*Proceedings of 20th International Scientific Conference. Transport Means. 2016*

# Using the SW modeling and simulating tools in transport of hazardous cargos

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**Abstract**

This contribution looks into the possibilities of contemporary software tools for simulating and modeling the crisis situations; and its usage in the field of transport. It deals with the possibility of application of these tools in solving extraordinary situations that can occur relating to the transport of hazardous substances.

**KEY WORDS:** software, transport, modeling, simulation, extraordinary situation

## 1. Introduction

Today's society is not able to work without possibility of transport. Billions of tons of goods, materials or other things are transported every day all over the world. But the transport carries also with dangers. This danger is even multiplied when it comes to the transport of hazardous substances, for example chemicals, oil products or explosives. Related to these dangerous materials it is necessary to be prepared for these situations.[1, 2]

Nowadays we distinguish several kinds of transport; generally, we can say land and water transport, and air traffic. These single categories can be further divided to more specific areas. As well as that, there should be the same approach while solving the extraordinary situation and modeling the simulations. It is quite difficult to determine the real range of extraordinary situation, therefore leakage of hazardous substance, but in spite of that we need to know the possible danger zones in case of leakage. For this aim were developed the models of leakage of hazardous substances, which were later implemented to software applications. There are various software applications, but which one is the best for modeling extraordinary situation? For answering this question, it is necessary to compare these applications.[1, 2]

This contribution further looks into the using of software tools for modeling and simulation of leakage of hazardous substances applied to needs of solving extraordinary situations connected to transport of these substances.

## 2. Basic software for modeling and simulation in crisis management enforceable in problematics of transporting hazardous substances

In advance, there is a need to say that it is necessary to add input data in program; based on this data there is created an output report, mostly containing data about zones and concentration of substance in these zones.

First software is ALOHA. This program was created by U.S. Environmental Protection Agency in cooperation with National Oceanic and Atmospheric Administration (United States of America). It is a freeware (freely available software), which is designed to model leaking chemicals in the air, and their dispersal. The advantage is relatively voluminous database of substances; disadvantage is that it works only with variant of non-reacting substances (therefore, it does not consider reaction with surroundings). It also does not take into account any other influences. The next advantage is that it's possible to connect this tool with measuring devices and work with their data. Program works with Gauss model and Dispersing model of heavy gasses. Output is created both in text and graphics.[2]

Next software is TEREX, this program works not only with chemical substances, but also with explosive systems. Disadvantage is too small database of chemical substances. Advantage is that this program is very easy and connected to GIS. Program works on principle of conservative prognosis (therefore it counts with the worst variant). Program, as the name already predicts (TEREX – TERroristEXpert), was determined as a tool for modeling the attacks with usage of explosives and chemical substances, however, it's also possible to use it for needs of modeling the substances leakage, because the circumstances are similar.[3]

SW SAVE II – it is a numeric program, which is usable for needs of modeling the substances leakage and disperse in atmosphere. Program is based on methodic CPR 14 and CPR 18, but it also uses the Gauss model. With this software it is possible to model and simulate: continuous leakage followed by dispersing of toxic substance, disposable leakage followed by dispersing of toxic substance, continuous leakage of substance followed by the explosion of the cloud, disposable leakage of substance followed by the explosion of the cloud and turbulent jet substance leakage.

SW EFFECTS – This program works with toxic and flammable substances, whereby it provides approximation of possible physical effect (whence its name) of leakage of this kind of substances. As well as the most of the programs, this program Effect has mathematic model defined for flat (smooth) surface. This program allows not only to assign coefficient of surroundings by the form of numerical value, but also choosing from the pre-set options.[4]

SW ROZEX Alarm – is designed for modeling and simulating leakage of chemical substances. In its database it's quite a huge amount of them (about 10,000). This program uses its own computational program (ROZEX 2003). It offers 19 different scenarios and it's possible to display results in GIS. Even there is used the principle of maximum possible damages. Program is designed for the minimum need of input data.[5]

If we take in consideration that any model is perfect (what is backed up in evidence[6]), it's clear that even software outputs, which are not counted on model bases, contain inaccuracies, or mistakes. Therefore, it serves as tool for solving extraordinary incident, but the responsibility is still in crisis worker's and authorized member's hands, that's why it is necessary for these people to use the information acquired from programs only as tentative aid. It is necessary to take into account many factors, what the program cannot do, thus the responsibility of considering such factors lays on human side.[1]

For instance, in situation that ammoniac leaks in the air, the software can evaluate the endangered area for example 500 m, but from the experience it is known that with preset parameters was never measured the amount more than 200 m. Even though, it's better to count on the worse variant, it's not even desirable to amplify panic in vein and for example evacuate the area that will not be stroked.

## 3. Comparing of the SW tools outputs in field of transport

In this part of article will be two first mentioned software shown on example and then compared (due to accessibility of software). Method of comparing SW Aloha and SW Terex will be used, together with counted value using the method CEI. Let's consider for our needs that there will be the leakage of ammoniac from tanker. Let's consider that it is one-off in total amount of 5kg, with the speed of wind 4 m/s, tanker (height 2 m, length 11 m) is full from 75% (approximately 17 tons) and in 70% of height there comes to rupture of the casing, hole is 10 cm in diameter, weather day, summer, 30oC.

For needs of visualising in GIS modules we will use the road E55, part in Czech Republic between Hustenovice and Stare Mesto.

The first software tool is SW Aloha. After implementation of basic data described above the program counted following (Fig. 1.):

```
SITE DATA:
  Location: UHERSKE HRADIŠTI, EESKA REPUBLIKA
  Building Air Exchanges Per Hour: 0.89 (unsheltered single storied)
  Time: August 6, 2016  1835 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: AMMONIA
  CAS Number: 7664-41-7                    Molecular Weight: 17.03 g/mol
  AEGL-1 (60 min): 30 ppm   AEGL-2 (60 min): 160 ppm   AEGL-3 (60 min): 1100 ppm
  IDLH: 300 ppm      LEL: 150000 ppm     UEL: 280000 ppm
  Ambient Boiling Point: -33.8° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from ese at 3 meters
  Ground Roughness: open country           Cloud Cover: 5 tenths
  Air Temperature: 30° C                   Stability Class: D
  No Inversion Height                      Relative Humidity: 50%

SOURCE STRENGTH:
  Leak from hole in horizontal cylindrical tank
  Flammable chemical escaping from tank (not burning)
  Tank Diameter: 2 meters                  Tank Length: 11 meters
  Tank Volume: 34.6 cubic meters
  Tank contains liquid                     Internal Temperature: 30° C
  Chemical Mass in Tank: 17.1 tons         Tank is 75% full
  Circular Opening Diameter: 10 centimeters
  Opening is 1.40 meters from tank bottom
  Note: RAILCAR predicts a stationary cloud or 'mist pool' will form.
  Model Run: traditional ALOHA tank
  Release Duration: 16 minutes
  Max Average Sustained Release Rate: 2,670 kilograms/min
     (averaged over a minute or more)
  Total Amount Released: 4,964 kilograms
  Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 1.5 kilometers --- (1100 ppm = AEGL-3 [60 min])
  Orange: 4.2 kilometers --- (160 ppm = AEGL-2 [60 min])
  Yellow: 8.1 kilometers --- (30 ppm = AEGL-1 [60 min])
```

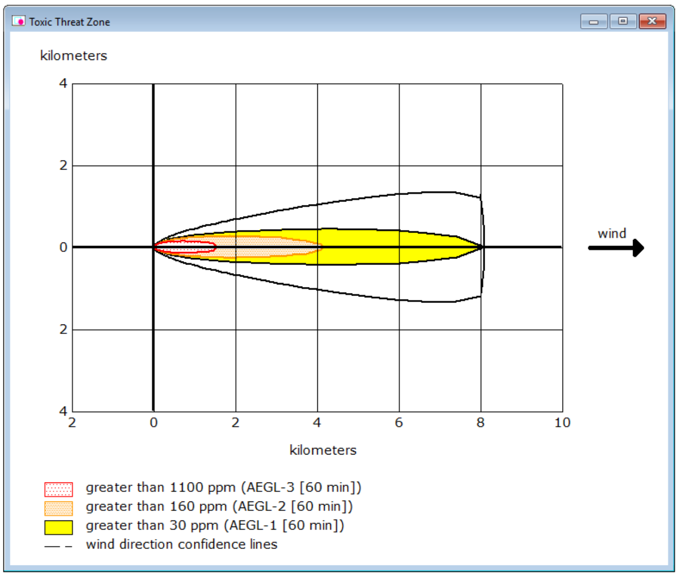


Fig. 1. The output from SW Aloha left and right text representation concentration.

SW Aloha's advantage and also disadvantage is that it's very complex. We can set there for example parameters of container, its filling with substance, size and characteristics of the hole that the leakage comes from, complexly set atmospheric conditions, etc. Thanks to this is its usage relatively lengthy what doesn't have to be desirable when there is necessity of immediate usage, but on the other hand it will be desirable for planning.

The output itself from the modelled situation is shocking, for approx. 5 kg leaked ammoniac SW Aloha counted the zone endangering life for 1.5 km, zone endangering health 4.2 km and zone of endangering for 5,1 km, which are obviously over-dimensioned data and for planning or intervention can't be relevant (see Fig. 2.).

SW Terex is much easier. One of the pre-set setting is chosen and then are only data about weather, substance, etc. filled in. Result is displayed similarly in the form of extract, but easily, by switching the result on map field can be displayed. (GIS).

Output of the program for our comparing needs is resolutely different from the program output Aloha. Here we have the resultant danger zone set to only 35 m.

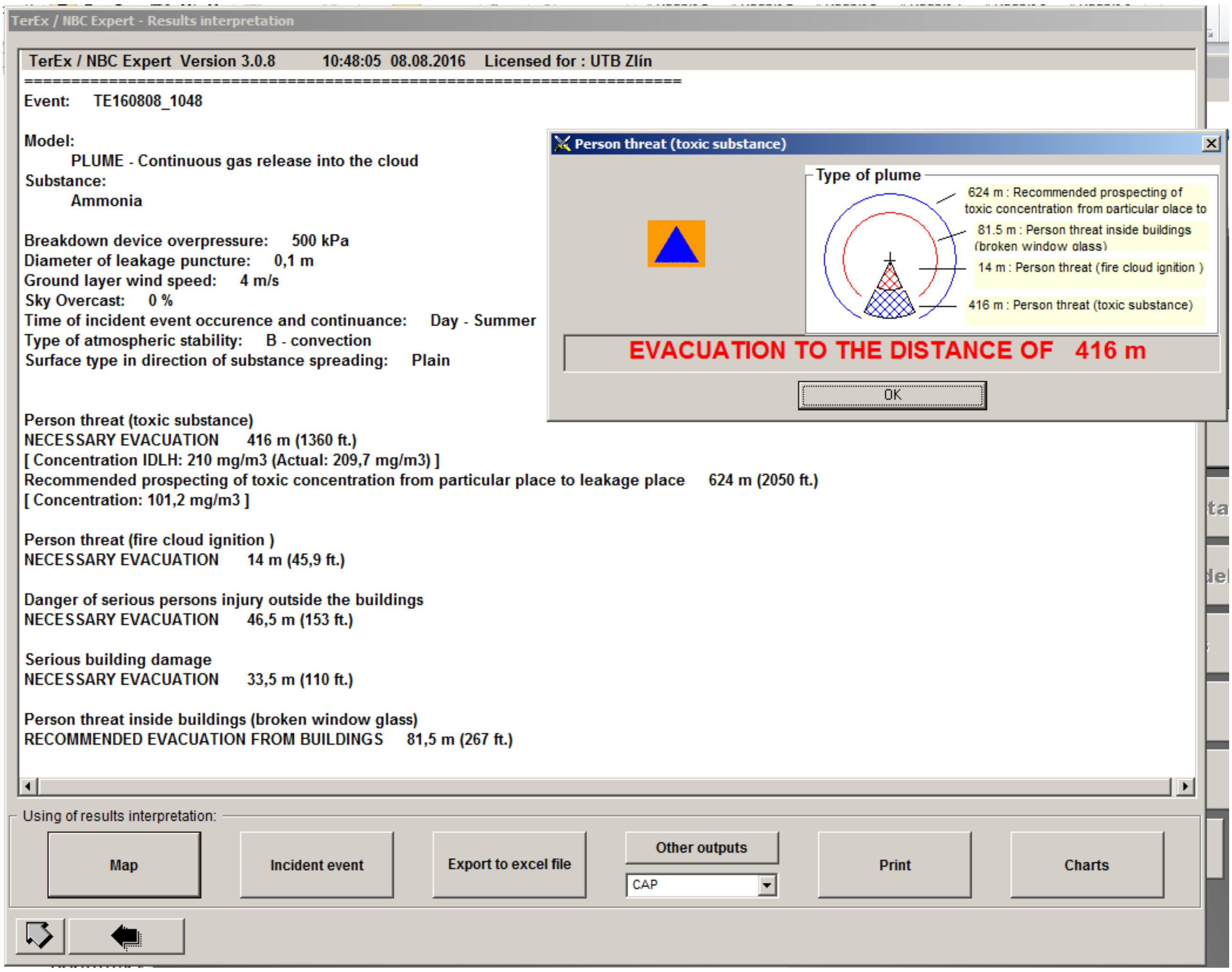


Fig. 2. No exit from the program Terex.

To get more relevant estimation, which one of the results is more accurate, we add counting the danger zone by the CEI method. For needs of comparing we consider that the whole amount of dispersed amount is AQ=0,0445 kg/s. Values of ERPG for ammoniac are: ERPG 1 – 17,5 mg/m3, ERPG 2 – 105 mg/m3, ERPG 3 – 1050 mg/m3. Values are set to formula[7, 8]:

$$HD_1 = 6551 * \sqrt{\frac{AQ}{ERPG_1}} \tag{1}$$

Similarly, it's counted for all HD, whereby AQ is whole amount of dispersed amount, ERPG are Emergency Response Planning Guideline and HD is resultant distance.

After substitution in formula are the results for HD1 (for ERPG 1)(monitoring – increased concentration) 320 m, for HD2 (for ERPG 2)(hazardous to health) 135m and HD3 (for ERPG3)(life-threatening) 42,6m.

As it is possible to see from the pictures above and read from the above mentioned, the programs vary. Counting of endangering due to CEI method is also tentative, however, it is possible to see that the program Terex is closer with its results to counted value. For better understanding the advantages and disadvantages below will be mentioned comparing by the SWOT analysis method.

### 3.1 Evaluation of comparing SW Aloha and SW Terex

In following point there will be mentioned comparing by SWOT analysis. SWOT analysis was chosen intentionally and intentionally there was used only the first part, thus only mentioning the strong and weak sides, opportunities and threats. Intentionally we stepped to this variant, because in counting the following SWOT analysis occurred to almost same values and it would not be provable which software is more suitable. This is caused mostly by that each one software is different, and each one is good for another type of modeling and simulations. Where the one has advantages, the other has not, but finds advantages in using in another field of crisis management and vice versa (see Table 1. And Table 2.).

Table 1. SWOT analysis Aloha.

| SWOT - Aloha | Helpful | Harmful |
|---|---|---|
| **Inner source** | Strong sides:<br><br>Bigger possibility of simulation,<br>Bigger complexity<br>Extended database of dangerous substances with the external database | Weak sides:<br><br>Weak counting modules, which relatively significantly do not correspond reality |
| **Outer source** | Opportunities:<br><br>Improvement of counting models,<br>Improvement by focusing on outreach usage. | Threats:<br><br>Excessive load in case of using current results as resources for decisions. |

Table 2. SWOT analysis Terex.

| SWOT - Aloha | Helpful | Harmful |
|---|---|---|
| **Inner source** | Strong sides:<br><br>Results relatively correspond with reality<br>Possibility of outreach usage. | Weak sides:<br><br>Weaker possiblity of simulation |
| **Outer source** | Opportunities:<br><br>Creating better simulating interface, that would be possible to display in case of need | Threats:<br><br>In the future not updating the database with chemicals |

The result of these analysis is that both software programs are usable, but each one for something different. SW Terex is better to use for immediate action. Compared to that, SW Aloha is better for complex planning and simulation. It also depends on the attitude of specific crisis workers.

Analysis that are mentioned above will be taken into account in following chapter, which will deal with usability SW programs for transport needs.

**4. Conclusion**

What is the place for software tools for modeling and simulating in transport? Conclusively, in planning, especially when it comes to transport of hazardous cargo. Each European state, or rather each state all around the world has covered this sphere by legislation. Nevertheless, there are always discussions about planning and crisis management and right there these programs are used. Above were mentioned a couple of programs, however we could compare just two of them due to accessibility reason. Both of them have different final values in endangered zones. The first one is more suitable for the direct deployment of IZS forces and the second one for processing complex materials with the need of wide scale of variants of modeling and simulation.

It is logical that everyone wishes for the existence of program that would be able to take into account every single change and factor and provide absolutely exact data, however, such a program does not exist and presumably it will not exist for a while, yet. Therefore, it is important to take the problem as a tool, but the main responsibility must stay on the crisis management workers and authorized people. Only just these people must confront the results with experience and praxis and make decisions based on results evaluated exactly this way.

Therefore, software tools are very welcomed as a tool, but there leads a long path to their perfection. However, only just development of these tools and connecting them with sensors and actuators may in the future significantly contribute to minimize the impacts of crash within hazardous substances transport. It can be best seen on the example of that in the future it could be possible that the sensors placed in tanker could register, for example, leakage. Immediately, the actuators activate and this will prevent more substance leaking and it will alarm the crew, as well as they transfer the data to the software tool, which immediately counts the possible impacts and alarms appropriate forces and warns the surroundings. It's just only the future music; however, let's hope that it's the question of the nearest possible future.


## Acknowledgement

This work was supported by Internal Grant Agency of Tomas Bata University in Zlin, Namesti T.G.Masaryka 5555, 760 01 Zlin, Czech Republicunder the project No. IGA/FAI/2016/009.


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