Discrete Event Simulation in Future Military Logistics Applications and Aspects

Pavel Foltin[1], Martin Vlkovský[1(✉)], Jan Mazal[2(✉)], Jan Husák[3(✉)], and Martin Brunclík[1(✉)]

[1] Department of Logistics, Faculty of Military Leadership, University of Defence, Brno, Czech Republic
{pavel.foltin,martin.vlkovsky}@unob.cz, martin.brunclik.me@gmail.com

[2] NATO Modelling and Simulation Centre of Excellence, Rome, Italy
mscoe.det01@smd.difesa.it

[3] Multinational Logistics Coordination Centre, Prague, Czech Republic
mlcc.husak@email.cz

Abstract. The article deals with application of Discrete Event Simulation in professional training which focuses on analysis, planning, management and decision making support during military operations characterized by high complexity, dynamics, large number of influencing factors and utilization of advanced technologies. One of the key areas of the planning process and subsequent implementation of the logistical support to deployed units, especially during the first phase of the operation, is the Reception, Staging and Onward Movement (RSOM) process. Logistics planners seek a compromise option, i.e. optimum between time available, cost and quality of implementation when planning and subsequently implementing optimal solutions. The paper deals with the possibility of using simulation in the field of training and logistics planning by implementing a specific technology, possible future aspects, operating conditions and tactical entities – such as Autonomous Systems.

Keywords: Discrete Event Simulation · Supply chain performance RSOM process · Training

1 Introduction

Current security environment is characterized by high dynamics of change and interdependence of affecting factors. Increase in the intensity of armed conflicts [6] with the concurrent accumulation of natural disasters [15] accompanied by growing global complexity of national economies [1] occurs. Logistics operations thus take place in a dynamic environment, over long distances being affected by a large number of influencing factors [12]. Because of the interdependence of civilian and military logistics [5], logistics support to the entire process of earmarking and training military units, including adequate personnel education, can be considered the key success of military operations.

J. Mazal (Ed.): MESAS 2017, LNCS 10756, pp. 410–421, 2018.
https://doi.org/10.1007/978-3-319-76072-8_30

Logistic support thus creates an imaginary bridge between national resources and units deployed in the operation, whether under national command or within multi-national operations. Functionality and efficiency of the logistics support at the same time is significantly influenced by optimal determination of distribution and supply routes, decoupling points of supply chain and their subsequent optimization during the implementation of the military operation itself [3]. In the case of multinational operations outside the area of the sending states and providing a successful entry of the national contingents into the joint operation area (JOA), a significant role is played by the process commonly referred to as Reception, Staging and Onward Movement (RSOM) [4]. Its aim is to provide the required reception of military units, technology and material to the Joint Operational Area (JOA) and preparation of personnel, military material and technology prior to the planned deployment. Due to the international aspects of the RSOM process implementation and the requirement to provide a rapid entry into the JOA, emphasis is placed on the coordination of individual activities, especially in unloading sites, usually Points or Ports of Debarkation (POD). The crucial is also cooperation with local authorities in the operational area which is usually provided by specialists or Host State Support (HNS) units in cooperation with individual national contingents.

For the successful implementation of the individual activities of the RSOM process, a key issue is to provide appropriate preparation of logistics specialists, whether in management, planning or implementing working positions. Due to the extent and complexity of the activities carried out and a large number of influencing factors [8], use of simulation and modelling tools appears to be an appropriate complementary approach to the education of the logistics experts.

2 Provision and Implementation of the RSOM Process

One of the key areas of planning and subsequent implementation of the logistic support of deployed units is represented by the Reception, Staging and Onward Movement (RSOM) process, especially during the first phase of the operation at its launch [17]. During planning and subsequent implementation, logistics planners seek a compromise option, i.e. optimum between time available, cost and quality of implementation while analyzing the effects of possible limiting factors (LIMFAC).

In order to provide coordination of national contingents and their entry into the JOA, the decisive criterion is considered the time spent by units, their material and technology at embarkation points [14]. For this reason, relatively large demands are being put on the preparation and training of the core RSOM process activities in logistics staff of national contingents. Due to the economic demandingness of training and performing RSOM activities in vivo (i.e. in a real environment), it is more efficient to perform them in silico (e.g. by computer simulation) [10]. Engagement of the units into creation simulation models and mastering suitably differentiated scenarios - variants of models, provides a participant with modern approach to preparation and training [2]. Use of simulation tools creates space and appropriate assumptions for testing possible scenarios and preparation of the logistics staff for real-life situations characterized by a number of influencing factors. These are primarily factors that may adversely affect the RSOM process or some of its phases.

Education, training and exercising of military units thus represents just one of the key factors of success in the real deployment of such units [9]. The aim of modern training is to provide the exercising units with required knowledge and skills at the lowest possible organizational costs. The output skills of the exercising units reflect in carrying out the appropriate activity in real-life conditions with the highest possible efficiency. In the past, training of transport units often required high costs associated with transportation, handling operations, etc. At present, it is possible to carry out training even under limited costs while meeting all the training objectives. Sophisticated software products that allow simulation of real scenarios with a reasonable degree of abstraction can represent a possible tool [13].

Simulation preparation itself provides the designer with a profound insight into the large-scale real-world military deployment planning and helps to understand the processes carried out as well as their mutual relations [16]. Subsequently, once a model in the simulation environment is created, it is possible to quickly perform and simultaneously analyze alternative scenarios and use the simulation environment for searching for the optimal solution [11]. This approach also allows quickly extending and modifying the created model according to the specific conditions and requirements under the effect of influencing factors. Because of these properties, simulation tools are suitable for logistics planners and their preparation.

In the RSOM process, similarly to the civil sector, it is appropriate to simulate more simple process activities with a higher repetition rate which may allow variability in time, capacity, or quantity of indicators. A typical example could be simulation of operations related to cargo unloading or loading in ports, where it is necessary to coordinate the handling and unloading of container units along with the exit of military vehicles and, in addition, to plan drivers' circulation for the vehicles concerned.

The object of such a simulation model is to choose and subsequently verify the variant minimizing the times of individual handling operations with simultaneous more effective use of available capacities (personnel, handling and transport means). Finding the optimal way of unloading, respectively loading allows optimal use of available capacities while optimizing the funds spent. For the needs of armed forces, it is possible to use a modular principle and verify different scenarios depending, for example, on the different unit size (volume of stock) and unit type (type of stock). The situation is more complex if it is necessary to simulate not only the activity of one unit but more units in a multinational context where more than one army of the North Atlantic Treaty Organization (NATO) unloads the stock and vehicles while simultaneously implementing the time schedule of the multinational operation commander.

3 Research Goal, Methodology and Limitations

Two research questions have been formulated within the research:

1. What are the benefits of the logistics analysis using a simulation model in the preparation training of transport units for the implementation of the RSOM process?

2. What are the influencing factors for the inclusion of autonomous means of unloading/loading process for the training of logistics staff?

In terms of planning and implementation of the RSOM logistics processes, a qualitative approach based on a grounded theory has been primarily chosen, while the individual partial conclusions result from the classical optimization task of the model situation created in the simulation environment. To test and optimize the access, discrete simulation in Simul8 software environment (version 2017) has been used, using primarily modelling and simulation methods supported by the queuing theory [7]. For these purposes a model of port debarkation handling and transport operations (POD) has been created on the basis of the formulated assumptions and a simulation of these operations was carried out. It introduces a logistics simulation as a tool that can be used to provide insight into potential outcomes of the deployment plans. The research is focused mainly on the alternative scenarios of the RSOM process. Outputs for logistics analysis have been formulated based on testing and verification of the created model. They can be used in the training phase of the experts in the field of the RSOM process logistics implementation.

The limitations of the model created are primarily in the scope of simulated activities in the Ports of Debarkation and restriction to only three basic activities: ISO 1C containers, non-standard containers and military equipment unloading from the ship cargo space.

4 Model Creation and Its Modification

Crucial aspects of the training of logistics experts of the RSOM process preparation and implementation have been identified by expert judgment using a grounded theory. It dealt with the assessment of the content and forms of the methodical work, professional courses carried out, distance education, internships, drills, practical exercises and possibilities of using simulation tools. The following main aspects have been identified as main advantages when using simulation tools, compared to other types of training:

- *Speed:* Use of simulation tools and creation of training models is relatively fast and affordable; a whole range of software products is offered on the market, allowing for a high degree of variability in approaches to training; highly sophisticated products that allow tailored solution are also available;
- *Low economic demandingness:* Due to the absence of personnel, material and technology transfers to training areas, preparation of equipment, etc., training using simulation models can usually be carried out directly at the home base of the exercising units;
- *Simplicity, variability and modularity:* When needed to include different factors, it is possible to create a similar model or test a similar RSOM implementation scenario. The simulation tool usually provides the possibility of fast modification by including other planning factors, unit size or unit structure changes as well as the quantity and structure of supplies or military technology type change.

Apart from the main advantages, the following disadvantages of using in silico approach have been identified:

- *High abstraction level of the simulation model:* The risk that the model will be too distant from the reality and training will not provide the participants with required knowledge and skills;
- *Complexity of the simulation model:* Use of advanced software applications with too complex algorithms and controls, similarly to the inclusion of too many factors, can cause that the model and hence the training itself become incomprehensible and therefore unnecessary for the participants;
- *Need to create a model:* For very complex models, it may be a time-consuming activity that usually requires assistance or direct involvement of an expert in the use of simulation tools, usually when the model, which can then be used modularly, is first created.

Based on the assessment carried out, a Sea Port of Debarkation (SPOD) scenario for unloading has been developed. The presented model with a reasonable level of abstraction has created the prerequisites for a logistics analysis of a real example of the first phase of the RSOM process, namely the process of admission of military supplies and vehicles in the SPOD. The following assumptions and limitations have been defined for the model being created:

- A Ro/Ro Container Ships which allows individual ramping/unloading of military vehicles and storage of container units on the upper deck was used for transporting and unloading (containerized) supplies and military vehicles;
- 145 standard container units (using ISO 1C containers) and 5 non-standard container units were unloaded;
- In addition, 50 military vehicles which took advantage of Roll-Off technology – a separate exit from Ro/Ro ships, respectively Ro/Ro Container Ships, were used;
- Dangerous things which need special treatment or conditions during unloading were not part of the cargo;
- The amount of supplies was determined according to the model type of the task force (platoon or battalion task force);
- Unloading was carried out in a model port which had one unloading ramp for unloading Ro/Ro ships and three port gantry cranes;
- An unlimited number of handling devices (container carriers) and unlimited storage capacity for container units storage was available for moving container units in the port;
- The driver unit was a changeable variable, which got the values d = 1, 2,…. n (set of natural numbers); when a ‘return vehicle’ driver who has been permanently entered into the system and the type of return vehicle (depending on the number of persons transported - drivers) has not been included in this variable;
- 100% efficiency of individual devices and equipment was used in the model (i.e. faults of handling equipment, of containers and vehicles unloaded, drivers’ accidents, etc., have not been simulated);
- During the simulation, the unloading ramps, gantry cranes, handling devices, number of disposable drivers and the distances were fixed.

To illustrate the use of the simulation tool for training of the logistics experts, a model was developed to find the answer to the question: *What is the optimal number of drivers (d) when it applies that the time required for vehicle exit will be shorter than or equal to the time required for unloading the container units, i.e.:*

$$t_d \leq t_c \tag{1}$$

where:

- t_d is the time required for exit of the vehicles from the ship, including parking and return of the drivers, using n drivers (see changeable variable d);
- t_c is the time required to unload the container units of a given task group (fixed in the model, it can also be used as a changeable variable under real conditions).

Achieving equality was considered to be only the theoretical ideal solution. An optimal solution in real conditions may be considered when the following conditions apply:

$$\text{for}\, d:\ t_d \leq t_c \tag{2}$$

$$\text{for}\, d-1:\ t_d > t_c \tag{3}$$

The total time of the ship anchoring in the port is in this case given by the time t_c, because the unloading and the outgoing takes place at the same time and by providing an additional driver, the optimum unloading time can be achieved. The optimum conditions for the simulation model outputs were as follows:

- The average unloading time of the container unit (using ISO 1C containers) by the crane to the handling means (container carrier) is 6 min; for non-standard container units the time is 120 min;
- The average transport period of the container unit to the lay-by area, including loading (part of the crane unloading) and unloading of the container unit, is 19 min;
- The unloading of 5 non-standard containers has priority in terms of the complexity of handling operations, but their unloading takes place simultaneously with the unloading of standard container units;
- The vehicle's exit time from the ship oscillates between 15 and 20 min, and the time of moving and parking is 30 min; part of the calculation contains also the time for the return of the drivers (10 min).

On the basis of the considered approaches to education and the necessary information inputs, a simulation model has been created. The object of the model was the display of inventory flows (container units) and military vehicles system, which in this case was represented by a port with a given handling technique. The model is applicable modularly, with the possibility of rapid expansion and modification according to the type and size of the task forces. The schematic presentation of the created model is shown in Fig. 1.

The output of the simulation model is a transparent overview of the whole process of the reception phase – unloading of container units and military equipment and

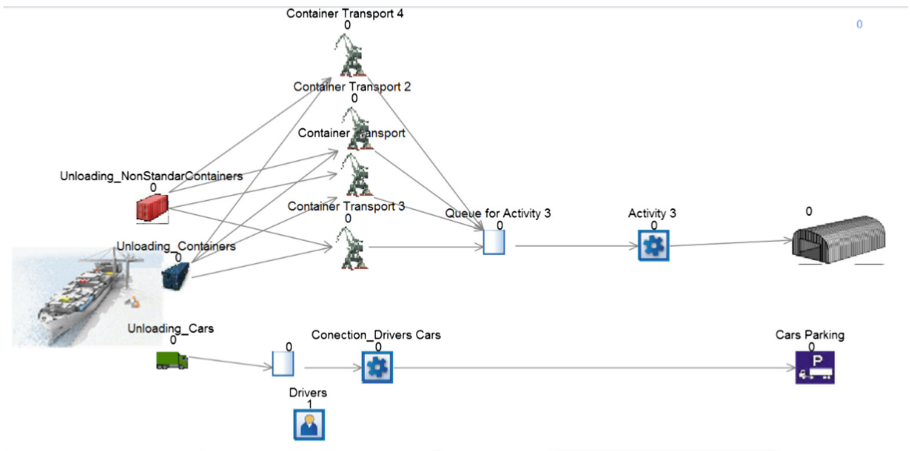

Fig. 1. Simulation model (SIMUL8) (Source: own)

providing standardization of the activities carried out. The benefit of the simulation model is determination of the maximum waiting ship time depending on the defined changeable variable – number of drivers. Created model can be easily modified by identifying other changeable variables, and observing differences in the output characteristics of the model.

5 Results and Discussion

The created model provides basic characteristics of the unloading process, the use of resources and their overall efficiency. When searching for the answer to the question of adjusting the optimal number of drivers, a range of 1 to 10 drivers was set at the beginning of testing (see the capacity possibilities of the movement control teams), number of replications was set on 10. In terms of the model optimization, following model outputs have been compared:

- The total time required to complete the unloading of all container units and all vehicles;
- The efficiency of the use of handling and transport means for unloading containers;
- The efficiency of using the capacity of drivers when unloading military vehicles.

In the case of testing the option of using 10 drivers, the simulation run ended at 895 min when all the vehicles were parked, but not all standard and non-standard container units were unloaded until 936 min. If only 1 driver was used, unloading of all container units took place at 936 min, while the exit of all vehicles by one driver terminated in 2061 min. The simulation outputs are shown in Table 1.

It is clear from the table that for the repetition of five simulation runs, the time needed to exit the vehicles (t_d) is longer than the time required for unloading container units (t_c) to the number of 4 drivers according to the model parameters. According to

Table 1. Model characteristics and outputs for different number of drivers (10 reps)

Number of drivers d [PAX]	Time (Container units) t_c [min.]	Time (Vehicles) t_d [min.]	Time (Total) t [min.]	Utilization of drivers [%]	Utilization of cranes [%]
1	936	2061	2061	79.63	26.98
2	936	1365	1365	89.49	40.75
3	936	1109	1109	91.80	50.13
4	**936**	**925**	**936**	**83.34**	**59.41**
5	936	899	936	75.75	59.41
6	936	902	936	64.17	59.41
7	936	897	936	59.75	59.41
8	936	898	936	53.56	59.41
9	936	896	936	50.44	59.41
10	936	895	936	47.39	59.41

Source: Own.

only one changeable variable (d), t_c is constant if the exit of vehicles from the RoRo ship is realized by at least 4 drivers. In real conditions this time would oscillate around a given value, which is simulated further using a random number generator. The optimal variant is the use of 4 drivers, in which all vehicles are unloaded at 925 min, i.e. the closest time to the time of unloading all container units. For the exit of military vehicles by four drivers, the two set conditions (2) and (3) are met.

Simulation model creates prerequisites for a quick analysis of the possible RSOM implementation scenarios and optimal use of available resources. These are both the efficiency of their use and also its possible blocking by other activities; see Fig. 2 Drivers' load and Fig. 3 Utilization of port logistics capacities.

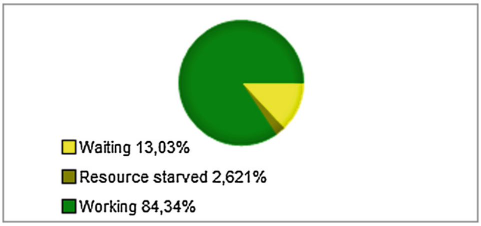

Fig. 2. Drivers' load (Source: own)

In addition to capacity load, it is also possible to monitor the use of available capacities over time and subsequently modify the deployment of other sources or the distribution of existing resources over time, see Figs. 4 and 5.

The outcome of the simulation was also a recommendation for risk analysis of the first phase of the RSOM process resulting from the distribution of time needed for

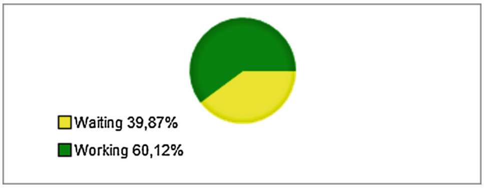

Fig. 3. Utilization of port logistics capacities (Source: own)

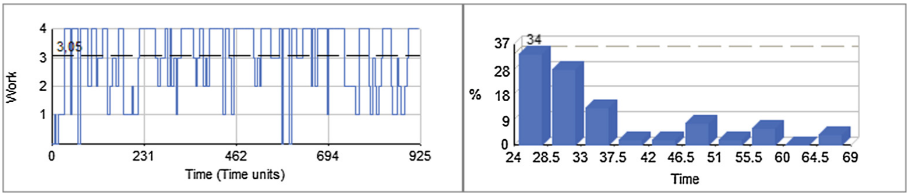

Fig. 4. Involvement of vehicle drivers during unloading (Source: own)

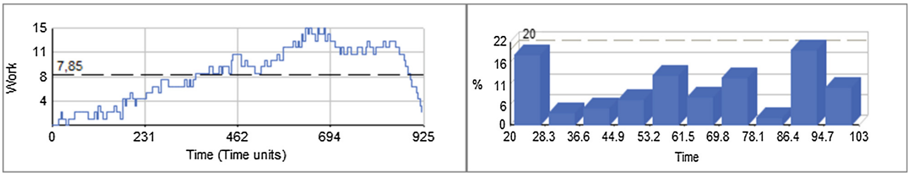

Fig. 5. Utilization of port logistics capacities during unloading (Source: own)

parking the vehicles, and the possibility of testing possible options such as technical failures in the port logistics or in exiting the vehicles, individual driver experience during unloading of vehicles and possible consequences of landing disturbance, for example due to safety regulations or adverse weather conditions.

In addition to these standard outputs of the Simul8 environment, it further enables logistics planners to financially evaluate individual simulated processes and optimize possible scenarios in terms of total costs. Similarly to financial analysis, it is possible to evaluate individual activities in terms of their environmental burden and analyze the environmental impacts of simulated activities (ecological footprint per individual entities and the whole simulated scenario).

6 Conclusions

The presented model created in the Simul8 environment demonstrates a possible complementary approach to the training of logistics staff of the armed forces for the preparation and implementation of the RSOM process. Accuracy of the model depends on the input data, i.e. for obtaining accurate results by a simulation model able to simulate a particular situation (scenario), it is appropriate to use specific data of the terminal, in this case the port. If average time periods of handling and transport operations are available, a very clear idea of the duration of the investigated activities can be obtained. This overview allows finding the optimal solution from the point of view of the set parameters and possibly determining other variables as changeable ones.

The main advantages of incorporating simulation tools into the process of logistics staff preparation for the implementation of the RSOM process can be summarized as follows:

- Insight into the problem and subsequent broad possibilities of logistics analysis of processes implemented within RSOM;
- Possibility of detailed analysis of specific scenarios, their fast modification according to specific ports and possibility of testing alternative solutions, including supply chain security and overall resilience;
- From the preparation point of view, logistics specialists may not have specific skills and knowledge of applied simulation and modelling, but it is appropriate to engage them in this issue for the future possible preparation of alternative scenarios and possibility of their modification on the basis of evolving exercise requirements;
- Variability of the created scenarios and implemented solutions makes it possible to analyze different types of ports and technologies used, including ports with autonomous unloading/loading systems.

The approach chosen is fully applicable to other areas of logistics support, including analysis and testing of logistics support implementation plans and testing the scenarios for technology and material life cycle management.

Acknowledgement. The paper was written with the support of the project of long-term strategy of organization development: ROZVOLOG: *Development of Capabilities and Sustainability of Logistics Support* (DZRO ROZVOLOG 2016–2020) funded by the Ministry of Defence of the Czech Republic.

Abbreviations and Acronyms

ACR	Army of the Czech Republic
ISO	International Organization for Standardization
NATO	North Atlantic Treaty Organization
POD	Port of Debarkation
Ro/Ro	Roll-on/Roll-off
RSOM	Reception, Staging and Onward Movement

References

1. Arvis, J.-F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., Raj, A., Naula, T.: Connecting to Compete 2014 - Trade Logistics in the Global Economy: The Logistics Performance Index and Its Indicators. The World Bank, Washington, 76 pp. (2014). https://goo.gl/Ddn1kM
2. Charbonneau-Gowdy, P., Čechová, I.: Blind alleys: capturing learner attention online and keeping it: the challenges of blended learning programs in Chile and the Czech Republic. In: Proceedings of the International Conference on e-Learning, ICEL, pp. 40–47. Academic Conferences Limited, Orlando (2017). ISSN 20488882, ISBN 978-191121835-7
3. Chrobáková, A., Foltin, P., Šikolová, M.: Possible approaches to classification of factors and criteria of transnational supply Chain elements. In: Sborník příspěvků z mezinárodní vědecké konference Region v rozvoji společnosti 2014, pp. 333–340 (2014). Mendelova univerzita v Brně, Brno (2014). ISBN 978-80-7509-139-0
4. EEAS 00787/12. EU Concept for Reception, Staging, Onward Movement and Integration (RSOI) for EU-led Military Operations, 26 pp. European Union Military Committee, Brussels (2012)
5. Foltin, P., Gontarczyk, M., Świderski, A., Zelkowski, J.: Evaluation model of the companies operating within logistic network. Arch. Transp. **32**(4), 21–34 (2015). ISSN 0866-9546
6. Gleditsch, N., Wallensteen, P., Eriksson, M., Sollenberg, M., Strand, H.: Armed conflict 1946-2001: a new dataset. J. Peace Res. **39**, 615–637 (2002). https://doi.org/10.1177/0022343302039005007. Oslo, p. 621. ISSN 00223433
7. Hauge, J.W., Paige, K.N.: Learning SIMUL8: The Complete Guide, 2nd edn. PlainVu Publishers, Bellingham (2004). 983 pp. ISBN 978-0-9709384-3-5
8. Rehak, D., Novotny, P.: Bases for modelling the impacts of the critical infrastructure failure. Chem. Eng. Trans. **53**, 91–96 (2016). https://doi.org/10.3303/cet1653016. ISBN 978-88-95608-44-0, ISSN 2283-9216
9. Rehak, D., Dvorak, J., Danihelka, P.: Algorithm of the process of military training activities environmental impact assessment: hazard & impact index. Ekológia Bratislava **30**(1), 110–121 (2011). https://doi.org/10.4149/ekol_2011_01_110. ISSN 1335-342X
10. Robinson, S.: Simulation: The Practice of Model Development and Use. Wiley, Chichester (2004). 339 pp. ISBN 0-470-84772-7
11. Sherman, N.: A Stochastic model for joint reception, staging, onward movement, and integration (JRSOI), MS thesis, 99 pp. Wright-Patterson Air Force Base, Air Force Institute of Technology (2003)
12. Vlkovský, M., Pochobradská, K., Foltin, P., Zajíček, V., Binar, T.: The cargo securing based on Euroean standards and its applicability in off-road transport conditions. In: ICTTE Belgrade 2016 - Proceedings of Third International Conference on Traffic and Transport Engineering, pp. 603–607. Scientific Research Center Ltd., Belgrade (2016). ISBN 978-86-916153-3-8
13. Urban, R., Oulehlová, A., Malachová, H.: Computer simulation - efficient tool of crisis management. In: International Conference Knowledge-Based Organization, pp. 135–141. "Nicolae Balcescu" Land Forces Academy, Sibiu (2017). ISSN 2451-3113
14. Vlkovský, M., Vlachová, H.: Cargo securing and accident rate in the army of the Czech Republic. In: The 23rd International Conference The Knowledge-Based Organization: Applied Technical Sciences and Advanced Military Technologies, pp. 148–154. Nicolae Balcescu Land Forces Academy Publishing House, Sibiu (2017). ISSN 1843-682X, ISBN 978-973-153-275-2

15. World Humanitarian Data and Trends 2014. OCHA: United Nations Office for the Coordination of Humanitarian Affairs. OCHA, New York (2014). https://goo.gl/DhX8mP. Accessed 31 Aug 2017
16. Yildirim, U.: A multi-modal discrete-event simulation model for military deployment, Doctoral thesis, Eskişehir, 150 pp. Bilkent University, p. III (2009)
17. Fucík, J., Melichar, J., Kolkus, J., Procházka, J.: Military technology evolution assessment under growing uncertainty and complexity: methodological framework for alternative futures. In: Proceedings of the 2017 International Conference on Military Technologies, University of Defence, Brno, pp. 682-689 (2017). ISBN 978-1-5386-1988-9