Optimization of transportation of unexploded ordnance, explosives and hazardous substances – vibration issues

Rafał Burdzik[1], Ireneusz Celiński[2], Piotr Czech[3]
Silesian University of Technology, Faculty Transport, Katowice, Poland
[1]Corresponding author
E-mail: [1]*rafal.burdzik@polsl.pl*, [2]*ireneusz.celinski@polsl.pl*, [3]*piotr.czech@polsl.pl*

(Received 10 November 2016; accepted 14 November 2016)

Abstract. The paper presents discussion on vibration issues for larger concept of new method for optimization of transportation of unexploded ordnance, explosives and hazardous substances in the road network. The study is focused only on one aspect determine the route of special military vehicles – carrying munitions and explosives. The discussion is limited to vibration issues and possibilities of its application for the presented task. Also it presents basic criteria for evaluation of track movement defined in the transport network for the transport of hazardous materials. One of the key aspects of the safe transportation of hazardous materials including unexploded ordnance is to provide best choice of path taking into consideration state of the surface on all sections of the selected route.

Keywords: hazardous materials, road network, unexploded bomb, pavement conditions.

1. Introduction

Transportation of hazardous materials requires proper selection and securing the route. This also applies to transport military materials such as unexploded ordnance, explosives and other dangerous substances. While some of the materials should be transported by rail in the deliberately formed and properly secured configurations that are specific cases where transport must be carried out with the use of the road network. Regardless of the location of unexploded there is always the problem of finding the way to the nearest railway station or the nearest polygon.

Unusual situations that require routing of the only road network, are in the case of unexploded ordnance where the choice of route is determined mainly by case determined by the place of discovered unexploded ordnance. The transport of these materials is developed by the military, police and municipal services in terms of logistics. The Authors assume that not all of aspects are taken into account for this type of problem e.g. dynamically changing the state of the road surface. This is especially important with regard to the dense road network occurring in the areas of agglomeration and conurbation. In these cases, the locations qualities found unexploded ordnance may cause specific problems associated with determining the route of their movement and secured passage. In addition, networks of dense traffic of high intensity remained late into the evening and early morning starts hindering the transport of dangerous goods over long distances movement in vast areas of the metropolis.

The problem of determining optimal paths for routing a transportation of hazardous materials is commonly explored field of research. The objective is to find the probability of accidental leakage of hazardous material [1]. The paper [2] presents a model to assess risk and efficiency in transportation of hazardous materials. Due to increase of volume of intermodal transport the authors of paper [3] presents optimization framework for routing rail-truck intermodal shipments with hazardous materials. The author also considered factors impacting congestion risk in rail-truck transportation of hazardous materials [4]. One of the most important issue is to choose proper vehicle. The paper [5] presents new generation of special vehicles and applications of wheeled platforms for special purpose vehicle.

In this article the Authors focus only on one aspect of determining the route of special military vehicles – carrying munitions and explosives. The discussion is limited to vibration issues and possibilities of its application for the presented task. The presented concept of routing of hazardous materials can also be used by other services, e.g. the police.

2. Road transportation of hazardous materials

The paper is limited to the road transport which is result of analysis that it is mode of transportation used in all dislocation processes. It is also strategic mode of transport for all military actions, especially for discussed a case study of dislocation of unexploded ordnance, explosives and other dangerous substances (Fig. 1).

Fig. 1. Bomb disposal vehicles [6, 7]

The issue of proper selection and securing the route for the transport of dangerous goods on the road network can be described by an ordered six:

$$THM = \langle TM, TP, TW, SEI, SDM, HM \rangle, \tag{1}$$

where: TM – set of transport means; TP – trip path; TW – trip start windows; SEI – set of parameters describing the socio-economic infrastructure; SDM – spatial distribution of military or any other which may be recycling/disposal of unexploded ordnance or other hazardous materials; HM – type of hazardous material.

In the case of transportation of dangerous materials, the choice of route on the road network will be basically limited to the road specialty vehicles remain supplied with troops or vehicles for general use. Influence of parameters of socio-economic infrastructure for the transport of hazardous materials Authors will present in further publications. In the present concept will also be omitted aspect of the spatial distribution of military and type of hazardous material transported. The authors of this article will focus on the analysis of a set of allowable displacement paths and set allowable time windows for implementation of cargo transportation. Each track movement defined in the transport network for the transportation of hazardous materials should meet basic criteria:

$$TP = f\big(GP, PC, TF(tw)\big), \tag{2}$$

where: GP – set of geometric parameters of the displacement path; PC – parameters of the surface state of the road segments located in the path of movement; TF – set of parameters describing the traffic conditions as a function of the time window chosen for the implementation of the transport of hazardous materials;

A collection of geometric parameters describing the path of movement applies to parameters such as the width of lanes, gauge roads, flyovers, tilt, longitudinal and lateral location of the tunnels. These parameters, describing the infrastructure of the road network are generally determined in a long time horizon. The effect of these parameters on the transport of hazardous materials Authors will present in further publications. The set of parameters describing the traffic conditions as a function of the time window can be defined by basic characteristics of traffic, such as traffic density, traffic and queue remaining on the inlets. Note in this context that despite security routes in the immediate vicinity of the path of displacement (besides, behind and before the column transport) continues to be located a large number of other, generally civilian vehicles. Thus, the need to take into account the motion parameters in a transport network, not only on the path of movement but in its immediate vicinity. This set of parameters is highly stochastic and depends on local conditions in the transport network. The dense network determines a need to determine the legitimate path of displacement of the off-hours night and evening.

It tis paper the authors focus on the parameters of the surface condition of the road segments located in the path of movement of hazardous materials.

3. Pavement conditions vs hazardous materials

The issues of absorption of vibration, vehicle dynamics and stability in terrain become big factors for developing project and new constructions. Especially for special vehicles operated in different environment and on irregular ground surface. These type of vehicles have large scope of loads, from general cargo to concrete. It can be designed, developed, produced and installed truck bodies and trailers for any kind of use according to special and individual requirements [8, 9].

Thus, one of the key aspects of the safe transportation of hazardous materials including unexploded ordnance is to provide such a choice path displacement (in addition to other previously described aspects) to the state of the surface on all sections of the selected track displacement was the best:

$$TP^{ch} = \max \sum_{i}^{n} Mint_i, \tag{3}$$

where: TP^{ch} – selected path displacement; n – number of road sections in the path of movement; i – section index; $Mint_i$ – assessment of surface section of the road for the transport of hazardous materials [-];

In order to assess the state of pavement on sections of track movement advocates the use of universal mobile recorders. This DVR is based on an application for Android or Windows Mobile is able to register a vehicle linear accelerations in three axes, in practice, the interval of up to 10 ms. The mobile device application from the measurement should be attached to the rigid parts of the vehicle body.

Such application can collect data on the different movements (relations) in the transport network. Courtesy of such an application in a sample of drivers in the transport network enables distributed and extensive measurements of parameters of the transport network in the indirectly state of its surface. The state of the surface is essential for the safety of the transport of dangerous goods including mainly unexploded ordnance. Such materials (military) remain dormant often for a period of decades. It is therefore appropriate to transport them to the place of storage or disposal in conditions providing them the least dynamic overload. This in turn requires that the surface condition was the best possible all-pass path column unexploded (Eq. (3)).

Applications provide a measurement of linear acceleration in three axes while the vehicle is fitted with the application in the road network. Out of state roads such application maps the traffic conditions in the transport network (Eq. (2), the parameter TF). Example parameters of the road network as measured using the application shown in Fig. 2.

4. Conclusions

Every vehicle on the road network equipped with such an application is moving in the direction of movement of the belt setting for each measurement interval at a known location in the geocentric system (WGS84) of linear acceleration in three axes. In the Y-axis direction of movement of the belt in the X-axis lateral acceleration relative to the direction of movement of the vehicle. The Z-axis data is being recorded to the vertical surface of the road lane. Each inequality recorded on the surface of the road (deformation, damage the surface layer) is represented in the form of implicit in the values of linear acceleration measured in the individual axes. Deformation of the road surface will be reflected mainly in the data recorded in the Z axis. Question of the procedures used is the extraction of information on the state of the surface of the road segments that make up the displacement path of the transport of dangerous goods or unexploded ordnance. Information gathered in this way thus allows for the extraction of data on road network, providing a path selection movement that provides the least dynamic loads in the individual axes, which may affect the unexploded ordnance.

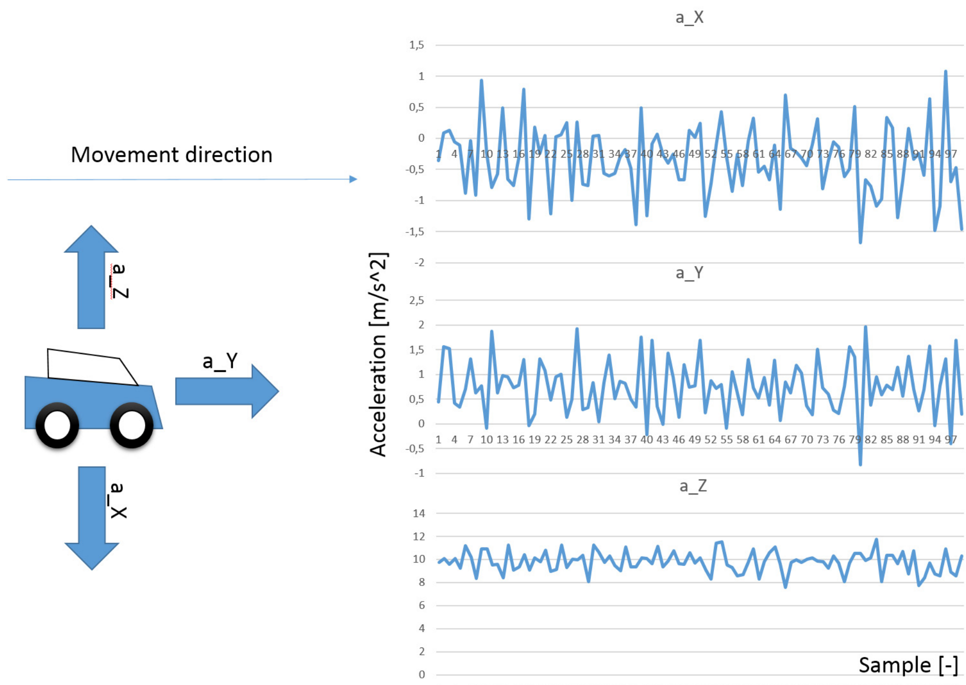

Fig. 2. Mobile application data for describing linear accelerations

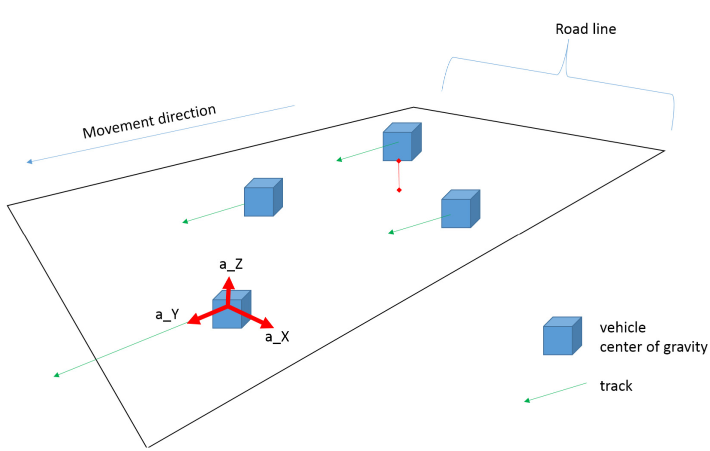

Fig. 3. The section of the road network with presentation of measurement algorithm

Road segments which are included in path of movement could be limited to the nearest position of the vehicle specified by using the GPS system. This means that when using the AGPS $Mint_i$ values (Eq. (3)) can be determined to the limit as the nearest lane width, which means that the basic description of the data field is a square of approx. 2.5 m. Thus each section of the road network should be divided into spatial units. The value TP^{ch} (Eq. (3)) expressed as a path displacement should be calculated for each spatial unit forming part of the path of displacement. The section of the road network with presentation of measurement algorithm have been depicted in Fig. 3.

The use of a sufficiently large sample road network enables the vehicles very carefully parameterized surface condition of each section of the road network. In practice, the use of tests with drivers of vehicles with different characteristics behavioral the result that the characteristics are quasi continuous in time and space of the road network. In contrast to the specialized methods of measurement using a special rolling stock proposed method is cheap and allows you to extract the data in a dynamic way.

References

[1] **Rajan Batta, Chiu Samuel S.** Optimal obnoxious paths on a network: transportation of hazardous materials. Operations Research, Vol. 36, Issue 1, 1988, p. 84-92.

[2] **Current J., Samuel Ratick** A model to assess risk, equity and efficiency in facility location and transportation of hazardous materials. Location Science, Vol. 3, Issue 3, 1995, p. 187-201.

[3] **Manish V., Verter V., Zufferey N.** A bi-objective model for planning and managing rail-truck intermodal transportation of hazardous materials. Transportation Research Part E: Logistics and Transportation Review, Vol. 48, Issue 1, 2012, p. 132-149.

[4] **Ghazal A., Ginger Y. Ke, Manish V.** Planning and managing intermodal transportation of hazardous materials with capacity selection and congestion. Transportation Research Part E: Logistics and Transportation Review, Vol. 76, 2015, p. 45-57.

[5] **Szczęśniak G., Nogowczyk P., Burdzik R., Konieczny Ł.** Application of wheeled platforms for special purpose vehicle. Journal of Measurements in Engineering, Vol. 4, Issue 3, 2016, p. 133-139.

[6] http://alfa-img.com/show/us-navy-bomb-disposal.html

[7] http://www.thejournal.ie/army-bomb-disposal-units-devices-2642959-Mar2016

[8] **Ostrowski T., Nogowczyk P., Burdzik R.** The constructional solutions for absorption of vibration in special vehicles operated in terrain. Vibroengineering Procedia, Vol. 3, 2014, p. 249-253.

[9] **Ostrowski T., Nogowczyk P., Burdzik R., Konieczny Ł.** Technical elements for minimising of vibration effects in special vehicles. Vibroengineering Procedia, Vol. 6, 2015, p. 259-263.