

## MODELLING AND SIMULATION IN THE ENVIRONMENT OF LOGISTICS OF HUMANITARIAN OPERATIONS

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### *Abstract*

The article deals with the use of modelling and simulation as a tool for planning humanitarian operations. The aim of the article is to outline the possibilities of using simulation for the need of humanitarian logistics in the context of a fiction scenario. The model situation is the state in which the distribution of humanitarian aid, more precisely the flood situation in the Czech Republic, is planned. The introductory part of the article focuses on a brief introduction to the general problems of both humanitarian logistics and modeling and simulation. Subsequently, this model situation is presented with an example of the simulation model creation process. The conclusion of the article summarizes the lessons learned about the use of simulation for this crisis situation, together with the generalization of results for wider use in humanitarian logistics.

**Key words:** Humanitarian logistics, modelling, simulation, distribution, complex processes

### **1. INTRODUCTION**

Humanitarian logistics is a specific logistics part. Its main task, which at the same time distinguishes it from commercial logistics, is to ensure the timely delivery of humanitarian aid to sites affected by natural or man-made disasters or to places affected by war (Kovacs, 2007). However, a number of challenges and obstacles arise during this clearly defined task that make it difficult for the arrangement of humanitarian aid. In addition, some of them cannot be predicted in advance at all or only with a certain degree of probability. Ultimately, these phenomena can completely or at least partially alter the execution of a scheduled operation and affect its outcome. Given that this results in ensuring the health and safety of the population, the risks that could affect the humanitarian operation must be minimized.

Like management in the business sector, the logistics management of humanitarian aid organizations is struggling with the issue how to plan all sub-processes to ensure the smooth running of any logistics operations.

One of the possibilities how to check the feasibility of the set plan, check its weak and strong points and the optimal amount of resources involved is modeling the problem and then simulating this model.

## **2. LITERATURE REVIEW**

The solving of the humanitarian crisis has become very important topic and is receiving increasing attention. The reason to it is the increasing frequency of the natural or man-made disasters, such as hurricanes, floods, earthquakes or even nuclear disaster like the one in Japan in 2011 caused by the massive earthquake and tsunami. Also, these disasters have increasing impact on the material damages and people's lives. Considering the usage of modeling and simulation in this topic, several different models have been developed for relief supply chain in response to particular disasters. Bravata et al. (2006) modeled regional and local supply chain for antibiotics and medicinal supplies to estimate the mortality when anthrax bioterrorism occurs. Hupert (2002) created the model for several level of disease prevalence bioterrorism response scenarios.

Kovacs and Spens (2007) present a thorough review of the literature available. They focused on understanding and describing the specific characteristics of humanitarian logistics in disaster relief and show parallels between humanitarian and business logistics. Cozzolino (2012) brings a detailed review of the current state of knowledge and understanding of humanitarian logistic consisting the humanitarian logistics and supply chain management, the stages of that operation such as preparation, response, mitigation and reconstruction. They underline the importance of the intense cooperation among all players involved in the humanitarian operation.

We could continue with the list of already published literature or studies, but this paper aims much more to the simulation and modeling methodology in order to present what steps are very important in order to prepare appropriate model with transparency and understandable outputs.

## **3. MODELING AND SIMULATION**

### **3.1. Modeling**

Modeling is a method that allows a user to create a simplified idea of a particular object or phenomenon in the real world (Robinson, 2011). Models exist in different forms. For example, models of transport such as trains, cars or airplanes; cartographic models creating different map bases; models of medieval cities; human body models and countless others.

All these examples represent a more or less plausible copy of their real foundations. However, none of them can fully capture the real image of their form.

This would not even be desirable. Train simulation loses its original weight and other characteristics that are essential to real train operation, while at the very least it would be impractical in a rail model. The model depicting the appearance of the city when it is founded does not aim to capture all the houses, wells or trees in their original locations. Its essence is to allow the observer to create a coherent picture of how the city might have looked, what was its fortification, or how large a castle it was.

So the essence of the model is abstraction. Abstraction creators in terms of scientific exploration and complex systems make it possible to avoid endless work with information, data and model details that would not yield anything fundamental. The observer of the model makes it easier to concentrate, so he can focus on a substantial part of the problem and work with it.

As far as complex systems are concerned, it is necessary to pay attention not only to the part where the model is created but also to its subsequent analysis. It should bring new discoveries - for example in the form of confirmation or refutation of a certain hypothesis or finding a new approach to solving a particular issue. While simple models can be deduced from mere observation, complex systems, including humanitarian logistics processes, can be more effectively investigated through computer simulation.

### **3.2. Simulation**

Simulation is a method of dealing with probabilistic dynamic systems that is studied through experiments in a computer model. With it, it is possible to predict system behaviour when changing internal or external conditions, as well as optimizing the processes according to specified criteria, such as profit, cost or reliability. The result of the simulation is not the exact value but only the parameter estimate. Simulation can also explore different alternatives to system changes, validate their impacts, and choose the solution that best suits your situation.

Due to these characteristics, computer simulation is often used to analyze business processes such as supply, production, or distribution.

As far as the creation of the simulation project is concerned, it can be divided into several consecutive basic phases, which are (Dlouhý, 2007):

- identifying the problem and setting goals;
- creating a conceptual model;
- data collection;
- creating a simulation model;
- model verification and validation;
- conducting experiments and analyzing results;
- model documentation;
- implementation.

The main advantages of the simulation are that (IT Release, 2019):

- allows you to work with relatively complex systems that cannot be processed by simple analytical methods;
- is less time-consuming and expensive than real-world experiments;
- some simulation programs allow animation of the system to illustrate its operation.

However, the simulation cannot be understood as a method that would solve all problems for the processor. It is merely a tool to support him in successfully solving the problem, and the responsibility for its optimal use lies with him. In modeling, it must take into account some of the disadvantages of computer simulation, which include, in particular, that (IT release, 2019):

- requires the purchase of software in the form of a simulation program, or the project of the company involved in the activity;
- studying the program is time consuming;
- the result of the simulation is not a specific value for selecting the optimum but estimating the parameter;
- interpretation of results may not always be unambiguous.

#### **4. HUMANITARIAN LOGISTICS PROCESSES**

In the context of humanitarian logistics, aid can be divided according to the moment of the crisis. During and after the disaster, the aid phases are distinguished as follows (MZV ČR, 2010):

- Immediate assistance, which applies to the first days to weeks after the disaster, and includes, in particular, elementary aid to save lives (paramedics, paramedics and medical supplies) and the primary support of survivors (food, water, emergency shelter, generators, emergency sanitation). Depending on the scale of the crisis and the functionality of the authorities of the affected country, civilian and possibly military crisis management structures are in place at this stage.

- Next one is the phase of early rehabilitation, a period of about 2 weeks - 3 months after the disaster. In particular, it covers the care of displaced persons as a result of a disaster (shelter, food, water, health and psychosocial care) and the pursuit of rapid recovery of elementary infrastructure.

- Renewal (and development) phases are under way, generally within two years of the disaster, in the context of humanitarian aid. Includes comprehensive recovery in affected areas.

In addition to timing, humanitarian logistics can be divided from the point of view of providing assistance. Specifically, we distinguish domestic and foreign operations. Domestic humanitarian logistics mainly includes transport or storage of humanitarian material such as food, medicines, medical equipment, tents, temporary shelter material, etc. The humanitarian material is mostly the distributed within the IRS - for example by the Fire Rescue Service, the State Material Reserves Administration and the Czech Army. Republic. Private actors in the form of logistics companies, retail chains and others can also be involved in the humanitarian aid process.

Foreign aid is even more challenging. Operations take place in places that are often not easily accessible, and in addition, their infrastructure does not provide a wide choice of alternatives to find the best way to help. For example, there are missing material storage facilities or other equipment to facilitate on-site work (Weberová, 2013).

## 5. ENGAGING SIMULATION IN THE PROCESS OF ORGANIZING HUMANITARIAN AID

Engaging modeling with simulation is possible at virtually all stages of humanitarian aid, both at home and abroad. Above all, it is a suitable method for planning processes with a high occurrence of quantities that are random phenomena. They cannot be described by a simple mathematical function and their results can be simply calculated. This results in the advantage of simulation especially in the immediate help phase. However, simulation alone does not provide process optimization, but rather creates some support for decision-making in specific situations.

### 5.1. The main issue and goal of its solution

As an example of involving modeling and simulation, one can imagine a crisis situation in the form of floods in the Czech Republic. Specifically, the flood in a part of the Olomouc region, see Figure 1. In such a situation, the main objective is to ensure the safety of people in the affected area as quickly as possible. This most often means their evacuation and subsequent material security. More specifically, it is about finding the most appropriate range of resources involved to deliver a specific volume of humanitarian material.

**Figure 1.** Floods in part of Olomouc region



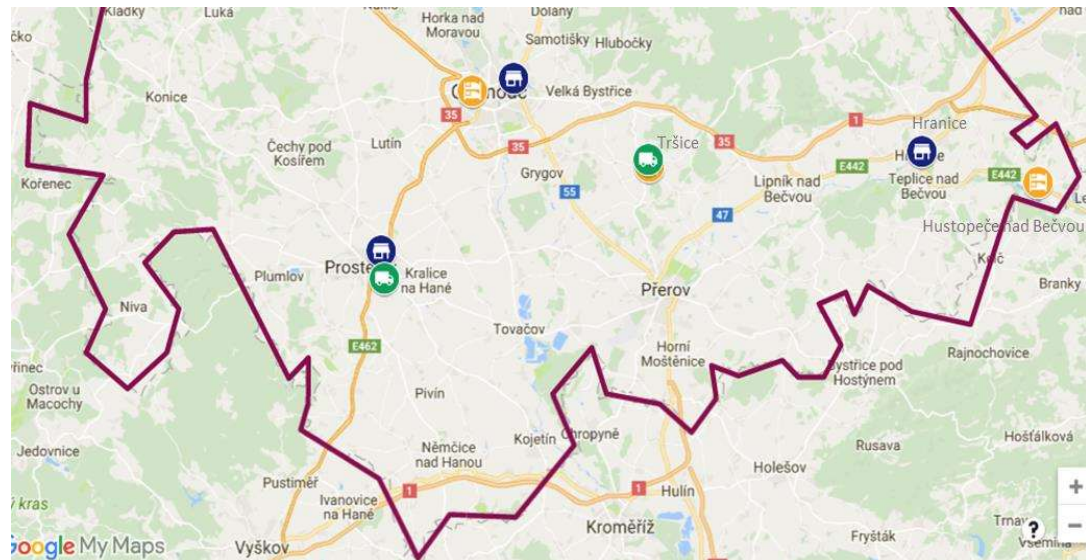
Source: HF Biz (2019). Povodňový plán Olomouckého kraje

### 5.2. Conceptual model

When creating the model, it is necessary to know the places for evacuation in the event of floods and their capacity, the places from which the material will be distributed, as well as the stations of the Fire Rescue Service (FRS) and, where appropriate, the location of private logistics companies, which will enter and transport the material to the destination. In summary, these locations can be called model

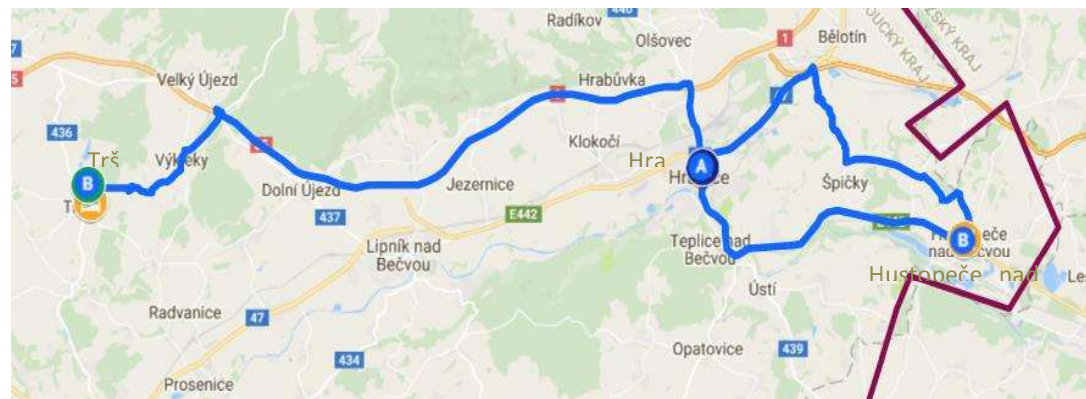
elements. For the sake of clarity, it is appropriate to record these elements in a map background similarly to Figure 2 together with the route plan between them, see Figure 3.

**Figure 2.** Elements on the map background (car - fire station; shop - material store; beds - evacuation center)



Source: Vogal (2017). Distribution of material stock in regions affected by natural disaster

**Figure 3.** Example of elements connection



Source: Vogal (2017). Distribution of material stock in regions affected by natural disaster

### 5.3. Data collection

The above information is sufficient to create a conceptual model, i.e. to create a general overview of the problem and its possible solution. A simple view of the conceptual model is shown in Figure 4. For further processing, it is necessary to collect more detailed data on the individual elements and then to base them on, i.e. to modify the model to a form suitable for simulation.

The quality of the model and its capability to describe the real system as much as possible depends on the quality of available information about all elements included in the system. It consists not just the information about existing infrastructure

and the real environment as the background where the humanitarian crises occurs, but the most important information about the probable behaviour of all elements in the system such a demand for the material, number of transport means, its speed and capacity and also accessibility from the depo to presumed target point. Quality of available data is crucial assumption for appropriate response from the model.

**Figure 4.** Conceptual model scheme



Source: Vogal (2017). Distribution of material stock in regions affected by natural disaster

#### 5.4. Simulation model

The simulation model can be compiled using a program from a variety of products. These include ARENA, SIMUL8, SIMIO, ANYLOGIC, GPSS / H, PROMODEL, MEDMODEL, WITNESS and others. Unlike earlier simulation programming languages, these programs provide users with a comfortable visual environment (Dlouhý, 2007). You can also use the special tool Microsoft Excel to solve SOLVER decision tasks.

In the selected simulation program, we will include specifically defined elements that appear here as icons. In the example, these elements are evacuation centers, fire brigade stations, and department stores with which the State Material Reserves Administration works in similar cases. To do so, we assign the collected data representing their properties, which we can further adjust. These include, for example, the location of elements, storage capacities or the duration of some activities.

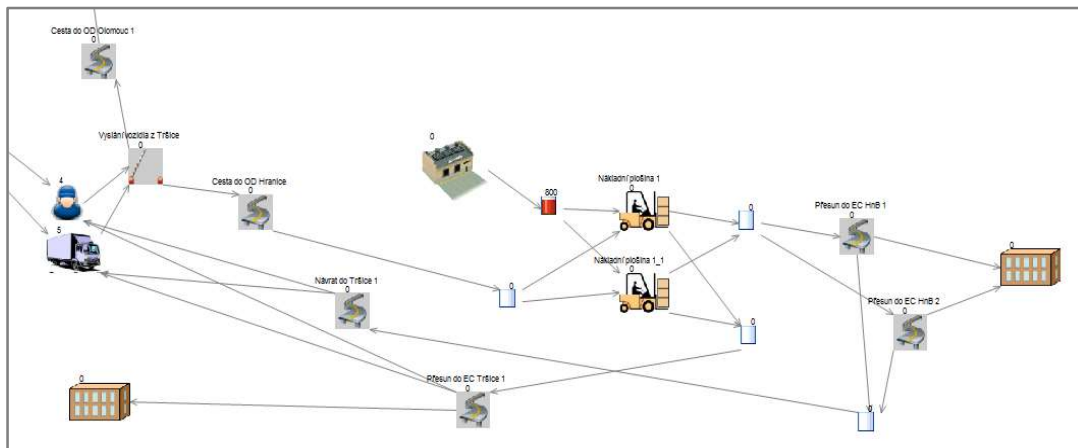
When setting up evacuation center data, it has to be assumed that even if they have a maximum capacity, their actual occupancy correlates with the extent of the flood. The location of the centers and their basic facilities are also determined.

Fire stations are defined in the program by their location, and thus by distance to evacuation centers and department stores. Also, the number of drivers per station and the amount of technique that is known to be similar to occupancy centers is known. The greater the range of floods, the smaller the amount of distribution technology available due to its involvement in the field. Drivers also have working hours, which can, however, be more adapted to the current need in a crisis situation.

Last but not least, the positions of department stores or material stores are determined. There is a time for waiting lorries for check-in and loading.

Figure 5 shows a part of a similar simulation model created in Simul8. A car with a driver is the source of a fire station, a warehouse with carts indicates where the material flows, and two houses indicate evacuation centers.

**Figure 5.** Parts of simulation model



Source: Vogal (2017). Distribution of material stock in regions affected by natural disaster

## 5.5. Verification

This model can be run in the program simulation environment to verify that it works as intended and matches the original design. This means, for example, whether the cars actually leave the fire station first to the material loading location and only then to the evacuation point and not vice versa. In this way, the simulation model is verified.

## 5.6. Validation

After verifying the correct function of the model, there is room for its validation, which is the biggest advantage of the simulation. The user can create a number of scenarios that may occur. It enters the data for each scenario into the verified model and observes which model element settings are most appropriate for the scenario.

## 5.7. Analysis of experiments

Several scenarios can be created for the course of the flood situation according to its extent. On the basis of historical data, it is possible to determine the size and course of flooding of the area for a given flood stage over time and to continue to simulate it. For example, in lower floods there is no danger of flooding the bridge, which is located on the shortest route to the evacuation center, and the transport of the material does not have to be bypassed. Firefighting units do not have to deal with a large-scale crisis, thus reducing the risk of overloading human resources. On the other hand, in the case of a more extensive flood, which is very fast, there is a risk that flooding of roads will lead to the isolation of an evacuation center within hours of the outbreak of the disaster. In this case, it is necessary to designate such a center as a priority in the model. Flood dependent variables are much more.

After running all the scenarios, the results are evaluated and a suitable range of settings for the variables for each situation is found.



## 6. DISCUSSION

The simulation captures the dynamic distribution model and allows it to run with different event scenarios. The result of the simulation is the basis for decision-making, containing general information about inputs, routes and other model variables, especially the range of their values for different flood conditions. Those results include, in particular, the necessary amount of human and capital resources, a number of centres providing stocks and a number of fire stations involved in the process to provide the assistance to the extent required.

The solution of the model situation shows that it is possible to use the simulation for planning the distribution of humanitarian aid in a crisis. It acts as a basis for the solver and assists him in making effective decisions. This means that the use of simulation in this case is not only appropriate but also justified. This conclusion can be generalized for domestic humanitarian logistics, as the solution of the crisis is a part of it.

In the context of foreign humanitarian logistics, this conclusion is not clear. Unlike domestic help, the data needed to create a simulation model is not so readily available. In addition, coordination of international bodies is applied. However, the use of simulations for these cases is not excluded. Further research is needed in this area.

## 7. CONCLUSION

Modeling and simulation have become a modern tool for solving relatively complex systems, especially in business processes. Simulation can capture dynamic processes without realization or production interruptions.

However, the simulation is not restricted to the commercial sphere. The use of this tool is quite wide. It is also justified in humanitarian logistics, as outlined in this article. Its advantages can be applied both in the planning of the distribution of humanitarian material in a crisis situation and in a number of other activities that the humanitarian logistics deals with.

The biggest challenge is foreign humanitarian logistics. There are a number of obstacles to addressing the simulation that need to be addressed. An example is the lack of information on storage options, transport routes or infrastructure. At the same time, there are a number of other factors that have an impact on foreign aid planning, such as the political or security situation in the country or a possible war conflict. Together, these obstacles make it difficult to create a simulation model. However, the assumption for this area remains the same. The suggestion for future exploration is therefore to verify this hypothesis.

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