RESEARCH METHODS IN HUMANITARIAN LOGISTICS – CURRENT APPROACHES AND FUTURE TRENDS

Petr Tulach
Logio, s.r.o., Czech Republic
E-mail: tulach@logio.cz

Pavel Foltin
University of Defence in Brno, Faculty of Military Leadership, Department of Logistics, Czech Republic
E-mail: pavel.foltin@unob.cz

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Abstract

The article sums up contemporary use of operational research, modelling, and simulation (OR/MS) methods and approaches in the field of humanitarian and emergency logistic, based on the records in international research databases World of Science (WoS) and SCOPUS. In both databases were analysed more than 500 articles published in the period of 2014 until 2018. The keywords and content analysis with subsequent literary research was as a main research approach processed by the Python programming language Pandas Library. Main research goal was focused on the identification of the areas and methods used by the scientific community in the examination within humanitarian logistics, published in journals and proceedings indexed in WoS and SCOPUS databases. The stochastic optimization was identified as a most common methods used to solve humanitarian logistics tasks. The research results show that the use of simulation methods in the field of humanitarian logistics are marginal and these methods are not widespread. Further research into the use of dynamic simulations for humanitarian logistics has the potential to enrich scientific knowledge and contribute to the application of scientific methods to the practice of humanitarian logistics.

Key words: Humanitarian logistics, dynamic simulation, operation research, modelling and simulation, methods.

1. INTRODUCTION

Despite the development, humankind achieved in last 2000 year, we still have not even a limited control over natural powers, such as earthquakes, fires and floods. It is reported that an increasing number of disasters have led to overwhelming losses in recent years (Xiong, 2017). Higher density of population contributes to increasing

consequences of such disasters. As confirmed by Damon Coppola, there are following global trends in disasters (Coppola, 2011):

1. the number of people affected by disasters is rising;
2. disasters are becoming less deadly;
3. disasters are becoming more costly;
4. poor countries are disproportionately affected by disaster consequences;
5. the number of disasters is increasing each year.

During a crisis, high requirements on relief distribution appear, especially in the phase of first response (within 72 hours), when it is necessary to distribute urgent humanitarian aid. The recent large scale disasters and relief efforts (e.g. 2004 Asian tsunami, 2005 Pakistan earthquake, 2010 Haiti earthquake) highlight the need for improved logistics in the field (Huang, 2012). During the first three days, when significant uncertainty appear, distribution system is formed and set including setting necessary contracts and securing sustainability of such logistics system for previously determined time (Campbell, 2011). Based on the severity and impact of natural disasters, loss of life, health and property may occur. Simultaneously critical infrastructure of the region is usually damaged, including transportation and communication networks (Urban, 2017).

Capabilities for distribution are therefore substantially constrained and it is often necessary to secure alternative means of distribution usable at least until former means are restored. Because of complex nature of natural disasters, their potential impact and concurrent demand for securing distribution of humanitarian relief and provisions, it is important to study function of logistics system in conditions of high uncertainty and variability (Senovsky, 2013).

2. LOGISTICS IN COMMERCIAL AND HUMANITARIAN FIELD

In terms of the globalization of distribution chains, the civilian sector has long faced potential disruption risks (Senovsky, 2013). The Business Continuity Institute (BCI) studies are available for long-term analysis of the causes and impacts of disruption of distribution chains in terms of scale, impact and losses (Alcantara, 2017). By comparing the available studies in 2011 and 2018, it is possible to identify a shift in the perception of the main sources of disruption to distribution chains. In 2011, natural disasters were the main cause of the disruption of logistics chains, in 2018 this was an unplanned disruption to the communication and information systems functionality (BCI, 2018).

Logistics and disasters are entangled in two ways. First is the impact of disasters on logistics infrastructure. Second lies in the fact, that logistics is important part of all operations that are related to humanitarian aid. As Kunz stated: „*From this perspective, disaster management and relief aid require complex logistical activities, as the resources they need are rarely available at the location of the disaster*“ (Kunz, 2014).

The urgency of humanitarian relief distribution is also highlighted in the Council of Supply Chain Management Professionals (CSCMP) definition of logistics as: *the*

process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements (Council of Supply Chain Management Professionals, 2013). Similarly definition from Thomas a Mizushima define humanitarian logistics as the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from point of consumption for the purpose of meeting the end beneficiary's requirements "(Thomas, 2005). Both definitions are virtually identical.

From this perspective, disaster management and relief aid require complex logistical activities, as the resources they need are rarely available at the location of the disaster or in close surroundings (Zajíček, 2015). These logistical activities are generally referred as humanitarian logistics (Kunz, 2014), and for both forms of disasters with natural and/or man-made disasters sources, with slow or fast onset, as depicted in table 1.

Table 1. Examples of disaster forms.

	Natural	man-made
sudden-onset	earthquake hurricane tornadoes	terrorist attack coup d´Etat chemical leak
slow-onset	famine drought poverty	political crisis refugee crisis

Source: Wassenhove-Van, 2006

From the point of view of logistical support, the methods and approaches of business logistics are becoming more prominent in humanitarian logistics (Foltin, 2015). The primary reason for this is to speed up the process of distributing humanitarian aid, while at the same time trying to optimize overall logistical costs.

As concerns the application of civil approaches in humanitarian logistics, in 2017, Gavidia introduces the Enterprise Resource planning (ERP) model for Humanitarian Supply Chain Management (SCM) (Gavidia, 2017), while in 2009 Huifen describes the rapid implementation of the ERP system in the Sichuan earthquake (Huifen, 2009). In the commercial sector, the OR/MS methods are usually applied only when they are converted into easy-to-use software that can be used after appropriate training.

Even now, the expansion of decision support systems in commercial applications is relatively lower, but is considered one of the key technological challenges of the past 5 years (Panneta, 2018). Even the current wave of mobile applications often uses rather complicated mathematical procedures, but these are hidden from the end user and the device or application "just works". Simulation has the potential to become a similar application.

3. CURRENT STATE OF RESEARCH METHODS IN HUMANITARIAN LOGISTICS

Humanitarian and business logistics setting aside some specifics can benefit from the same methods and approaches, which is implied in the definition of humanitarian as well as logistics in general, which are very similar.

Implications arising are that researchers have studied more immediate responses than preparation and/or prevention events, and that preparation and prevention activities, which include a supply chain perspective, have been neglected by the relevant authorities due to the fact that there are few studies which analyse preventive actions to deal with such disasters (Coppola, 2011).

Using operational research methods that seek to find the most appropriate solution, the question arises of how to evaluate whether the solution found is the most appropriate or available solution to compare. In commercial terms, the maximization of profit is usually the evaluation criterion. In humanitarian logistics, this scale cannot be easily applied (Fikar, 2016). It is necessary to ensure that humanitarian aid is fairly distributed so as to minimize the impact on the disabled. All this while deploying resources that are not sufficient. The specificities of humanitarian logistics are the main reason why methods and procedures from commercial logistics cannot be automatically adopted without further investigation.

Supply chain design and processes management takes into account specifics humanitarian logistics, especially donor issues, last mile problems. There are two distinguished approaches in specific humanitarian logistics information systems development. These are specific software tools for humanitarian operations, e.g., SUMA, LSS, UniTrack, Helios, LogistiX or Sahana. On the other hand, there are in practical use commercial software solutions, e.g., Orion-PI, Enterprise One, mySAP SCM (Blecken, 2008).

Literature revise are an essential part of all kinds of research, especially as concerns the content and frequency analysis (Kotzab, 2005). While in the social sciences and humanities a large number of disaster management articles are represented, less attention is paid to this issue in the field of operational research (Altay, 2006). The use of advanced analytical tools in humanitarian operations can be seen as an important tool to optimize the use of scarce resources in crisis conditions, i.e. with uncertainty and uncertainty. While in the social sciences and the humanities there is an abundance of disaster management articles, the operational research community has yet to create a critical mass of publications (Altay, 2006). However, as noted Van Wassenh, approximately 15 years of delay in the use of advanced logistics analysis tools for humanitarian organizations can be identified, as opposed to the approaches used by the private sector who realized the importance of using efficient supply chains, particularly due to given increasing opportunities to “go global” (Wassenhove-Van, 2006).

As early as 2006, Van Wassenhove set out possible directions in which operational research can contribute his expertise and transfer knowledge to the field of humanitarian logistics. This is mainly deals with (Wassenhove-Van, 2006):

- supply chain design and management (donor issues, last mile supply issues, mutual transfer of experience between the private sector, military and humanitarian organizations);
- system and technology (disaster management information systems, knowledge management);
- project management;
- risk management;
- coordination and strategic alliances;
- performance management;
- standardization of processes (e.g., Total Quality Management, Six Sigma, training).

The authors of follow-up studies and monographs often criticize, the focus of published articles, such as Coppola, states that researchers focus more on the issue of immediate response than on preparatory and preventive activities (Coppola, 2011). Chiappet et al. in their analysis of literature between 2007 and 2016 report that most of the articles included in the study were theoretical and as a consequence rarely touched on a particular disaster, its type, the humanitarian aid phase and the type of humanitarian organization (Chiappetta Jabbour, 2017).

There are many areas where OR academics can offer their expertise and transfer their knowledge to have a positive impact. On one hand, simulations are used to train-practice surgical procedures but are limited in practice to support disaster decision making. On the other hand, several approaches appear, e.g. scenario-based two-stage stochastic programming (Alem, 2016). These conditions and wider circumstances leads authors for formulate the one working hypothesis, which is as follows:

Hypothesis:

H: Methods of OR/MS and DES are explored in humanitarian logistics significantly frequently.

Analysis is focused to the difficulty to grasp conceptual models, without practical implications, as it is discussed in final part the article.

Based on the literature research and declaration of methodological approach, next part of the article is focused to find out whether there is visible change in trend over the past five years and what operational research methods are being focused and published.

4. KEYWORDS ANALYSIS

The analytical effort is laid to identify and review articles, their focus on the description of theoretical approaches, and their possible relation to other aspects of disaster, phases of disaster relief, type of humanitarian organization and/or humanitarian logistics and relief distribution. In order to find out which methods for dealing with humanitarian logistics are being investigated and what problems are being addressed in the research of reviewed articles, an analysis of the occurrence of

keywords was conducted on a sample of articles available in the international SCOPUS scientific work database and World of Science (WoS) database. For analysis purposes, articles containing the keyword "*humanitarian logistics*" or topics for WoS were selected and the selection was limited to 2014 to 2018.

When searching in SCOPUS, more than 500 articles are searched for logistics and simulation, while after adding a humanitarian keyword, the number of articles decreases to just 9. A similar situation is in software in general.

A database of individual keywords was processed from the keywords using the Python programming language Pandas library. Identified text strings have been cleared of invisible characters. The source code for the transformation is shown in Figure 1.

Figure 1. Source code of keyword transformation from export from SCOPUS database.

```
import pandas as pd
scopus = pd.read_csv("scopus (6).csv")
scopus['Author Keywords'] = scopus['Author Keywords'].astype('str')
scopus['Author Keywords'] = scopus['Author Keywords'].str.split(';').tolist()
keywords = scopus['Author Keywords'].sum()
kw = pd.DataFrame({'keyword':keywords})
kw['keyword'] = kw['keyword'].str.strip()

kw.to_excel('keywords.xlsx')
```

Source: Authors' analysis

Based on the use of keywords in SCOPUS, 378 relevant articles were identified, 1807 keywords were further analysed. From the WoS database was possible to retrieve 820 records, with 1977 unique keywords. For the purpose of our analysis only author keywords were selected, as World of Science Keyword plus are usually only one-word keywords and preliminary results were incomparable to SCOPUS keywords.

Subsequently, the frequency of occurrence of keywords was determined and categorized. Keywords were divided into three groups according to their meaning, as follows:

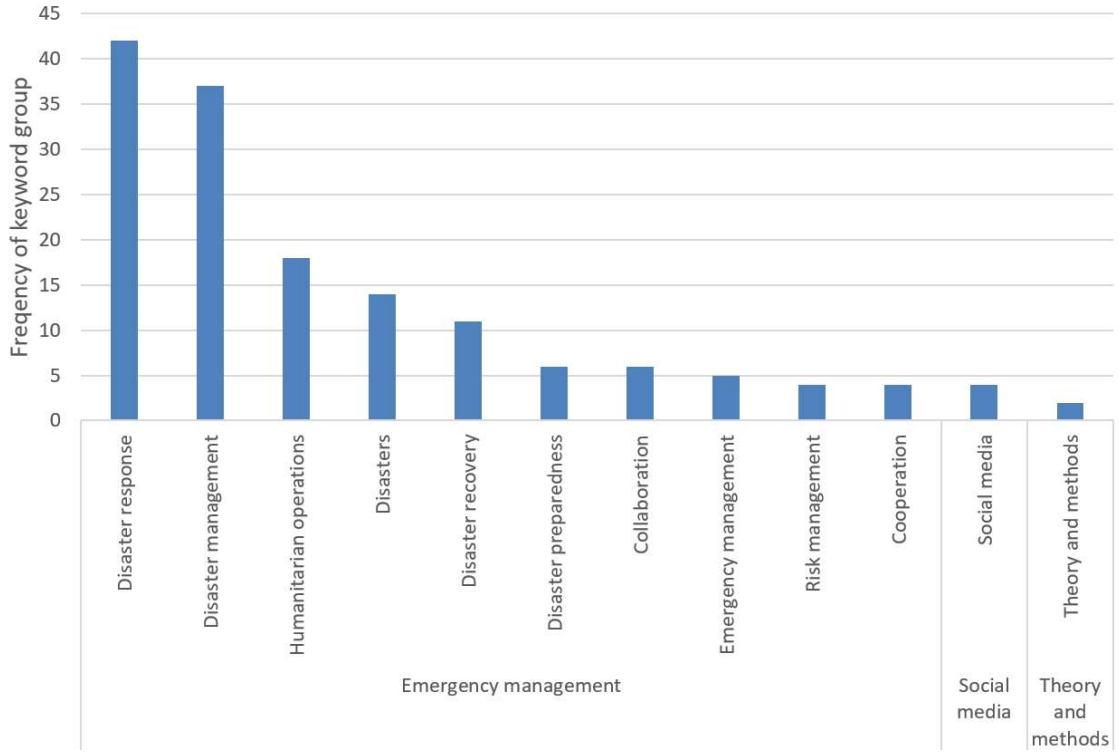
- research area;
- methods;
- tasks.

In these groups, the keywords identified were categorized and grouped for further analysis.

Research Area

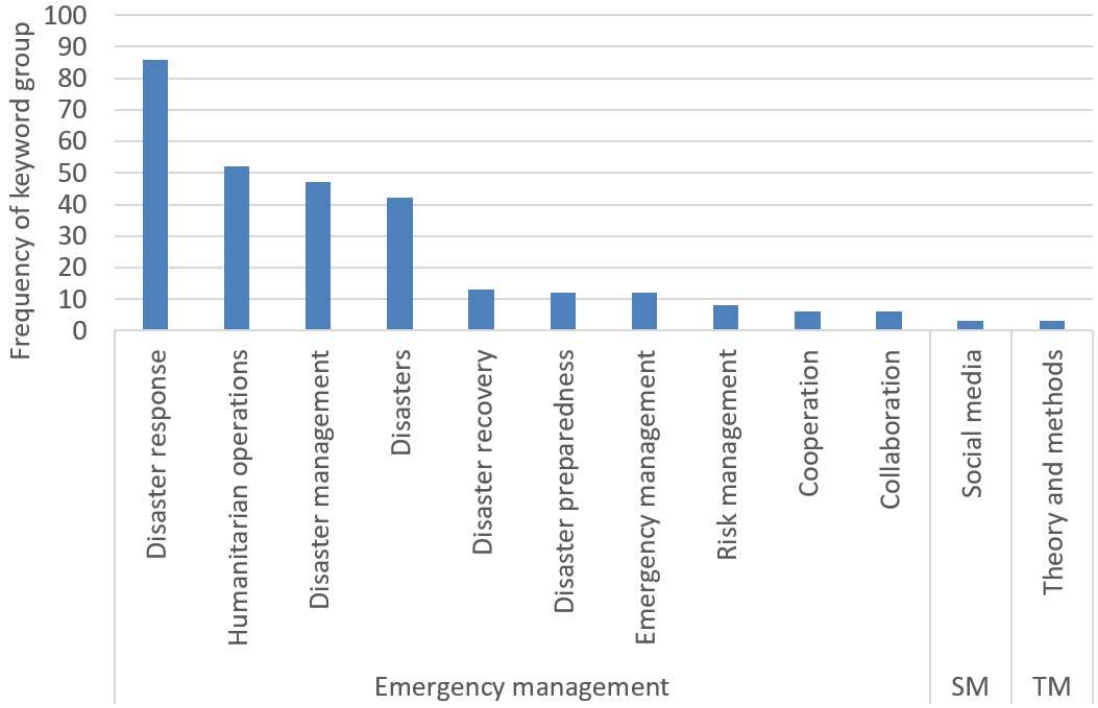
Two levels of categories were selected in the "Research Area" group. The categorization has made it possible to clarify the described research area, and to remove the found duplicate keywords identifying the same research areas. The resulting frequencies for the categories are shown in Figure 2.

Figure 2. Key words frequency in humanitarian logistics research SCOPUS



Source: Authors' analysis.

Figure 3. Key words frequency in humanitarian logistics research WoS



Source: Authors' analysis

Research areas show that there is still a strong focus on disaster response methods. The "Disaster response" category is most common. The "Disaster

Management" category contains only the word "Disaster Management", which is considered synonymous with "Emergency Management". It is therefore a general term that logically relates to the field of humanitarian logistics.

Disregarding the general keywords, it was possible to rank the various phases of crisis management as follows:

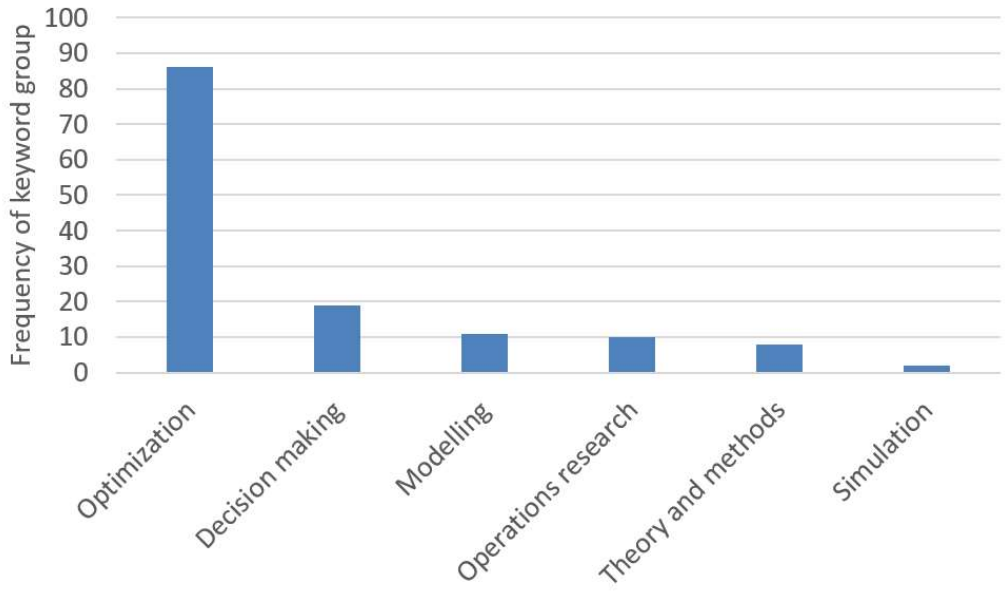
- disaster response (i.e. a response to a crisis event);
- disaster recovery (i.e. recovery after a crisis event);
- disaster preparedness (i.e. preparing for a crisis event).

Ranking of keyword groups is similar in both SCOPUS and WoS databases. The "disaster prevention" area does not fall into the field of humanitarian logistics and therefore this phase does not appear in the keyword survey.

Methods Examined

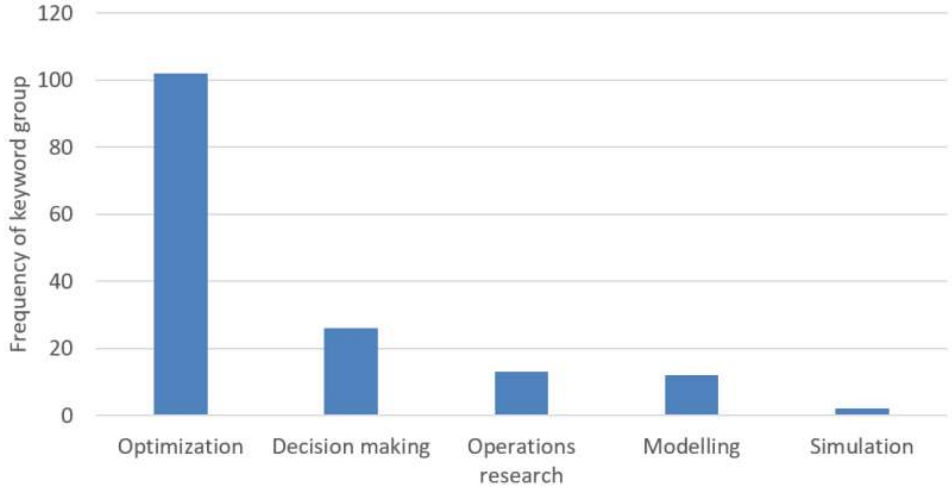
In the field of applied methods, the division into two levels was performed. Figure 4 shows the first level distribution of method's groups found in SCOPUS, which refers to the most commonly reported method, namely "optimization". The frequency of other methods is considerably lower, i.e. optimization methods are significantly prevalent. The simulation approach is examined only marginally and in all cases it is sort of "agent simulation".

Figure 4. Key words frequency – used research methods SCOPUS.



Source: Authors' analysis

Figure 5. Key words frequency – used research methods WoS.



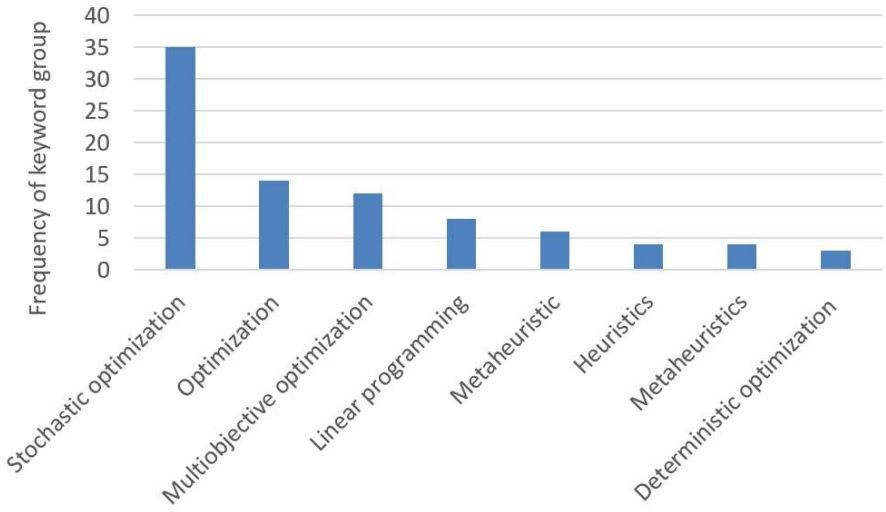
Source: Authors' analysis

As can be seen on both figure 4 and figure 5 the frequencies and ranking of keyword groups in this case are also similar with different ranking of simulation which has higher ranking in SCOPUS than in WoS database.

In the second level of classification, there is a significant division of the optimization methods shown in Figure 6. In the group of optimization methods, the most significant part was identified as stochastic optimization, e.g., stochastic programming. The occurrence of a generic term optimization can be explained by the fact that keywords often include both general and detailed differentiation of the methods used.

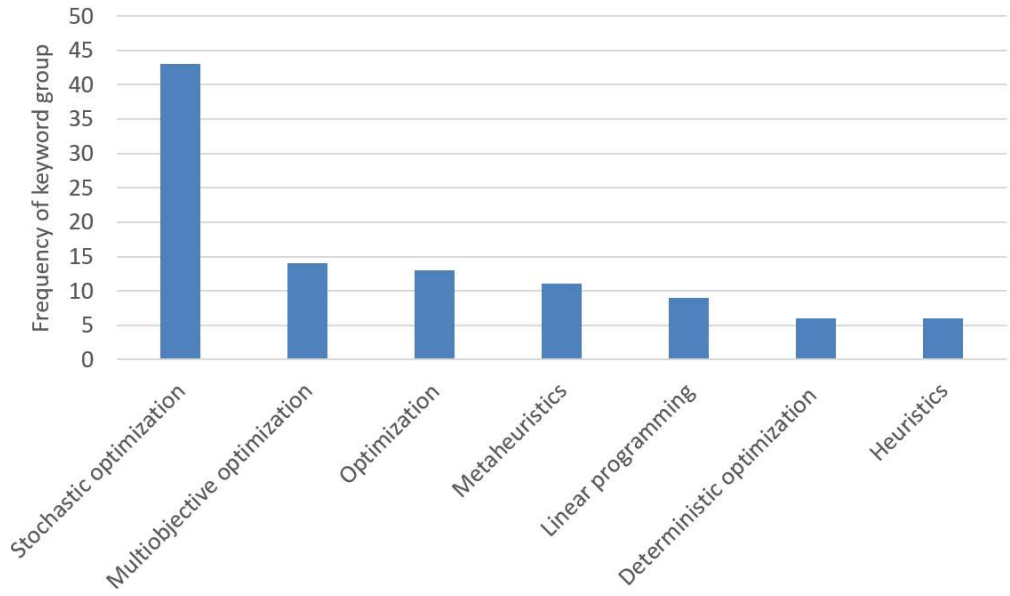
Similar distribution of frequency among the optimization methods was found in WoS database keywords. The differences in being the ranking of generic term "optimization and the ranking of the long-tail of less common keywords like Linear programming, Heuristics, Metaheuristics and Deterministic optimization.

Figure 6. Key words frequency – detailed view of types of optimization methods SCOPUS



Source: Authors' analysis

Figure 7. Key words frequency – detailed view of types of optimization methods WoS



Source: Authors' analysis

Greater attention is paid to stochastic optimization methods in 2014-2018, as practice points to the appropriateness of using deterministic optimization methods to solve random input problems. The main reason is the possibility of simplifying the problem, which is often at the expense of accuracy and precision. Nevertheless, linear programming methods (i.e., deterministic) are examined and presented relatively frequently in the articles published in both Scopus and WoS database.

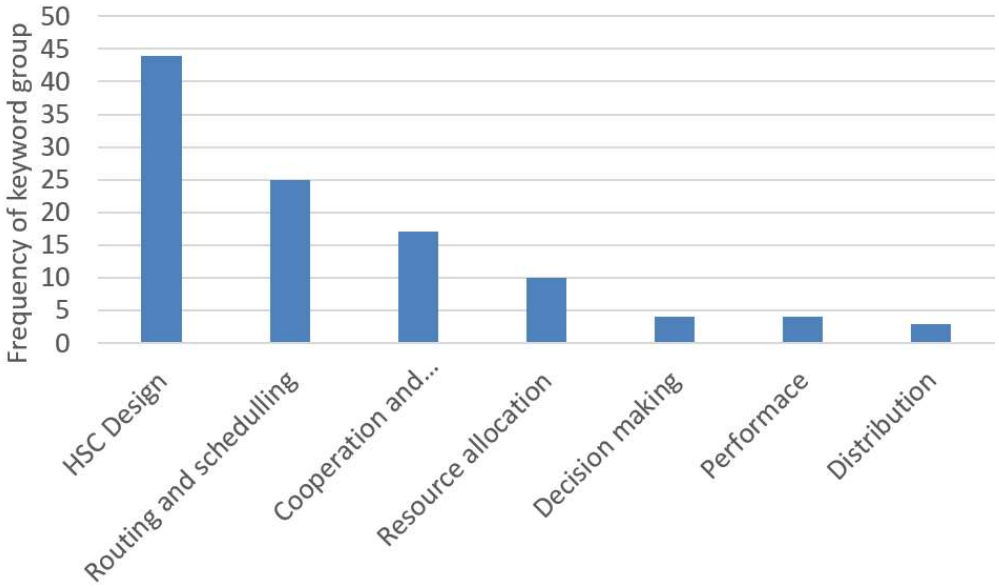
Humanitarian Logistics Tasks

In the group of humanitarian logistics tasks depicted in Figure 8 and 9, there are important tasks related to the design of humanitarian supply chains (HSC), i.e., "HSC design". It is a relatively broad category including the placement of temporary shelters, the management and allocation of stocks and the location of their warehouses. At first glance, it is surprising that this category prevails. It appears to be in direct contradiction to the low frequency of "Disaster preparedness" mentioned in Chapter 3.1. The explanation is hidden in detail when a significant portion of the keywords in this category deal with the operational deployment of resources in a disaster situation.

The second important part is the "Routing and scheduling" category, which includes the different types of delivery problem (e.g. Vehicle Routiong Problem - VRP), which is related to the distribution of humanitarian aid in the affected area. The second part is the task of scheduling work for humanitarian workers.

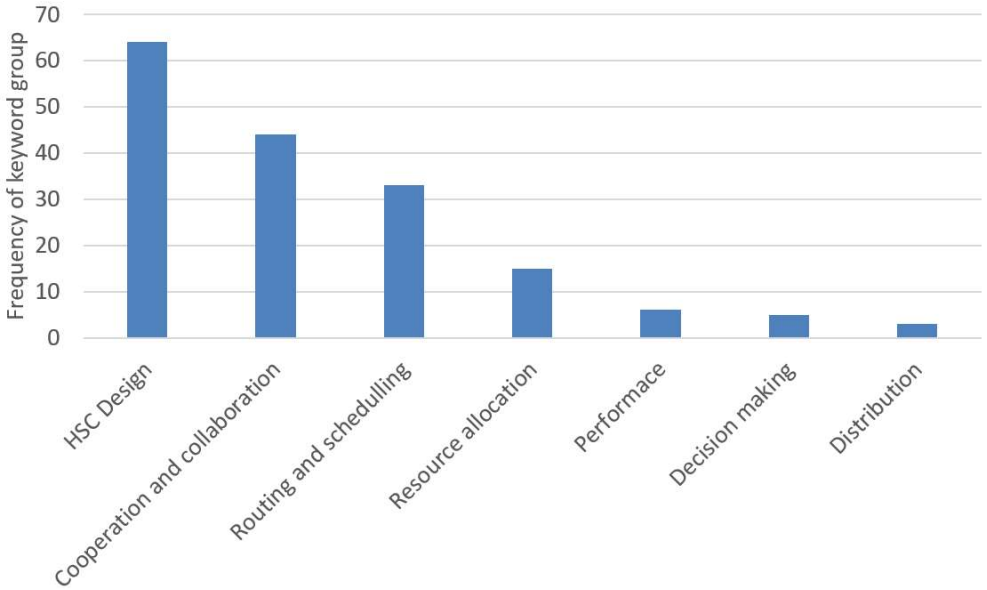
Cooperation and collaboration category is covered more in WoS database and this is both in absolute as well as relative numbers.

Figure 8. Solved tasks in humanitarian logistics – key words frequency SCOPUS.



Source: Authors' analysis

Figure 9. Solved tasks in humanitarian logistics – key words frequency WoS.



Source: Authors' analysis

4. APPLICATION OF OPERATIONAL RESEARCH METHODS TO PRACTICE

In the commercial sector, the OR/MS methods are applied only when they are converted into easy-to-use software that can be used after appropriate training. ERP systems are now widespread in the commercial sector. When applying advanced methods of operational research (OR/MS methods), it is the basis on which to build

and integrate other software that uses advanced data processing methods that are recorded in ERP systems.

User-friendliness and productivity are a prerequisite for extending OR/MS methods. An example is the expansion of mobile applications, many of which use advanced methods and algorithms. Their use would not be possible without the complexity of the solution being hidden from the user, and the program enabled user-friendly applications and uses.

There are other complications in the field of humanitarian logistics, which may limit the extension of modern methods. For example:

- limited communication options (unavailable internet connection);
- obsolete hardware;
- unavailability of electricity.

In the field of humanitarian supply chain management, logistics management systems have begun to emerge since 1992 (Blecken, 2013):

- SUMA later LSS developed in 1992 by Pan American Health Organization;
- the Helios system, developed in 2001 at the Fritz Institute;
- LogistiX system used by the MSF since 2006;
- Sahana system developed by Sahana foundation in 2004.

The use of commercial ERP systems is not excluded either. E.g. Huifen describes the rapid implementation of the ERP system in the 2009 Sichuan earthquake (Gavidia, 2017). The basis for applying advanced methods to practice is therefore available and it is possible to work on the application of theoretical knowledge, methods and models in the field of humanitarian logistics.

5. DISCUSSION

The analysis showed that the trends in the scientific research of humanitarian logistics have not changed much. Coppla's conclusions in 2011 confirm the focus on the immediate response and neglect of the planning phase. The current state of research is focused on the transfer of know-how in the field of optimization methods. The focus is on methods that take into account the stochasticity of modelled processes, which is very important in the field of humanitarian logistics.

Dynamic simulation is a method that is examined only marginally. It is possible to formulate the question to what extent this fact is related to the focus on immediate reaction, where until recently the longer time for creation and higher computational complexity of simulation models did not allow to use dynamic simulations to support real-time decision making. Recently, there has been a shift trend in simulation conferences to support immediate decision-making, whether through the rapid verification of decisions, or by using a combination of heuristics and simulation (called sim-heuristics). Still, in the area of humanitarian logistics, the potential of better planning and testing of practices that cannot be verified in the real world remains to be exploited. Humanitarian disasters are inherently times when there is no time and space to test new approaches. The simulation methods give us the

opportunity to test the news in advance in a computerized environment and enter into more crises with better preparation.

For further and more detailed research, it would be appropriate to extend the research to other sources, both academic and practical. It is hard to imagine that humanitarian organizations do not improve their functioning on the basis of knowledge acquired in disaster management. Humanitarian Logistics Management Systems show that humanitarian organizations are not waiting for the benefits of scientific research, but are forced to implement solutions that may not be optimal but bring immediate effects, or eliminate the significant weaknesses identified in the past crisis.

Based on the analysis outputs, both for Scopus and WoS databases, is possible to state, that working hypothesis is not confirmed. Outputs of the analysis of both databases presents lower frequency in use of OR/MS and discrete event simulation (DES) in the field of humanitarian logistics, in comparison of the other analytical approaches to support decision making and analytical approaches in humanitarian logistics optimization.

6. CONCLUSION

The concept of humanitarian logistics is one of the key aspects of reducing the negative impacts of crisis events. A key aspect of humanitarian logistics is the rapid distribution of material supplies and humanitarian aid in the first 72 hours, immediately after the crisis. Advanced analytical approaches and tools commonly used in civilian supply chain conditions can be used to design and manage the system for the subsequent distribution of humanitarian aid.

In the framework of the realized research, the analysis of key words and subsequent literary research was carried out with the aim to find out what tasks in what areas and by what methods are examined by the scientific community. Based on the analysis of articles available in the international Scopus database, the focus of the current professional community has been identified primarily to support decision-making, in the immediate disaster response phase. The most common methods used to solve humanitarian logistics tasks are optimization, especially stochastic optimization.

Another of the objectives of the research was to identify how and to what extent dynamic discrete simulation is used. The results show that the use of simulation methods in the field of humanitarian logistics is marginal and these methods are not widespread. At the same time, the areas in which dynamic simulation has the potential to contribute to solving tasks (i.e. designing, planning and validating new processes) are only marginally studied in the literature. Research into the use of dynamic simulations for humanitarian logistics has the potential to enrich scientific knowledge and contribute to the application of scientific methods to the practice of humanitarian logistics.

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