
The Model of the Vehicle Exploitation System within the Framework of Logistic Provision Tasks Accomplished by the Air Base

Submitted 01/12/21, 1st revision 15/12/21, 2nd revision 19/01/22, accepted 20/02/22

Tomasz Chukowski¹, Marcin Kiciński², Jarosław Bartoszewicz³

Abstract:

Purpose: The purpose of the paper is to assessment, research and development of a mathematical model of the systems of the vehicle exploitation system of the Tactical Air Base (TAB). The article describes the organization of the vehicle exploitation system in the Polish Armed Forces and in the TAB.

Design/methodology/approach: Statistical research enables the understanding of the functioning dependencies in the examined exploitation system. The impact of the technical material supply system on the TAB vehicle exploitation system was examined. The research results were analyzed, and exploitation problems and functioning relationships were identified. A mathematical model of the vehicle exploitation system and stages of its creation were presented.

Findings: Based on the Technical Service Cards (TSC) functioning in the Polish Armed Forces and using appropriate IT tools, it is possible to make a proper assessment of the vehicle exploitation system. The assessment is limited to indicators based on data included in TSC. The technical material supply system has a significant impact on the TAB vehicle exploitation system. The research enable to set functioning dependencies and formulate operational problems.

Practical Implications: The developed mathematical model reflects the dependencies occurring in the examined vehicle exploitation system and can be used as a tool supporting decision making aimed at solving operational problems.

Originality/Value: The research presented in the article contributes to the current literature on mathematical modeling of the Armed Forces vehicle exploitation systems.

Keywords: Air base, vehicle exploitation system, maintenance system.

JEL classification: H56.

Paper type: Research article.

Funding: Research financed from the own funds of the Poznań University of Technology.

¹1st Tactical Air Wing in Świdwin, Świdwin, Poland, t.chukowski@ron.mil.pl;

²Poznan University of Technology, Faculty of Civil and Transport Engineering, Poznan, Poland, ORCID ID: 0000-0003-1843-3405, marcin.kicinski@put.poznan.pl;

³Poznan University of Technology, Faculty of Environmental and Energy Engineering, Poznan, Poland, ORCID ID: 0000-0002-9426-6891, jaroslaw.bartoszewicz@put.poznan.pl;

1. Introduction

In recent years, the Armed Forces of Poland have been undergoing a restructuring processes and modernization in order to adapt them to the requirements of a modern army. In the area of the Military Logistic System (MLS), a territorial support system of the Polish Armed Forces was introduced.

The basic function in this system is played by Regional Logistics Bases (RLB) and Garrison Support Units (GSU) subordinated to them, which are tasked to provide logistic and financial support for military units in the allotted area of responsibility (“Guidelines of the Commander of the 1st Regional Logistic Base of 28 December 2016 on the operation of the technical supply subsystem in the area of responsibility of the 1st Regional Logistic Base,” 2016; “Guidelines of the Head of the IWsp Armed Forces of 9 December 2010 on the principles of operation of the supply system for troops stationed in the territory of the Republic of Poland.,” 2010; “Guidelines of the Head of the IWsp Armed Forces of 31 May 2016 on the operation of the technical subsystem of the Armed Forces of the Republic of Poland.,” 2016; “Guidelines of the Head of the Military Intelligence Agency of the Armed Forces of November 3, 2017 on the logistical support for the operation of the organizational units of the Armed Forces in 2018,” 2017; “Logistic doctrine of the Armed Forces of the Republic of Poland DD/4 (B) - 888/2014,” 2014). Tactical Air Bases (TAB) followed the changes, which often meant expanding the scope of tasks and reorganizing structures.

Currently TAB, as one of the few operational units, simultaneously perform operational tasks and logistics support tasks (the same as GSU). From the perspective of several years of the new regulations being in force, it can be assessed that TAB has met new challenges and successfully implement the tasks of logistics support of their own subunits and military units deployed in allotted area of responsibility. Much has already been done in the area of modernization of the Military Logistics System, but the direction of further changes should still be maintained to increase the effectiveness of the logistic support of the Armed Forces.

One of the main elements of the functional logistics system of the Armed Forces is the technical subsystem (Łodygowski *et al.*, 2018; “Logistic doctrine of the Armed Forces of the Republic of Poland DD/4 (B) - 888/2014,” 2014). The management of the utilization of military equipment is a very important function of the technical subsystem, which requires further improvement. Modern IT tools based on a properly selected methodology for the evaluation of exploitation systems and mathematical models supporting decision-making processes coupled with existing systems can be very helpful in effective management of the exploitation of military equipment (Chukowski and Kiciński, 2019).

2. Principles of the Military Vehicles Operation System

Organization and processing of exploitation is aimed to create and maintain in the Polish Armed Forces such organizational and technical conditions that the utility functions of the military equipment (ME) may be used within the time, place and with a certain intensity. The essential criteria of the exploitation management (Campbell and Reyes-Picknell, 2016; Niewczas *et al.*, 2018; Niziński, 2002; Wallace *et al.*, 1986):

- technical readiness of ME, including technical efficiency,
- security,
- economy of exploitation.

The basic strategies for exploitation of ME applied in the Polish Armed Forces:

- exploitation strategy according to service life consumption,
- exploitation strategy according to the actual state.

According to the instruction DD 4.22 (A) (“Instruction on the management of equipment of the tank and car service DD-4.22.2,” 2013; “Instructions on the management of the use of military equipment in the Armed Forces of the Republic of Poland, General principles DD-4.22.13(A),” 2018; “Technical support and security for the Armed Forces of the Republic of Poland. Principles of operation DD-4.22.(A),” 2017), the head of the military unit responsible for the logistic support of the Polish Armed Forces (in this case GSU, RLB, Air Base) manages the exploitation phase of the ME in the Polish Armed Forces.

Military units mentioned above are responsible for the stage of support and provision as well as defining the rules and norms for the exploitation of ME, with the partnership of proper ME administrator, as well as supervision over observance of the exploitation rules. Maintenance of equipment, depending on the scope of operations and the period of use, are divided into the following types (Murphy, 2014; Niziński, 2002; Palmer, 2019; Wallace *et al.*, 1986; Żółtowski and Niziński, 2010):

- current service: pre-departure review, review during way, handling after use,
- periodic maintenance – after a mileage or time of storage: periodic maintenance No. 1, periodic maintenance No. 2, subsequent periodic maintenance, special handling.

The scope of servicing depends on the type of service, type of ME and its current technical condition. Detailed scope of service activities is defined in the technical documentation (handling instructions, ME cards / technological guides, technical bulletins and other documents specified by Central Logistic body of ME, etc.). ME repair is a group of organizational and technical undertakings aimed at

reconstructing the utility functions of ME by removing breakdown and damages resulting from use or reconstructing the service life by performing specific operations in accordance with the required technology.

Depending on the place of realization, repairs are carried out by:

- ME users,
- logistic units like GSU, RLB, Air Bases,
- national industrial defense potential, including Economy Mobilization Program and the potential of the foreign industry.
- due to the scope, the following types of repairs are performed (Ben-Daya *et al.*, 2009; Campbell and Reyes-Picknell, 2016; Murphy, 2014; Niziński, 2002; Palmer, 2019; Wojciechowski and Ciskowski, 2018; Żółtowski and Niziński, 2010):
 - current repair (CR),
 - medium repair (MeR),
 - main repair (MaR),
 - maintenance repair (MtR),
 - dock repair (DR),
 - emergency repair (ER),
 - warranty repair (WR),
 - result repairs (RR),
 - repair of combat damages (R1....R5).

Due to the qualification procedure, the repairs are divided into planned and unplanned ones. Planned repairs are MeR, MaR, MtR and DR. Scope of planned repairs is based on technical documentation of ME (for example technological guides). Unplanned repairs are CR, ER, WR and RR. Inter-repair norms, inter-service standards, and labour consumption of are defined in the catalogs of ME exploitation standards and technical documentation of ME, technological guides, etc. Supplying technical materials is aimed at satisfying the needs of military units in terms of spare parts, mechanisms, equipment, repair kits and tools, accessories and other consumables used in the equipment exploitation process. In the Polish Armed Forces, the district supply rule applies. The executor for supplying are GSUs/Air Bases. They do it in accordance with the schedule of economic allocations of the Ministry of National Defense.

Within framework of the technical materials supplying process, planned and unplanned supplying are realized, planned supplies:

- is executed hierarchically, i.e. the higher level supply the lower level,
- GSUs / Air Bases supply the Military Unit and institutions in their area of responsibility,
- RLB supply GSUs/Air Bases, based on the approved annual supply plan,

- unplanned supply – Military Unit and institutions submit requests to GSUs/Air Bases and then technical materials are delivered from warehouses. In case of supply shortage, purchase is realized.

3. Organization of Vehicles Exploitation System in the Air Base

In Tactical Air Bases, vehicles are operated in accordance with the instructions provided in the previous chapter and the relevant guidelines of the Chief of the Armed Forces Support Inspectorate and the RLB Commander. The head of the vehicle service manages the work of vehicle service and is responsible for managing the vehicle exploitation system. The vehicle service is part of the technical section. Above service is also the main element in chain of supply of technical materials and in terms of repairs vehicles. The process of servicing and repairing vehicles is carried out on the basis of a wheeled vehicle repair platoon and diagnostics.

The repair and maintenance algorithm starts with the registration of the Technical Service Card (TSC) in the vehicle service department. Then the vehicle is moved to diagnostics to diagnose and determining the scope of the repair and/or determining the type of service. Later, the vehicle is directed to the workshop, where the representatives of the wheeled vehicle repairs platoon after taking the necessary materials and spare parts from the warehouse carry out maintenance and/or repair activities. After repair or service, the vehicle goes back to the diagnostics for verification of the service or repair of the vehicle. Supplying technical materials is carried out by vehicle service specialists who, in accordance with the instructions and guidelines require technical material at RLB and carry out their purchase in frame of their competences and financial resources. Technical materials are purchased in accordance with the Regulations for Public Procurement developed in TAB and national public procurement law. Purchases are carried out on grounds of signed contracts for the delivery of technical materials, and outside contracts in the case of unplanned needs.

3.1 Organization of Vehicles Exploitation System in the Air Base: Indicators

In the article the indicators of a general nature will be presented. This group of indicators are enough to asses vehicle exploitation system and includes, among others:

- technical availability indicator A [-],
- vehicle parking indicator for maintenance and repairs VP [-],
- burden factor at service station N [-],
- vehicle standstill time for servicing and repairs per 1000 km T^{sr} [h/1000 km],
- average number of (working) days of the vehicle being in servicing and repairs \bar{T}^{dsr} [days],

- real average service and repair time \bar{T}^{sr} [h],
- average passive downtime in service and repair \bar{T}^{pdsr} [h],
- average service and repair duration \bar{T}^{sr} [h],
- passive downtime indicator in service and repair PDI^{sr} [-],

Technical availability indicator A is the basic indicator of the reliability of a technical object involved in the operation process. In the case of mobile assets consisting of motor vehicles, the technical readiness indicator is determined according to the following formula:

$$A = \frac{\sum T_i^u}{\sum T_i^u + \sum T_i^f} \quad (1)$$

where: T_i^f is total time of failure of i -th vehicle and T_i^u is total time of the i -th vehicle use.

Another important indicator from the vehicle exploitation system point of view is so-called vehicle parking indicator for maintenance and repairs VP [-], which is determined from the formula:

$$VP(t) = \frac{\sum T_i^f}{\sum T_i^u + \sum T_i^f} \quad (2)$$

In the situation of technical facilities, the burden factor at service station N plays special role. It can be determined from the formula:

$$N = \frac{\sum T_i^{sr}}{T^{ass}} \quad (3)$$

where: T^{ass} is total availability of service stations [h] and T^{sr} is total duration of service and repair at the service station [h].

Having the mileage of the vehicle, average vehicle standstill time for servicing and repairs per 1000 km $T^{sr'}$ can be determine according to the below formula:

$$T^{sr'} = \frac{T^{sr}}{l} \cdot 1000 \left[\frac{\text{h}}{1000 \text{ km}} \right] \quad (4)$$

where: l is vehicle mileage for a period of time [km].

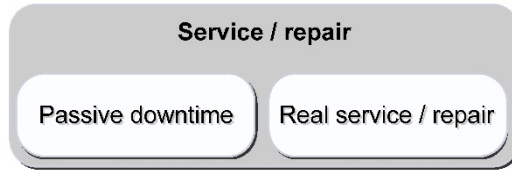
Average number of (working) days of the vehicle being in repairs and servicing is calculated from the formula:

$$\bar{T}^{dsr} = \frac{T^{sr}}{7 \cdot s} \text{ [days]} \quad (5)$$

where s is number of vehicles [-].

The repair or servicing at the workshop stand consists of two stages: vehicle passive downtime (i.e. waiting time for service/repair) and real repairs and servicing when maintenance and repair activities are carried out (Figure 1).

Figure 1. Stages of service/repair



Source: Own study

Considering the service/repair stages, it is worth using time indicators such as:

- Real average service and repair time \bar{T}^{rsr} [h] determined from the formula:

$$\bar{T}^{rsr} = \frac{T^{rsr}(t)}{n} \text{ [h]}, \quad (6)$$

where: $T^{rsr}(t)$ is total time of real service and repair in the period of time and n is number of services and repairs in the period of time.

- Average passive downtime in service and repair $\bar{T}^{pdsr}(t)$ [h] described by the equation:

$$\bar{T}^{pdsr}(t) = \frac{T^{pdsr}(t)}{n} \text{ [h]}. \quad (7)$$

Average service and repair duration \bar{T}^{sr} [h] is an addition of real average service and repair time \bar{T}^{rsr} [h] and average passive downtime in service and repair \bar{T}^{pdsr} [h]. From the point of view of the efficiency of the operation system, an important characteristic of the technical facilities is the passive downtime indicator in repair and service PDI^{sr} [-]:

$$PDI^{sr} = \frac{T^{pdsr}(t)}{T^{sr}} \text{ [-]}. \quad (8)$$

3.2 Determination of Selected Operational Indicators by the Test Method

As part of the research, all service and repairs registered in the Technical Service Cards in 2017 were analyzed, which related to vehicles belonging to the TAB. The data included in TCS allowed me to calculate the indicators characterizing the vehicle exploitation system described in article. Obtained results of the operation indicators for subunits and the Tactical Air Base as a whole are listed in table 1. In order to further investigate the problem, service and repair were identified as two separate processes.

Table 1. Operation indicators platoon of the transport company

Name of indicator	Platoon			Aircraft Ground Handling	Airfield service company	Special vehicles	TAB
	1st	2nd	3rd				
Milage 2017 [thousand km]	486,7	196,2	18,2	34,7	76,7	63,0	875,6
Average service consumption \bar{T}^{hs} [man hours]	10.14	11.93	10.50	10.00	8.27	12.44	10.13
Average repair consumption \bar{T}^{hr} [man hours]	24.41	30.27	19.25	28.50	35.6	18.00	24.56
Real average time of service \bar{T}^{rs} [h]	8.93	9.68	7.00	9.50	7.32	10.89	8.62
Real average time of repair \bar{T}^{rr} [h]	20.69	23.42	14.82	24.03	30.55	15.57	20.80
Average service duration \bar{T}^s [h]	10.40	14.50	7.00	13.00	10.50	14.78	11.47
Average repair duration \bar{T}^r [h]	51.07	51.42	31.5	65.06	80.85	35.2	48.06
Average passive downtime in service \bar{T}^{pds} [h]	1.47	4.82	0.00	3.50	3.18	3.89	2.85
Average passive downtime in repair \bar{T}^{pdr} [h]	30.39	28.00	16.68	41.03	50.3	19.63	27.33
Passive downtime indicator in service PDI^s [-]	0.14	0.33	0.00	0.27	0.30	0.26	0.25
Passive downtime indicator in repair PDI^r [-]	0.59	0.54	0.52	0.63	0.62	0.56	0.57
Average number of days the vehicle in service and repair \bar{T}^{dsr} [days]	16.70	9.58	6.40	11.48	9.42	6.96	9.46
Vehicle standstill time for servicing and repairs per 1000 km T^{sr} [h/1000 km]	7.21	8.88	49.16	83.82	24.10	21.66	12.94
Vehicle parking indicator for maintenance and repairs VP [-]	0.059	0.034	0.022	0.031	0.035	0.025	0.034
Technical availability indicator A[-]	0.94	0.97	0.98	0.97	0.96	0.98	0.97

Source: Own study.

Service and repair duration (T^s and T^r) is the difference between the dates of service and repair start and end registered in Technical Service Cards (TSC). The above time is presented in hours, assuming that one working day includes 7 hours of work at the service station. The real time of repair or service (T^{rs} and T^{rr}) results from the man hours and number of employees carrying out repair or service recorded in TSC and reflects the actual time of work at the service station. Passive downtime in service and repair (T^{pds} and T^{pdr}) results from the difference between service and repair duration (T^s and T^r) and real time of repair and service (T^{rs} and T^{rr}).

After comparing the data in Table 1, it can be clearly seen that the times and labour consumption of service differ significantly from the times and labour consumption of repair, which seems to be understandable, considering the different scopes of operation. Another regularity, which clearly comes from the presented results, is an extremely different passive downtime in service and repair. The results presented in tab. 1 indicate a higher average number of days the vehicle in service and repair \bar{T}^{dsr} in subunits with higher annual mileage. This, in turn, causes that the technical availability indicator A for these subunits is the lowest according to the formula (1) described in the article.

Mentioned technical availability indicator A describes the so-called stationary technical readiness independent of vehicle mileage. Considering the above, highly damaged vehicles can also show a high degree of stationary technical readiness with low intensity of use. To get a full picture related to vehicle reliability, you should also pay attention to vehicle standstill time for servicing and repairs per 1000 km T^{sr} . Analyzing T^{sr} indicator, I can be seen that it reaches the highest values for 3rd platoon of the transport company and Aircraft Ground Handling Platoon with low mileage.

3.3 Conducting Statistical Researches and Presenting as a Monthly Time Charts

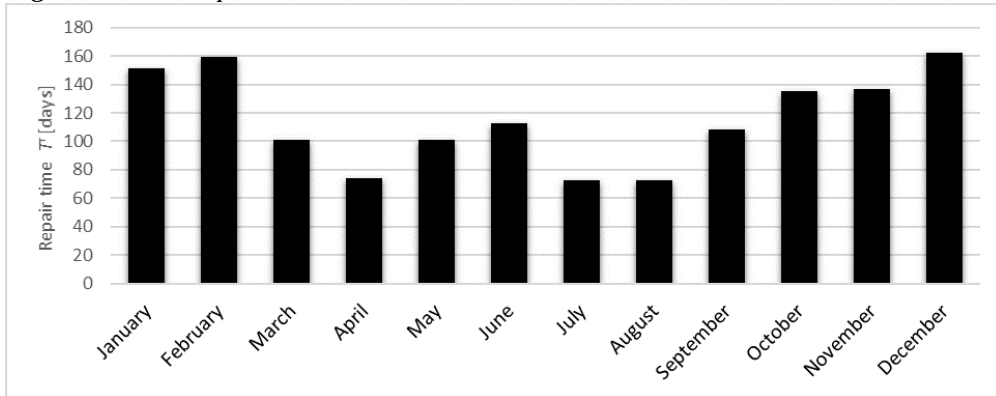
In order to find out the dependencies within the functioning exploitation system, many studies were carried out, which resulted in monthly time charts of various types of operational indicators showing their values in individual months over one year. One of the example charts is presented in Figure 2.

Considering the repair and service stages presented in Figure 1 the impact of real service and repair changes and passive downtime in service and repair on changes in total service and repair time were examined. Monthly time charts analysis and calculated correlation indicators show the following conclusions:

- the change in the average passive downtime in repair \bar{T}^{pdr} has a significant impact on the changes in the total repair time T^r (correlation coefficient is 0.90),

- in the case of the average real repair time \bar{T}^{rr} and the total repair time T^r , the correlation coefficient is only 0.39,
- there are no high correlations between the passive downtime in service T^{pds} and the total service time T^s , changes in real service time T^{rs} have a decisive impact
- on the changes in the total service time T^s (correlation coefficient is 0.96).

Figure 2. Total repair time T^r

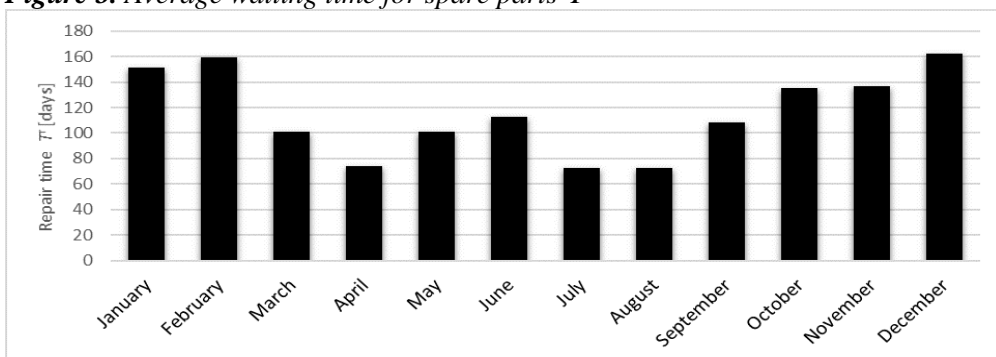


Source: Own study.

3.4 Analysis of Impact of the Technical Material Supply System on the Tab Vehicle Exploitation System

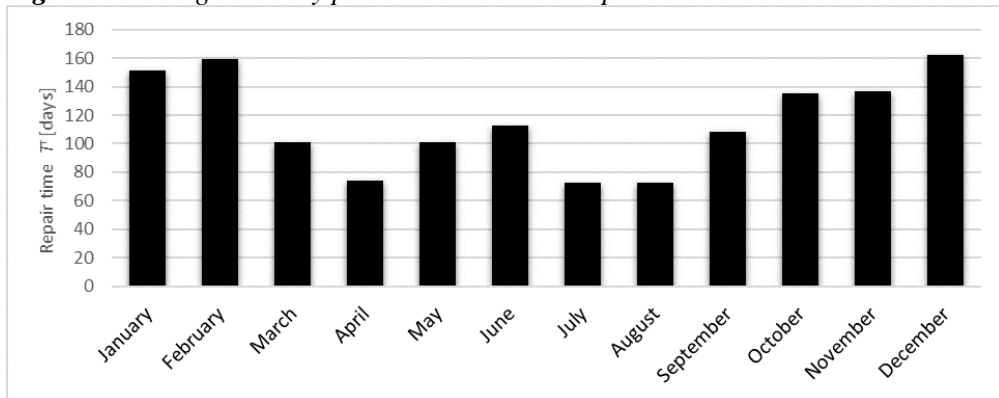
Given the very different opinions associated with the supply of spare parts, it was decided to investigate the impact of the technical material supply system on the vehicle exploitation system in TAB. After comparing the monthly average waiting time for spare parts (Figure 3) with the chart of the average monthly passive downtime in repair \bar{T}^{pdr} created on the basis of archived TSC (Figure 4) it turned out that the above charts show a high correlation of 0.82.

Figure 3. Average waiting time for spare parts \bar{T}^{wip}



Source: Own study.

Figure 4. Average monthly passive downtime in repair \bar{T}^{pdr}



Source: Own study.

Analyzing the results of the average annual waiting time for spare parts (24.3 hours) and the average annual passive downtime in repair (27.3 hours) and their monthly distribution, it can be stated that the time associated with the supply of technical materials has a significant impact on the time of passive downtime in repair, and thus on the functioning of the TAB vehicle exploitation system.

3.5 Test Results and Setting of Dependencies and Operational Problems

Conducted researches and calculations allow evaluation of the vehicle exploitation system in the Tactical Air Base. Technical Service Cards were the only source documents for creating spreadsheets. The following dependencies were distinguished in the frame tests of the vehicle exploitation system:

- there is a big difference in terms of times and labour consumption between repairs and services,
- the passive downtime during service is relatively small, while it is a significant part of the repair,
- operational indicators reach different values for subunits carrying out different transport tasks,
- the workshop's total production capacity is sufficient to secure the maintenance and repair needs of the TAB,
- the change of the passive downtime in repair has a big impact on the change of the total repair time,
- the dependence between the labour consumption time and the actual time in service and repair is determined by the indicator of employee elevation gain at the service station P,
- the time associated with the supply of technical materials has a significant impact on the passive downtime in repair.

After the researches, it is possible to point out the problems of the vehicle exploitation system such as:

- logistic delay related to the spare parts supply system has a significant impact on the vehicle's passive downtime, and thus on the functioning of the vehicle exploitation system,
- in certain periods of time, there is too much burden put on the workshop; the cause of this is, to large extent passive downtime of vehicles at service stations and organization of work at service stations,
- there are no precise IT tools describing the vehicle exploitation system,
- there are no mathematical models that could support the decision-making process under the vehicle exploitation system.

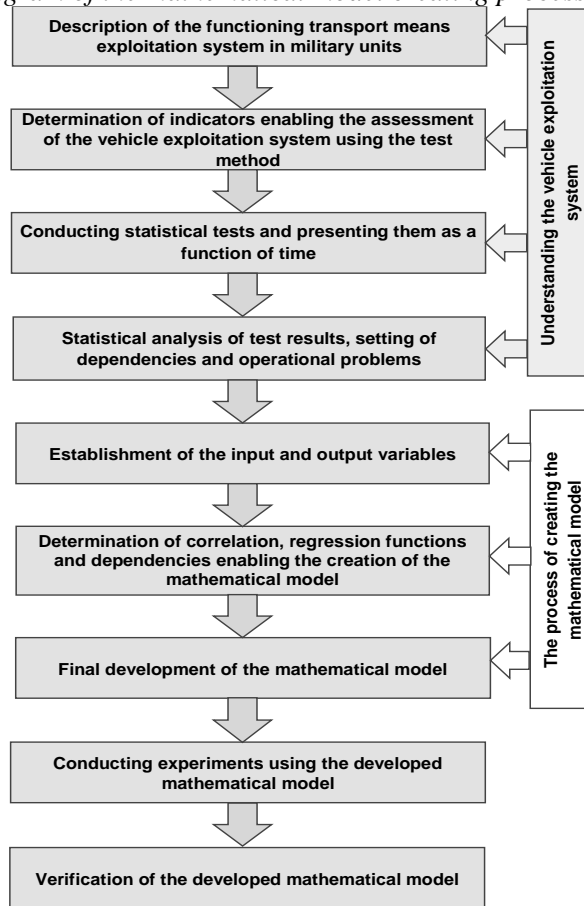
4. Model of Vehicle Exploitation System in Tactical Air Base

The development of a mathematical model which is able to map functioning of the vehicle exploitation system will allow the performance of computational experiments. Obtained results can be used to support decisions in the field of optimizing the vehicle exploitation system. Striving to improve the operation system, i.e. improving certain indicators, involves making certain decisions. The mathematical model of the vehicle exploitation system was created based on the experimental method widely described in the literature and on the basis of experience gained in the course of research. The diagram of the mathematical model creating process is shown in Figure 5.

Building the mathematical model was possible thanks to finding dependencies with a high correlation index within conducted statistical researches presented as the monthly time charts. The mathematical model presented in Figure 7 was developed using formulas described in the article and others widely known in literature (Campbell and Reyes-Picknell, 2016; Murphy, 2014; Wallace *et al.*, 1986; Żółtowski and Niziński, 2010)

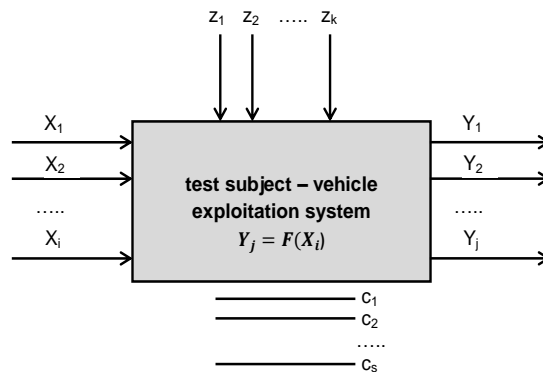
The aim of the experiment was to examine the output quantities value (operation indicators) with changes of the input quantities values (factor of employee elevation gain at the service station P and the average waiting time for delivery of spare parts \bar{T}^{wip}). Conditional analysis of data was used in the experiment. The modelled values of each exploitation indicator (output variable) are presented in the form of a data table with two input variables. The modelled values of average waiting time for delivery of spare parts \bar{T}^{wip} is a row cells and the modelled values of employee elevation gain at the service station P is a columnar cells (Figure 8). The results of the experiments were also depicted in the form of three-dimensional charts (Figure 9). Due to the limited size of the article only modelled values technical readiness indicator A are presented.

Figure 5. The diagram of the mathematical model creating process



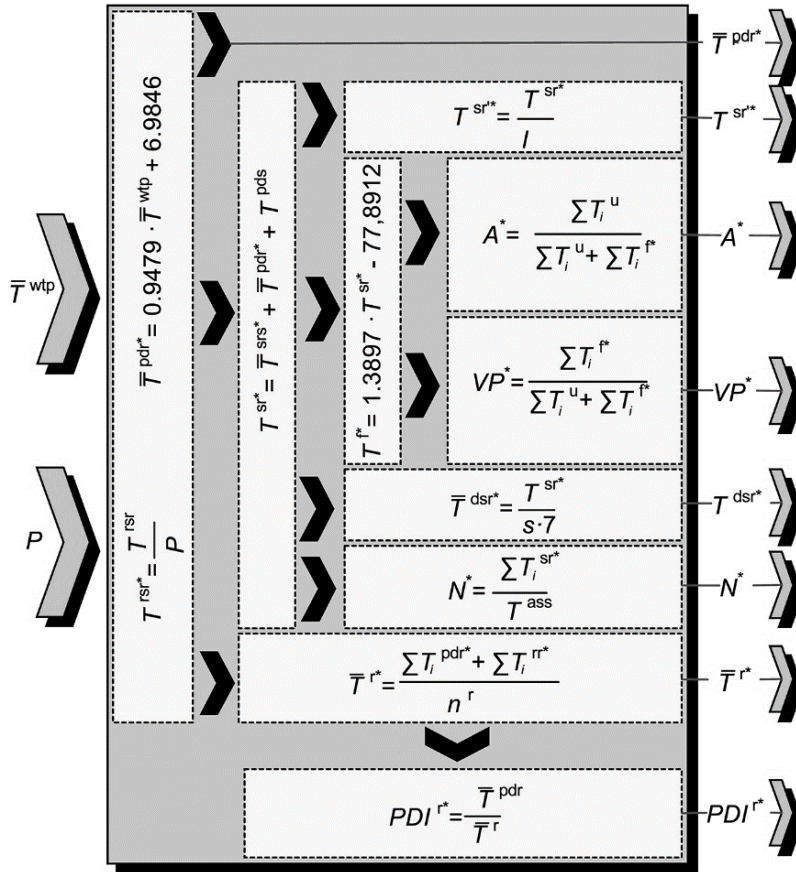
Source: Own study.

Figure 6. The General model of the vehicle exploitation system



Source: Own study.

Figure 7. The model of the TAB vehicle exploitation system



Source: Own study.

Figure 8. Modelled values of the technical availability indicator A [-]

Value of the exploitation indicator obtained as part of the tests - A

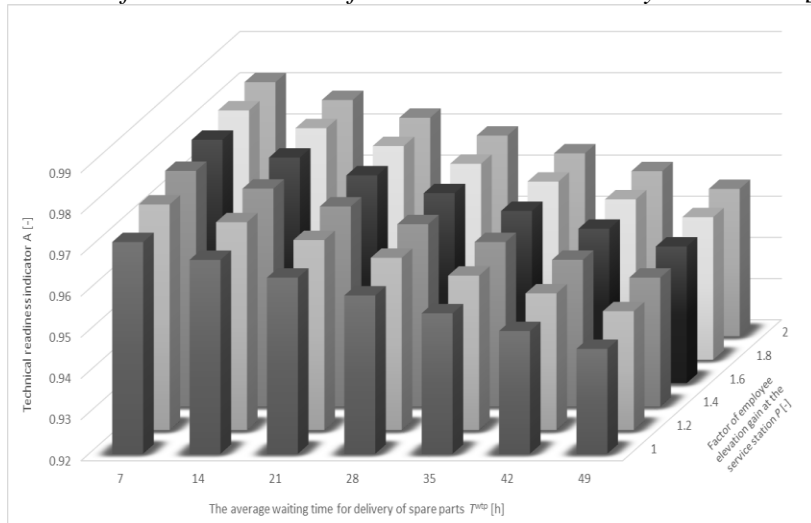
Modeled values of the average waiting time for delivery of spare parts - \bar{T}^{wtp}

0.97	7	14	21	28	35	42	49
1	0.971	0.967	0.963	0.958	0.954	0.950	0.945
1.2	0.975	0.971	0.966	0.962	0.958	0.953	0.949
1.4	0.977	0.973	0.969	0.964	0.960	0.956	0.951
1.6	0.979	0.975	0.970	0.966	0.962	0.958	0.953
1.8	0.981	0.976	0.972	0.968	0.963	0.959	0.955
2	0.982	0.977	0.973	0.969	0.964	0.960	0.956

Modeled values of the employee elevation gain at the service station P

Source: Own study.

Figure 9. Chart of modelled values of the technical availability indicator A [-]



Source: Own study.

5. Conclusion

Conducted research showed that:

- Based on the Technical Service Cards (TSC) functioning in the Armed Forces and using appropriate IT tools, it is possible to make a proper assessment of the vehicle exploitation system. The assessment is limited to indicators based on data included in TSC.
- The technical material supply system has a significant impact on the TAB vehicle exploitation system.
- The research enable to set functioning dependencies and formulate operational problems.

Analyzing the developed mathematical model and the computational experiments, it can be concluded that:

- The monthly time charts used in the work are not only a more accurate picture of the examined exploitation system but also allow finding the necessary correlations to build a mathematical model.
- In the developed model, the input data was selected to solve operational problems. When choosing the input data, real limitations, possibilities and a relatively fast time to make changes were taken into account. The output data is exact information about the exploitation system. It should be noted that certain quantities remain constant and all types of disturbance are not taken into account.

- The linear regression functions used in the development of the mathematical model are suitable for the model of vehicle exploitation system.
- The experiment is a simulation that gives the system manager a picture of the vehicle exploitation system resulting from changes of input parameters. Based on this experiment, conscious decisions can be made to improve functioning of vehicle exploitation system.
- The mathematical model presented in the article, created through experimental research, requires thorough analysis of the processes and cannot be used in the same form outside the research area. However, it is possible to create a methodology of the development of this type of models in the field of functioning exploitation systems (e.g., in the Armed Forces).
- The mathematical model created using the experimental method should include as large a research sample as possible to capture the actual cause-and-effect dependencies, not the random correlation.
- If it is not possible to find sufficiently high correlations between occurring phenomena (i.e. changes of one quantity do not cause changes of other quantities), then building a mathematical model without additional analysis is impossible.
- The developed mathematical model reflects the dependencies occurring in the examined vehicle exploitation system and can be used as a tool supporting decision making aimed at solving operational problems.

References:

- Ben-Daya, M., Duffuaa, S.O., Raouf, A., Knezevic, J., Ait-Kadi, D. (Eds.). 2009. Handbook of Maintenance Management and Engineering. Springer London, London.
<https://doi.org/10.1007/978-1-84882-472-0>.
- Campbell, J.D., Reyes-Picknell, J.V. 2016. Uptime: strategies for excellence in maintenance management, Third edition. ed. CRC Press, Taylor & Franics Group, Boca Raton.
- Chukowski, T., Kiciński, M. 2019. The characteristics of the Vehicle Maintenance System in Tactical Air Base. *Journal of Mechanical and Transport Engineering*, 71, 5-16.
<https://doi.org/10.21008/j.2449-920X.2019.71.1.01>.
- Guidelines of the Commander of the 1st Regional Logistic Base of 28 December 2016 on the operation of the technical supply subsystem in the area of responsibility of the 1st Regional Logistic Base, 2016.
- Guidelines of the Head of the IWsp Armed Forces of 9 December 2010 on the principles of operation of the supply system for troops stationed in the territory of the Republic of Poland, 2010.
- Guidelines of the Head of the IWsp Armed Forces of 31 May 2016 on the operation of the technical subsystem of the Armed Forces of the Republic of Poland, 2016.
- Guidelines of the Head of the Military Intelligence Agency of the Armed Forces of November 3, 2017 on the logistical support for the operation of the organizational units of the Armed Forces in 2018, 2017.
- Instruction on the management of equipment of the tank and car service DD-4.22.2, 2013.
- Instructions on the management of the use of military equipment in the Armed Forces of the Republic of Poland, General principles DD-4.22.13(A), 2018.

- Łodygowski, T., Ciałkowski, M., Pielecha, I. 2018. Nasze stulecie. Nauka dla obronności. Poznan University of Technology Publisher, Poznań.
- Logistic doctrine of the Armed Forces of the Republic of Poland DD/4 (B) - 888/2014, 2014.
- Murphy, D. 2014. Fleet Purchasing, Maintenance and Reliability. Industrial Press, Inc.
- Niewczas, A., Rymarz, J., Debicka, E. 2018. Stages of operating vehicles with respect to operational efficiency using city buses as an example. *EiN* 21, 21-27.
<https://doi.org/10.17531/ein.2019.1.3>.
- Niziński, S. 2002. Operation of Technical Facilities. Military Institute of Armored and Automotive Technology in Sulejówek.
- Palmer, D. 2019. Maintenance planning and scheduling handbook, Fourth ed. McGraw-Hill Education, New York, NY.
- Technical support and security for the Armed Forces of the Republic of Poland. Principles of operation DD-4.22(A), 2017.
- Wallace, J., McCalib, D., Skipper, M. 1986. Vehicle Maintenance Control and Analysis Specialist (AFSC 47254). Maintenance Data Collection and Analysis.
- Wojciechowski, Ł., Ciskowski, T. 2018. Metoda optymalizacji procesu eksploatacji w ujęciu bezawaryjności pojazdu. Publishing House of the Lublin University of Technology, Lublin.
- Żółtowski, B., Niziński, S. 2010. Modelowanie procesów eksploatacji maszyn. Wydawnictwo Instytutu Technologii Eksploatacji, Radom 2010. Publishing house of the Institute of Sustainable Technology in Radom, Radom.