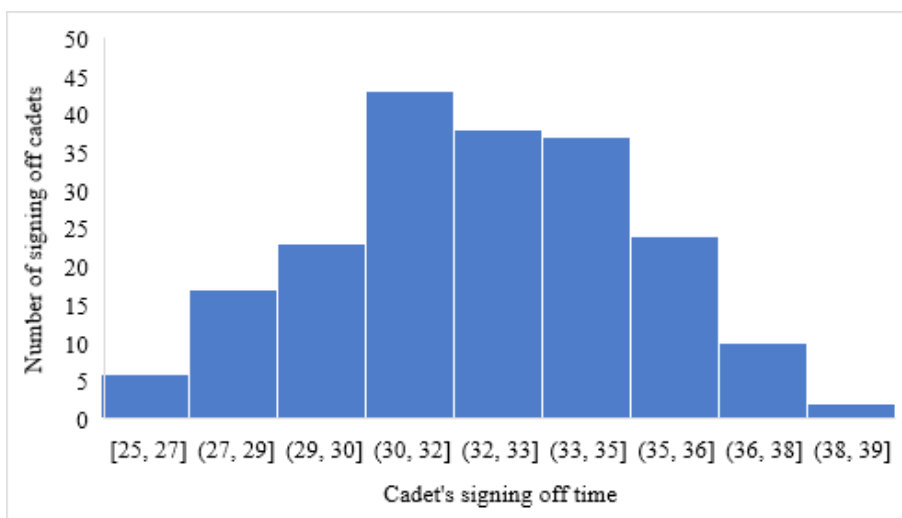


Fig. 5. Histogram of soldiers "checking out" times in the book of leaving the place of their stay  
Source: Own study

Next, the analysis covered the measurements of the duration of the process of cadets "ticking themselves off" in the Personal Combat Register. The values of the basic measures of descriptive statistics, were once more calculated and are presented in Tab. 2.

Table 2. Basic measures of descriptive statistics for measurements of cadets' "ticking off" times in the Personal Combat Register

Min.	1st Qu	Median	Mean	3rd Qu	Max	sd
6.775	10.293			13.278	18.28	2.17

Source: Own study

The evaluation of the results is very similar to the previous one. The median and mean values are the same, and the difference between the minimum and maximum values is significant. The collected observations are presented in Fig. 6, showing the differentiation of the process of cadets' "ticking off" time in the Personal Combat Register.

The above figure clearly shows the differences in the results of individual measurements. Some of them differ significantly from the average, and the interval between the minimum and maximum value is as much as 11.51 seconds. This gives the potential to introduce tools to improve the performance of this type of activity.

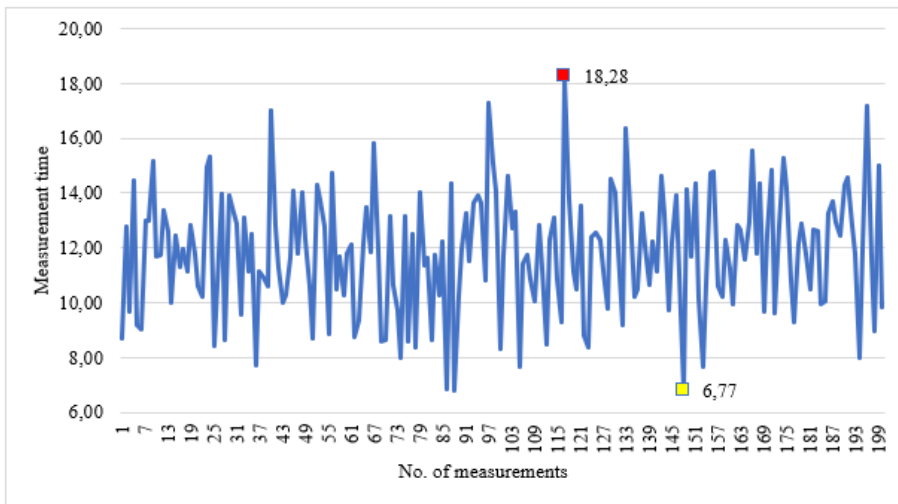


Fig. 6. Linear graph illustrating the cadets' "checking out" times in the Personal Combat Register  
Source: Own study

The empirical distribution is again consistent with the normal distribution, which was confirmed by the Lilliefors test, obtaining the test statistic value  $D = 0.0404$ ,  $p\text{-value} = 0.5909$ . The histogram of the "checking out" measurements in the Personal Combat Register is shown in Fig. 7.

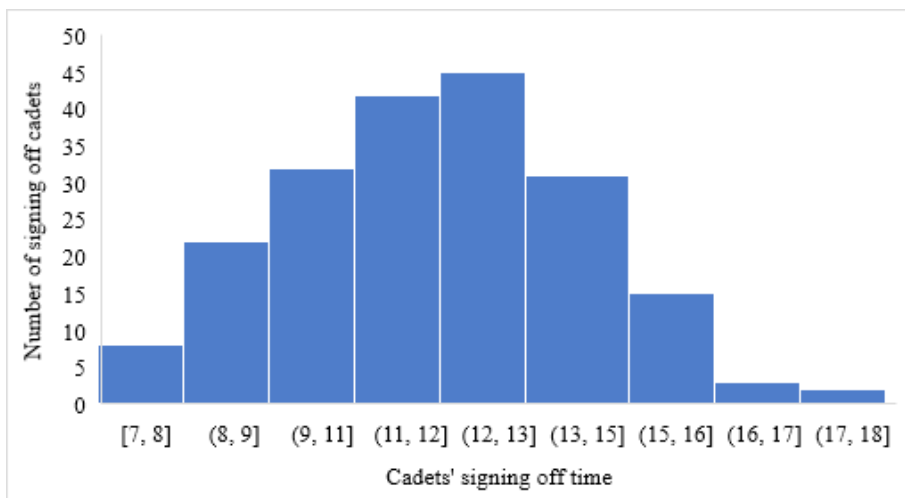


Fig. 7. Histogram of the cadets' "ticking off" times in the Personal Combat Register  
Source: Own study

The histogram of the time of persons' signing out in the Personal Combat Register is again unimodal. Despite the low level of complexity of the activity, a large percentage of soldiers did not complete it in a short time, which results in divergent results.

Next, an evaluation was made of the total time of performing both activities, necessary to be performed when the cadet leaves the sub-unit. Basic measures of descriptive statistics are presented in Tab. 3.

Table 3. Basic measures of the descriptive statistics of the total records making times of cadets leaving the subunit

Min.	1st Qu	Median	Mean	3rd Qu	Max	sd
34.80	41.54	43.93	43.92	46.30	52.23	3.321972

Source: Own study

The table above shows that "checking out" one soldier can take almost a minute, and at best more than half a minute. In a situation when a large part of the company leaves the sub-unit, this time is extended to several dozen minutes. This is clearly presented in Fig. 8.

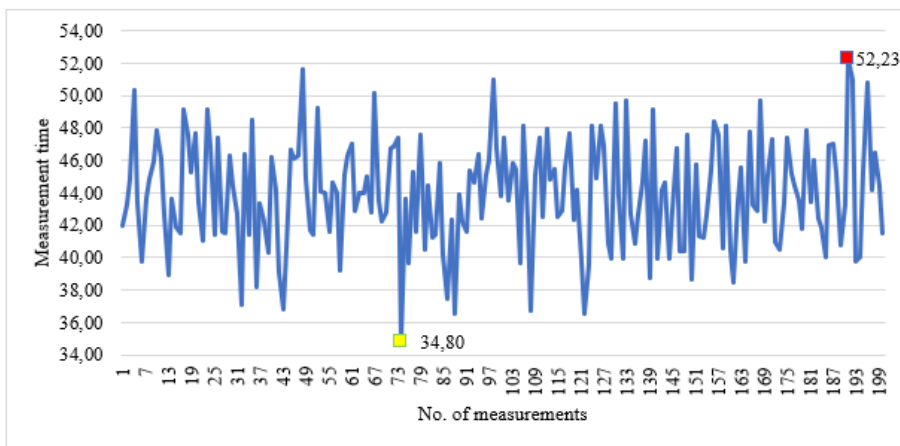


Fig. 8. Linear graph illustrating the measurements of the total time of recording cadets departing from the sub-unit

Source: Own study

In this case, the interval between the extreme maximum and minimum value is 17.43 seconds and it is the largest when comparing it with the above-calculated intervals for the book of leaving the place of stay, amounting to 14.10 seconds, and with the Personal Combat Register, equal to 11.51 seconds. The period for filling in both documents is significantly longer and is on average within 44 seconds.

## **A proposal to improve the examined process**

Summing up the considerations and analyses made so far, it can be stated that the time devoted to signing out in the book of leaving the place of stay and in the Personal Combat Register by soldiers of the Military University of Technology is undoubtedly long. Considering the number of cadets per one non-commissioned officer on duty (on average 130 people), the situation in which some military students intend to efficiently sign off in the above-mentioned documents becomes problematic. While in the case of situations of the daily course of service in a sub-unit, it does not interfere with its rhythm in a particular way, when performing tasks in which this time is important, it can definitely affect its course. The long-lasting process of cadets signing off in the Book of leaving the place of stay and in the Personal Combat register may result in the following consequences.

- No control of people leaving the sub-unit.
- Queues at the duty service desk.
- Possibility of making mistakes when making an annotation in the military documentation.
- Possibility of falsifying entries in the documents by third parties.

The answer to the problems presented above may be the replacement of an outdated and non-functional solution with modern systems equipped with proximity recorders operating, for example, on the basis of proximity cards. They rely on the radio technology, which transmits the signal thanks to the frequency of radio waves. They only need a few seconds to register a person after holding the card against the reader in the event of signing off on the pass. At the moment when the cadet intends to leave the sub-unit, he will only be obliged to bring his ID close to the card reader, without the need to manually making an entry in the documentation of the duty service. When the ID is held close, the proximity recorder will send a signal to the IT system in order to sign off a specific person. The information that the soldier is missing from the sub-unit can be confirmed on a device with Internet access. The commander of such a sub-unit will be able to check the current soldiers' status online at any time.

## **Summary and conclusions**

The aim of this article was to present the possibilities of implementing simple solutions belonging to new concepts in the field of the current industrial revolution and to assess the potential benefits resulting from their implementation.

Some imperfections in the functioning of the system of signing off soldiers have been shown. Such processes are not only time-consuming, but also generate numerous errors due to the presence of the human factor. The use of simple solutions

in the field of electronic data collection significantly optimizes the tested elements. First of all, it shortens the time to just a few seconds, and also provides reliable information, updated on a regular basis, readable in all conditions by authorized persons. It can be successfully used in many areas of military logistics operation, which is largely based on traditional accounting. A perfect example is recording the collection of military equipment for exercises (e.g. weapons), which is also a manual process and additionally carries the risk of a penalty for documenting false entries. The use of tags enabling electronic reading would allow efficient and error-free logging. Moreover, in the event of an emergency collection of military equipment in the warehouse, it would significantly reduce the time needed to collect and enter this activity. To sum up, the most important benefits of introducing the proposed solution are shorter process time, efficient leaving of the sub-unit - particularly important in the event of a crisis, elimination of queues, the possibility of remote viewing by the sub-unit staff and superior services of the actual state of the sub-unit; elimination of potential distortions, reliability. The proposed solution is of course on the theoretical level and requires further research in the actual conditions of the functioning of the sub-unit.

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