ANALYSIS OF RESPONSE ACTIVITY OF FIRE BRIGADES IN EVENT OF TRAFFIC ACCIDENT WITH OCCURRENCE OF HAZARDOUS SUBSTANCE NEAR PROTECTED AREA OF VILLAGE

Michal Ballay, Jaroslav Kapusniak, Jozef Kubas, Ludmila Macurova
University of Zilina, Slovakia
michal.ballay@uniza.sk, jaroslav.kapusniak@uniza.sk, jozef.kubas@uniza.sk,
ludmila.macurova@uzvv.uniza.sk

Abstract. When transporting dangerous substances, it is essential to comply with all regulations and obligations arising from legal regulations and international agreements regulating the transport of hazardous substances by road transport. The given type of transport is characterized by various risks. In traffic accidents within the transport of dangerous substances in case of leakage of a dangerous substance, its immediate spread into the surroundings occurs, which can cause extensive damage to property, the environment, the lives and health of people, animals and other components of the environment are at risk. The immediate surroundings are immediately exposed to the effects of a dangerous substance, which requires quick and effective intervention and cooperation of rescue services. The supporting part of the contribution is the analysis of the intervention activity of the fire brigades in the traffic accident of a tanker transporting hydrochloric acid in a volume of 22 tons. The authors had at their disposal documentation from the intervention of the accident in question, which was located near the protection zone of natural mineral resources, in the outskirts of the village. The article assesses the coordination of rescue operations with an emphasis on the analysis of the situation in the decision-making of the intervention commander and organizational breakdown of the place of intervention. As part of this assessment, a method focused on ongoing and subsequent activities that are subject to time analysis is applied. The conclusion of the article pays special attention to one of the most dangerous activities during an intervention, namely pumping of the dangerous substance into the replacement tank, as well as the rescue of the crashed tank.

Keywords: intervention activity, dangerous substances, time analysis, quality of life.

Introduction

The legal regulation related to the transport of dangerous substances was created due to the existence of possible risks resulting from road transport and its task is to prevent these risks, possibly eliminate them to the smallest extent possible. The Slovak Republic is bound by a number of international treaties and at the same time some important provisions are also defined in legal norms. The international agreement for the transport of dangerous goods by road is the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), which is divided into several parts and grouped into two appendices.

Accidents during the transportation of dangerous substances cause threats to the life and health of the population, material damage and have a great impact on the environment as well. From the point of view of fire brigades, this is one of the most difficult and complicated interventions. In most cases, the intervention is time-consuming and contains a number of necessary activities. In addition, cooperation with several components and authorities is necessary, and at the same time their coordination is required. In the conditions of the Slovak Republic, fire brigades carry out regular exercises in which they check their intervention activities, detect and work with means for the disposal of dangerous substances. The preparation is carried out regularly, but it is necessary to realize that each accident event is different in nature and scope, to which other intervention procedures are also tied. The solution to the mentioned problem is very specific, as it deals with the connection of intervention activities with methods of operational analysis, with an emphasis on supporting the education and preparation of firefighting units for intervention activities. The use of the PERT method is mostly used in project management. Zdzislaw [1] deals with the calculation of the exact probability distribution of time in a stochastic PERT network. In the framework of risk management, Tysiak [2] in his study deals with two approaches Monte Carlo and PERT. Each publication in the subject issue points to the management of uncertainty and risks in the follow-up activities of a comprehensive project [3; 4]. It is possible to use the mentioned method for intervention.

Description of progress of intervention activity of firefighting units

The traffic accident occurred on the road between two municipalities in the northern part of the Slovak Republic. The combination of a truck and a tank carrying 22 tons of a 33% solution of

hydrochloric acid overturned for unknown reasons and ended up off the road. The semi-trailer of the crashed car was located outside the roadway, in the field and was overturned on the side. The casing of the tank was deformed, but not punctured. The truck was off the road and on its wheels. AD Blue liquid was leaking from the tank of the crashed car. The driver of the crashed car was not injured. Firefighting units were called to the scene of the incident, to which the operational officer of the integrated rescue system dispatched a MB Vario fire engine with a crew of 1 + 1 and a CAS 30 T 815/7 vehicle with a crew of 1 + 1 [5; 6].

After arriving at the scene of the reported traffic accident, the incident commander conducted a survey and the fire brigade determined the direction of the wind, marked the scene of the incident and determined the technical condition of the tank. As a result of the traffic accident, AD Blue leaked from the vehicle. A petroleum product sealant was used to prevent further leakage. The truck driver provided the incident commander with the documents necessary to transport dangerous substances (Figure 1). Due to the fact that the tank was significantly deformed and there was a risk of leakage of the transporting hydrochloric acid, the commander of the intervention called in additional forces and resources for the intervention. Transfer of the transported dangerous substance was required. Firefighters developed two high-pressure jets, which were used to cool the crashed tanker. They developed the hose line from the MB Vario, which was used to provide water for the decontamination shower. Workers of the transport company brought an empty tank to replace the crashed tank and prepared equipment for pumping out the dangerous substance. A control staff, a decontamination workplace with a decontamination shower, as well as a place for providing first aid to the responding firefighters were set up at the site of the intervention [5-7].

Fig. 1. **Progress of rescue operations by fire brigades**

A dangerous zone was marked, and air monitoring was carried out in the vicinity of the tank. Monitoring was carried out during the entire intervention period. They reported the measured values to the commander of the intervention section, who in turn reported them to the staff members. While the hydrochloric acid was being pumped into the other tank, two officers in protective suits cooled the crashed tank with a high-pressure water stream. Only enough people stayed in the danger zone to maintain maximum safety during pumping and extrication of the crashed tanker. After pumping of the dangerous substance was finished, the crashed tank was connected to a Liebherr mobile crane and was pulled onto the road. The workers of the towing service secured the crashed tanker to the vehicle of the towing service and prepared it for the designated place. Firefighters cleared the road of soil and debris from the crashed tanker. Subsequently, the firefighters with the MB Vario vehicle accompanied the crashed tanker to its destination [5; 7; 8].

Evaluation of intervention activity

Firefighting units proceed according to the methodological sheets and instructions of the President of the Fire and Rescue Service of the Slovak Republic during emergency operations. In this case, all actions were performed when the alarm was declared in accordance with the Methodological letter no. 1 and the Fire President's Instruction No. 20/2007 on the issue of tactical-methodical procedures for the implementation of interventions in the valid wording:

- the declaration of an alarm to the designated fire department and the determination of the necessary number of forces and means to carry out an effective intervention in the event of the aforementioned emergency was carried out according to a valid and up-to-date alarm plan,
- the reception of the report of the event by the fire alarm, the announcement of the alarm and the departure of the fire department took place without significant complications and problems. The activities of the fire alarm operator, the response commander during the coordination of the exit and the members of the fire department were in accordance with the principles stated in the relevant methodical sheets and collections of instructions of the President of the Fire department [9-13].

Time analysis of subsequent activities of firefighting units

In the case in question, the response activity of fire brigades is supplemented by activities that must be carried out in the event of a hazardous substance leakage. The breakdown of all activities is shown in the following Table 1. The system of time indicators is built on the assumption of clearly determined durations of activities as part of a qualified estimate of the duration of individual activities. Estimates of the duration of individual activities were consulted with members of the fire and rescue service.

Table 1

Breakdown of intervention activities during transportation of dangerous goods and time estimate of duration

Schedule of activities		Time duration, mm
A	Notification of an accident event, departure of the fire brigade	2
B	Arrival at the scene of the traffic accident	15
C	Investigation of the scene of the accident	10
D	Initial measures	15
E	Deployment of firefighting equipment	20
F	Closure of the area of the accident event (dangerous and outer zone)	20
G	Informing the mayor of the village about the release of a dangerous substance	5
H	Creation of management staff	60
I	Ensuring safety during intervention	100
J	Deployment of water jets and creation of a decontamination workplace	180
K	Preparation of extinguishing agents (triple fire protection)	30
L	Creating a place for providing first aid	60
M	Cooperation with other rescue units	20
N	Monitoring of hydrochloric acid concentration	30
O	Application of sorbents or polyethylene film	15
P	Monitoring of the intervention site	15
R	Ensuring safety in the inner circle of the accident event	20
S	Pumping of hydrochloric acid	180
T	Elimination of the consequences of the traffic accident	120

It is advantageous to use the network analysis method to develop or assess already existing procedures for solving subsequent processes applied to specific situations, requiring a solution and management, especially from the point of view of time, when the indicators are secondary.

From the point of view of the mentioned specifics of dealing with extraordinary events, these are methods that deal with the time analysis of subsequent activities. The system of time indicators is built

on the assumption of clearly determined durations of activities. Qualified estimates of the duration of individual activities were created on the basis of consultations with members of the fire and rescue service. In order to follow the sequence of the applied method, calculations of the mean duration of the activities, the range, the dispersion and the standard deviation are performed first. These quantities are sufficient to calculate a PERT-type network graph, and the analysis itself can then be performed by reducing it to a deterministic model. After these individual steps, it was found that by calculating the PERT reduction to a deterministic model, we get a total duration of intervention activities of 722 minutes. Figure 2 shows the network analysis of the intervention activity of the accident event described above and the continuity of individual activities. For the needs of fire brigades, it is an overview of the activities performed and effective time coordination of intervention activities [14].

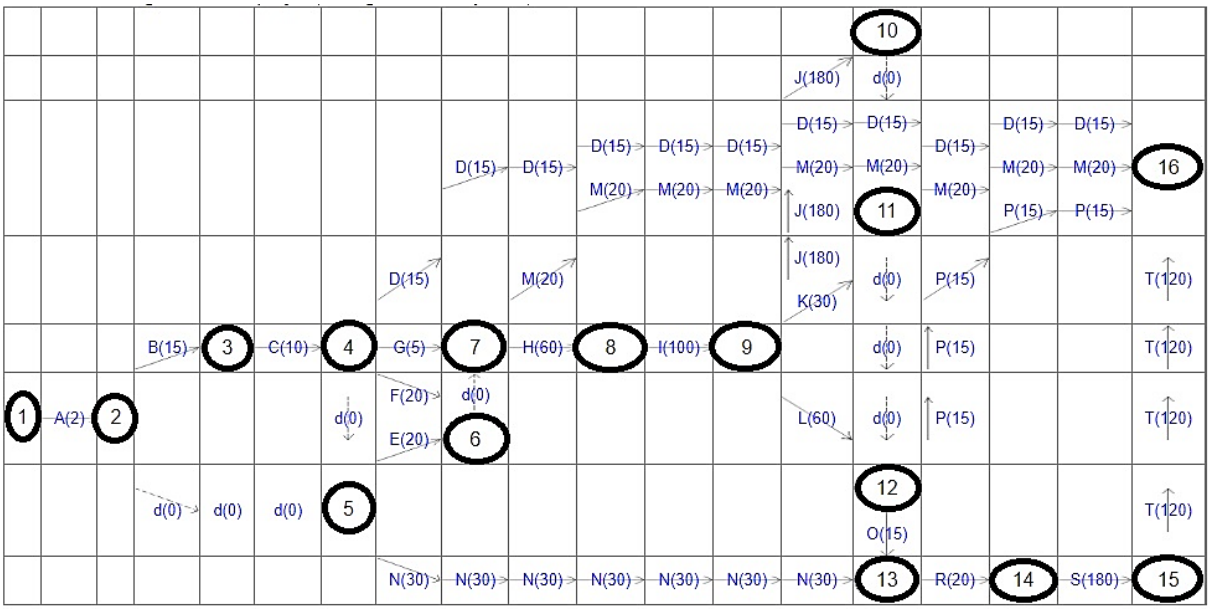

Fig. 2. **Application of the PERT method and overview of subsequent activities**

An important result of the applied method is the definition of the critical path, which represents the longest path from the initial peak (occurrence of the accident event) to the final peak (removal of the consequences of the accident event). The identification of critical activities means that the total time reserve for each of these activities is zero. Delaying the start of the activity or prolonging it would have a significant impact on the time course of the entire intervention activity. Figure 3 shows the critical response activity path of a tanker accident event.

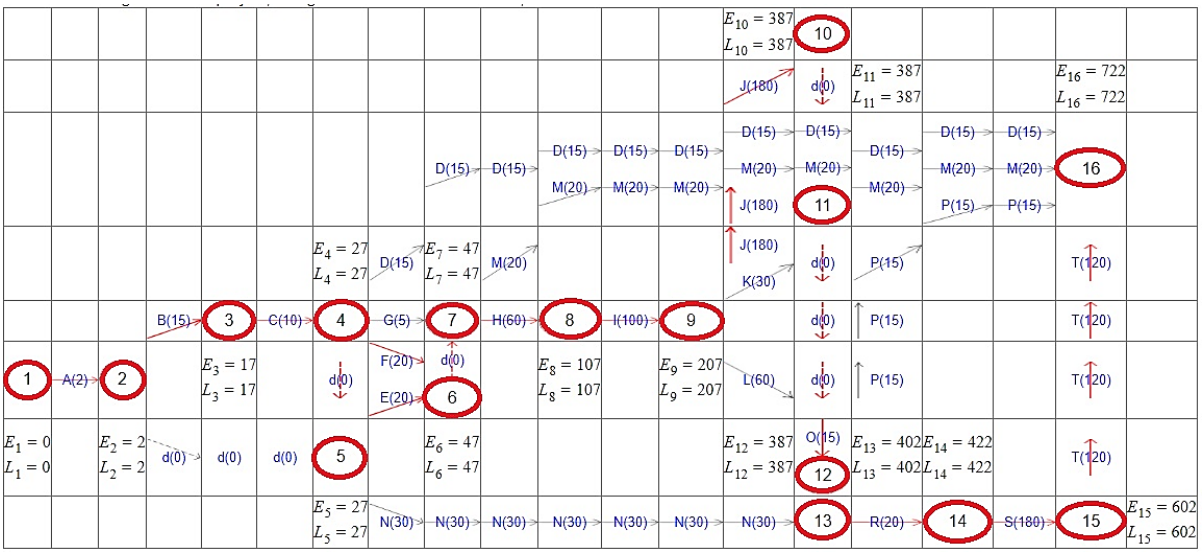

Fig. 3. **Results of the PERT method - identification of the critical path**

For other activities that are not on the critical path, they have a certain time reserve. This means that the delay at the beginning of the activity or its extension (as long as it does not exceed the amount of the reserve) does not affect the overall time course of the intervention activity. A more important task is the estimation of the probability of compliance with the planned time units of intervention activity, up to the end of the entire intervention activity of the firefighting units related to the standard value. Every single intervention is specific, and therefore it is not possible to determine exactly when the entire intervention activity will be completed. The execution of a time analysis of the accident incident indicates the estimated duration of individual activities within the intervention and points out the difficulty of the entire intervention activity from the point of view of the duration and activities of the firefighting units.

Conclusions

Successful liquidation of the consequences of an accident involving dangerous substances depends on several factors. One of the most important activities is obtaining the necessary information about the transported dangerous substance. Proper communication, the deployment of forces and means, as well as the cooperation of rescue services are also important. The amount of activities that are the content of the entire intervention must be properly coordinated. One of the most dangerous activities during an intervention is pumping of a dangerous substance. In this case, pumping was carried out by employees of the transport company using their own procedures and technical means. The technological procedure and fire-safety measures for pumping of a given dangerous substance can be known to the intervening members only from information within the framework of monthly trainings, from meetings, from professional-methodical orientations, respectively. From self-study, but it is not a systematic solution to the given problem. For the mentioned reason, it is possible to state the absence of an internal regulation regulating the mentioned activities. As part of the performed time analysis of intervention activity of a specific accident event, this PERT analysis can be applied in the educational and training program of firefighting units. From the point of view of the duration of individual activities, the fire brigades obtain a comprehensive overview of the entire intervention activity as part of the educational activity. The system of time indicators is built on the assumption of determined periods of activity. The fire brigades are familiar with the sequence and continuity of these activities as part of the educational activity. The analyzed accident event, in addition to the time assessment, points to the importance of some activities that must be performed during the intervention activity (activities listed on the critical path in the PERT method). In conclusion, it is possible to state that the intervention activity is very demanding in this direction and requires professional preparation of fire brigades.

Acknowledgements

This article was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic – VEGA No. 1/0628/22 “The Security Research in Municipalities with Emphasis on the Citizens’ Quality of Life”, and UNIZA grant system number 17332/2022.

Author contributions

Conceptualization, J.K., M.B.; methodology, L.M. and J.K.; software, M.B.; validation, J.K. and L.M; formal analysis, L.M. and M.B..; investigation, J.K.., M.B., L.M. and J.K.; data curation, M.B., J.K, and J.K..; writing – original draft preparation, L.M.; writing – review and editing, L.M. and M.B.; visualization, J.K., J.K.; project administration, J.K.; funding acquisition, J.K. All authors have read and agreed to the published version of the manuscript.

References

[1] Tysiak W. “Risk management in projects: The Monte Carlo approach versus PERT,” Proceedings of the 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems, Prague, Czech Republic, 2011, pp. 906-910, DOI: 10.1109/IDAACS.2011.6072904.

[2] Milian Z. “A note on computing the exact probability distribution of the project completion time in a stochastic PERT network,” 2013 IEEE International Conference on Industrial Engineering and Engineering Management, Bangkok, Thailand, 2013, pp. 78-82,

DOI: 10.1109/IEEM.2013.6962378.
[3] Mushrub V. A., Vybornov A. N. "Innovations in Teaching Network-Based Planning," 2021 1st International Conference on Technology Enhanced Learning in Higher Education (TELE), Lipetsk, Russia, 2021, pp. 14-16, DOI: 10.1109/TELE52840.2021.9482589.
[4] Zhang J. et al., "Research on the Method of Using the PRISM Model to Improve the Estimated Time of the Project," 2018 9th International Conference on Information Technology in Medicine and Education (ITME), Hangzhou, China, 2018, pp. 968-971, doi: 10.1109/ITME.2018.00216.
[5] Regional Directorate of the Fire and Rescue Service in Žilina. Consultations. 2022. [online] [2023-2-20] Available at: https://www.minv.sk/?kr-hazz-v-ziline.
[6] Markova I., Mitrenga P., L Makovická Osvaldová, Hybská H. 2022. Determination of the ignition temperature of hay for the purposes of fire risk assessment on farms–Slovak case study. In: Jurnal BioResources. Vol. 4. p. 6926. DOI: 10.15376/biores.17.4.6926-6940
[7] Markova I., Kubás J., Buganová K., Ristvej J. 2022. Usage of sorbents for diminishing the negative impact of substances leaking into the environment in car accidents. Frontiers in Public Health 10:957090. DOI: 10.3389/fpubh.2022.957090
[8] Hollá K., Sventeková E. Risk Management in the Area of Major Industrial Accident Prevention in the EU and Slovak Republic. In book: Risk Management, 2022. DOI: 10.5772/intechopen.98406
[9] Law no. 314/2001 Coll. Fire Protection Act
[10] Act of the National People's Republic of Slovakia No. 42/1994 Coll. on civil protection of the population.
[11] Law no. 129/2002 Coll. Law on Integrated Rescue System
[12] Decree no. 611/2006 Coll. Decree of the Ministry of the Interior of the Slovak Republic on fire brigades
[13] Decree no. 121/2002 Coll. Decree of the Ministry of the Interior of the Slovak Republic on fire prevention (as amended by No. 562/2005 Coll., 591/2005 Coll., 259/2009 Coll., 202/2015 Coll.).
[14] Ballay M., Sventeková E. Use of the Method of Operational Analysis in the Framework of Technological Safety of Emergency Work. Conference: 14th International scientific conference on sustainable, modern and safe transport, 2021·