ARCHIVES OF TRANSPORT *Volume 51, Issue 3, 2019*

ISSN (print): *0866-9546*
e-ISSN (online): *2300-8830*
DOI: *10.5604/01.3001.0013.6163*

INTEGRATED APPROACH TO INFORMATION ANALYSIS FOR PLANNING THE TRANSPORT OF SENSITIVE CARGO

Iouri SEMENOV[1], Ludmila FILINA-DAWIDOWICZ[2], Piotr TROJANOWSKI[3]

[1, 2, 3] *West Pomeranian University of Technology, Szczecin, Faculty of Maritime Technology and Transport, Szczecin, Poland*

Abstract:

This article presents the methodology of information analysis, required for planning safe road transport of sensitive cargoes. Based on the literature studies we found that the traditional approaches applied to analyze traffic information are insufficient to ensure safe transport of sensitive loads as they fail to take into account several threatening factors. In addition, the need was noted to develop the procedures that may allow to choose a transport route considering appearance of so-called high-risk zones within road infrastructure, analyze the interdependence of such zones with errors made during the design or operation of road infrastructure and investigate the impact of road traffic on the frequency of road accidents involving Heavy Goods Vehicle. Therefore, article aims to present an integrated approach to traffic information analysis. Thus a multiple stage data ordering procedures were proposed, based on grouping information on accident rates and inclusion of audit results of selected route sections. Considering that transport infrastructure plays an important role in transport safety, the proposed methodology includes the analysis of errors in infrastructure and a merger in the sections the detected risk zones within the road infrastructure in any location. Application of this methodology can improve the planning of road transport of sensitive cargoes. Its verification was carried out on the example of a selected route running through Poland. During the audit of the route, it was found that a number of incorrect design solutions were applied on its separate sections, which may lead to high values of the severity factor for potential collisions and indicator of possible post-accidental losses. As a result of the research, the areas of the route were identified, where high-risk zones are located that threaten the safety of road traffic of vehicles, including those carrying sensitive loads. Research results may be of interest for those, who are involved in planning and organization of sensitive cargo transport, both in domestic and in international relations.

Keywords: *transport planning, information analysis, sensitive cargo.*

To cite this article:

Semenov, I., Filina-Dawidowicz, L., Trojanowski, P., 2019. Integrated approach to information analysis for planning the transport of sensitive cargo. Archives of Transport, 51(3), 65-76. DOI: https://doi.org/10.5604/01.3001.0013.6163

Contact:

1) iouri.semenov@zut.edu.pl [https://orcid.org/0000-0002-2250-9591], 2) ludmila.filina@zut.edu.pl [https://orcid.org/0000-0001-6916-6066], 3) piotr.trojanowski@zut.edu.pl [https://orcid.org/0000-0001-8869-0656]

1. Introduction

"*We are data rich, but knowledge poor*"

The growth of motorization and development of international freight transport requires additional efforts and new ideas to maintain the position of transport companies on transport services market. Nevertheless, the observed high level of road accidents in Europe, including Central and Eastern Europe, significantly affects the risk of failure to perform a transport task, loss of competitiveness and, consequently, market position.

Improving road transport safety is one of the most important goals of the European transport policy, including Poland. Modern society perceives the growth of mobility to be an important factor improving the quality of life, and thus expects improved transport availability, with simultaneous reduction of risk of health and property losses for every participant of road traffic.

Unfortunately, various ways to achieve the above applied during the last few decades, did not bring about expected result. Severe injuries and fatalities of road accidents continue to cause economic, social and environmental losses worldwide. According to the World Health Organization, the average economic losses caused by the loss of road safety are estimated at 3% of the gross domestic product (WHO, 2018). The social consequences of road accidents include loss of jobs, financial difficulties of households, health and mental problems of victims of those incidents. Thus there is an urgent need for a new approach to the concept of increasing the level of road traffic safety.

Currently this issue is growing more and more complicated, as the transport of conventional goods is increasingly joined by transports of other groups of goods, including sensitive cargoes. Such loads include flammable, perishable, poisonous and radioactive cargoes, and products of the chemical and defense industries. These loads require compliance with specialized transport conditions, including the need to maintain the appropriate temperature and humidity levels, or keep the vibration levels in the cargo space under the threshold of permissible value.

The process of safety planning for such goods transport includes not only planning the route for these sensitive goods, but also their storage and handling, including measures to prevent emergency situations during the performance of the transport task. The enormity of the issues arising in the course of securing appropriate safety levels necessitates the development of an integrated approach to transportation planning for every haulage company, which usually uses the preexisting databases. Such an approach is justified in that it allows maximum risk reduction for sensitive cargo emergency situations, already at the planning stage.

This activity will not always be appropriate, and in case of sensitive cargo transport it may even be deteriorating for the intended objectives. Therefore the authors of the present article suggest the application of an integrated approach to transportation planning, based on knowledge discovery. The main objective of the operational planning is to plan a route that ensures an unconditional performance of the transport task, while reducing the risk of traffic accidents to an acceptable level (e.g. collision with other cars, collisions with a moving or stationary object, etc.), as well as possible damages in the event of a collision (e.g. emanation of harmful substances, toxic emissions, fire and spread of fire, cargo explosion, etc.).

What is of particular importance in the practices of transport carried out in Europe, including Poland is the risk of losing the safety of sensitive cargo transport. Possible manifestations of hazards during its transport require to develop strategies to ensure an acceptable level of road safety in conditions of increasing mobility of the society, and to develop appropriate tools to reduce the risk of injury to traffic participants, loss of traffic flow, property damage and environmental pollution. Effectiveness of work on the aforesaid strategy requires the access to reliable information, as well as the use of reliable methods for its analysis.

In this context we can conclude that there is still need for:

- development of procedures that will allow for the selection of transport routes in the course of so called high-risk zones on the road infrastructure map,
- analysis of the interdependence of such zones with errors made during the design or operation of sections of the routes along these zones,
- investigate the impact of road traffic, possible design errors, etc. on the frequency of road accidents involving HGVs (*Heavy Goods Vehicle*): there is no common approach to estimating and assessing these relationships, etc.

In order to find a solution to the aforementioned issues it is necessary to conduct appropriate analyses and apply efficient data processing methodology to research on road transport of sensitive cargoes.
The aim of the present article is to introduce an integrated approach to the analysis of information required to plan safe road transport of sensitive cargoes. Proposed methodology includes both the analysis of information on road accidents rates, as well as the analysis of information sourced from the so-called route auditing.

2. Literature review

The subject literature on road transport safety is broad, still the analysis of issues contained therein is somewhat selective. Problem of safety management is described, i.a. in Directive 2008/96/EC (EU, 2011) and ISO 39001 (road traffic safety management systems) standard (ISO 2012), which defines the standard of safety management and introduces recommendations concerning the activities of infrastructure managers, administrators and private entities. However, it is worth noting that ISO 39001 standard is too general, it does not take into account the specificity of ensuring the supply safety of individual groups of goods, including sensitive cargo (Rzeczpospolita 2017).
The literature emphasizes that due to the high number of road accidents (KGP, 2018; Li et al., 2016; Mashros, 2018; Piarc, 2007; WHO, 2018), there is still need for actions to increase the level of road safety. The causes and consequences of accidents are examined, and the impact of the human factor on the occurrence of adverse events is emphasized (Galkin et al., 2018; Khan and Abbasi, 1999; Macioszek, 2015; Muslim, 2018). It should be noted that the impact of faulty infrastructure solutions on traffic safety is often undervalued and falls within 2-4% of accidents, while European experts' research prove that inadequate infrastructure directly and indirectly contributes to some 28-34% of the accidents (Barcik and Czech, 2010; Piarc, 2007).
Available literature also presents methods for road safety management (Barcik and Czech, 2010; Brannolte and Munch, 2009; Csiszár and Földes, 2018; Gaca and Pogodzińska, 2017; Jamroz et al., 2014; Khan and Abbasi, 1999; Kostrzewski and Varjan, 2018; Lavson, 2011; Madsen, 2005; Morin, 1967, Norden et al., 1956, Ramos et al., 2015; Skrodzka, 2015). The authors point out attention to the occurrence of "black spots" and "black sections" of roads, designation of which is important from the point of view of ensuring road safety (Ghadi and Torok, 2017; Patankar et al., 2017; Sorensen and Elvik, 2007a; Sorensen and Elvik, 2007b; Sorensen and Pedersen, 2007; Vivek and Saini, 2015). The role of road audit during the assessment their status and potential places of hazards occurrence is emphasized (ETSC, 1997; TM, 2011). As it results from the recommendations contained in article (Ramos et al., 2015), the methodology of traffic safety management for each route studied should be based on the results of the traffic audit of this route, selection of evident difficulties in traffic due to various deficiencies both in the design of road infrastructure, as well as and its exploitation.
Furthermore, the attention is drawn to the importance of reliable information when making decisions on road safety (Ghadi and Torok, 2017; ISO, 2012; Jamroz et al., 2014). In practice, however, there is often discrepancy between accident data and the lack of well-structured database systems on road safety (Lamr, 2018; The World Bank, 2013). This causes difficulties in acquiring data that is detailed enough to allow for understanding and solution of traffic safety issues.
Our literature analysis demonstrated that there is no integrated approach to the analysis of information required to plan the transport of sensitive cargo, thus justifying the need to undertake our research.

3. Methodology

3.1. General assumptions of the methodology

The research problem is to develop an integrated approach to the analysis of information required to plan safe road transport of sensitive cargoes (table 1).
This approach should allow for identification of elevated risk zones on fragments of the road infrastructure in any location. Such zones are distinguished by a higher expected number of accidents than other parts of the infrastructure.
Four hypotheses can be thus formulated to further develop the methodology:

1) Each route has spots and linear fragments of increased risk of accidents, including so-called "*Black Spots*" and "*Black Sections*".
2) There are high-risk zones on each route, with risks to road safety, created by stable groups of

infrastructure fragments that are distinguished by the similarity of the "main causes" of accidents (Khan and Abbasi, 1999) and their "interconnection".

3) The roads under analysis have zones of high risk of loss of road traffic safety, characterized by similar characteristics of both factors causing the risk of loss of traffic flow, as well as the consequences of manifestations of these threats.
4) Separate concentrations of infrastructure risk zones have a high potential for safety improvement, and require similar preventive measures.

According to Hypothesis 1, the following concepts of black spots and high risk zone located on routes planned for use in the haulage of sensitive loads can be defined (Sorensen and Elvik, 2007a):

1) *Black spot* - any spot on the freight route, which is distinguished by a high probability of road collisions as a result of manifestations of local risk factors for their occurrence.
2) *High risk zone* - each infrastructure segment, in which there were more accidents than in other segments of the same infrastructure as a result of spatial and segmental risk factors.

Examples of infrastructure elements, where high-risk zones can be identified are presented in Table *2*. The four hypotheses mentioned and the requirements laid down in Directive 2008/96/EC (Sorensen and Elvik, 2007b) form the basis for further research into road safety. Therefore, the proposed methodology assumes that it is necessary to conduct:

1) Identification of dangerous fragments of the existing Polish road network ("*Black Spots*" and "*Black Sections*").
2) Risk assessments of selected infrastructure fragments (e.g. on the basis of route audits in accordance with guidelines (ETSC, 1997; TM, 2011)).
3) Preparation of data set on dangerous infrastructure fragments by grouping them.

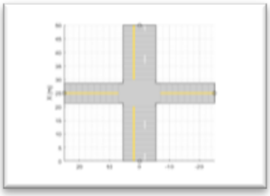
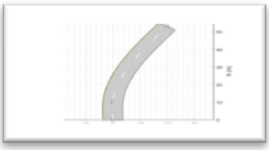
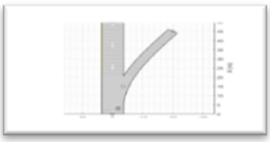
Based on the conducted analyzes it was found that for research on road safety of vehicles carrying sensitive loads, the following steps can be performed:

1) Analysis of the history of extraordinary situations that occurred on separate sections of the transport route. This will form the basis for grouping information about previous accidents.
2) Audit of examined transport route on which extraordinary situations may occur. During the audit we may:
   – designate the dangerous fragments of infrastructure,
   – elaborate sets of collected data concerning the designated fragments,
   – group information about designated fragments located in the so-called TAZs (*Traffic Analysis Zones*) or HRSs (*Hazardous Road Sections*).

Table 1. Components of integral approach to information support in the transport task planning process (own elaboration)

Description	**Components of integral approach**		
	Data preparation	**Data aggregation**	**Knowledge discovery**
Issue solved	Poorly structured data	Data file size is too big	Need for new approaches to planning the transport of sensitive cargoes
Applied databases	All	Sensitive loads, risk zones, accident statistics	Suitable for problem being solved
Algorithms used	1. Based on filtration and elimination of unreliable data 2. Based on recognizing the essence of components and their interrelations ERR (Entity and Relationship Recognition)	1. Based on the division of a set of elements into a specified number of clusters (Partitioning Algorithms) 2. Based on density assessment of element locations (Density-Based Algorithms)	1. Based on acquiring knowledge within the limits of available data 2. Based on acquiring knowledge beyond the limits of available data
Techniques applied	1. Human generated (data overview & evaluation) 2. Computer generated ETL (Extract, Transform and Load)	Agglomerative techniques - use of measures: 1. Distances of grouped elements – (the K-means technique) 2. Weighted centers of gravity of grouped elements WPGMC (weighted pair-group method using the centroid average).	Applied techniques: 1. Association rules 2. Sequence mining 3. Deviation and trend interpretation
Expected results	Well-structured information	Improvement of short-term operational planning of sensitive cargo transport	Improving the process of planning transport tasks in the medium-term

Table 2. Examples of high risk areas along the transport route (own elaboration)

Name	Illustration	Description
Intersection		An infrastructure segment that connects two or more roads at an angle of up to 90 degrees, allowing a vehicle to change its heading
Curved roads		An infrastructure segment shaped by regular curvature of the road path in order to gradually change the direction of vehicles movement
Exit ramp or off-ramp		An infrastructure segment designed to make vehicles access or exit the road in a controlled manner

3.2. Grouping of information on road accidents

We suggest utilizing a four-stage algorithm for grouping information on sections of route with increased road traffic accident risk.

Stage 1 - Collection of available reports containing information on prevalence of accidents on tested route. During this stage, information on the accident rate obtained from reports from the Police Headquarters is used, and recommendations made in a number of foreign and domestic publications are taken into account. An example of systematizing recommendations regarding the identification process for HRS in various countries is presented in table 3.

Table 3. Systematic recommendations on the process of identifying black sections in various countries (own elaboration on the basis of (Sorensen and Elvik, 2007b))

Country	Analyzed collisions	Length of the test section	Analyzed period
Denmark	Recorded	2-10 km	5 years
Germany	Recorded	3-10 km	3 years
Norway	Expected	1.0 km	8 years
USA	Expected	Every few miles	Optionally

High credibility of first stage results is possible due to a detailed analysis of official publications and data regarding accidents on public roads. Therefore the reliability of the aforementioned reports and the availability of information contained in them becomes significant.

Stage 2 - Analysis of accident statistics and their assessment, taking into account the location of HGVs accidents along the tested route. It can be performed in accordance with recommendations contained in publications (Lawson, 2011) and (Sorensen and Pedersen, 2007). Example of road safety assessment according to "Star Rating" categorization is presented in table 4.

Table 4. Example of road safety assessment according to "Star Rating" categorization (Lawson, 2011)

Parameter	Two-star road	Three-star road	Four-star road	Total
Road sections, numb.	32	482	87	601
Total length of road, km	127	165	22	314
Traffic performance, mln car x km	1663,72	2497,79	420,59	4564,1
Serious casualties, numb.	63	89	6	158
Casualty rate, mln car x km	0,038	0,036	0,015	0,035

Stage 3 - Identification of high-accident sections of the route. Due to the fact that some types of accidents are more severe, e.g. in the result of a collision between heavy goods vehicles and unprotected road users, they should be considered more significant than accidents, the effects of which are less severe (Sorensen and Pedersen, 2007).
In connection with the above, the following steps are proposed in the process of identifying HRSs on the routes for sensitive loads transport:

– Determination and assessment of the threshold value of the probability of safety loss on the route. It is defined as the mean of the total number of accidents recorded for all road sections, taking into account the level of confidence.
– Analysis of separate road sections, taking into account the principle that each and any infrastructure section is considered a HRS, provided the number of accidents recorded in this area exceeds the threshold value of:

$$LW > LW_s + PU * OS/no \quad (1)$$

where:
LW – is the number of road accidents on the i-th section of the analyzed route,
LW_s– is the average number of accidents recorded on the analyzed route,
PU – is the confidence interval,
OS – is the standard deviation,
no – is the total number of analyzed road sections.

– Selection of criterion for distinguishing sections of route with high frequency and severity of the consequences of accidents (table 5).

Stage 4 - Splitting the route into HRS according to adopted criteria. According to Madsen (Madsen, 2005), there is a need for a systematic approach to the isolation of Black Sections. Therefore, the authors suggest that during the selection of such fragments of the surveyed route the following groups of criteria should be applied:

– the minimum difference in the value of annual deviations in road accidents number and damage suffered as a result (three-year accident statistics required),
– maximum convergence of factors that could affect recorded accidents,
– maximum convergence of local risk factors related to infrastructure design and traffic management that had an impact on accidents.

Designated sections may refer to specific groups of sensitive loads and take their specificity into account. As a result of identification made, it was found that in majority of cases the location of selected HRS is similar to the existing locations on the tested route for transporting sensitive cargoes. Therefore, in further part of the article the attention was focused on selecting the road sections on which errors (miscalculations) appear, which affect the risk of non-performance of transport task.

Table 5. Criteria for distinguishing sections of the route with high frequency of accidents and severity of their consequences (own elaboration based on (Sorensen and Pedersen, 2007))

Criterion	**Initial assumption used for analysis**	**Conclusion**
Causes of traffic accidents	Driver errors during transport	Complete prevention of traffic accident is impossible
	Miscalculations of infrastructure designers	Reducing the risk of accidents possible
Effects of traffic accidents	Light damage. Damage to health resulting in inability to work not longer than 28 days.	Traffic accidents should not be prevented at all cost
	Severe damage. Damage to health that does not give a chance to survive	Investments in risk reduction required

3.3. Grouping of information based on the results of route audit

Yet another element of the proposed methodology is the analysis of information obtained as a result of route audit. We suggest to divide the procedure for organizing the dataset of information in this case into 5 stages:

Stage 1 - Assessment of impact of various factors on possible accident rates in the respective fragments of infrastructure. At this stage, fragments of infrastructure are identified as potential zones of increased risk and their interconnections are investigated. In order to carry out this assessment, method of analyzing the membership of the tested element to a set Z - zones can be applied. The result of stage 1 provides the basis for integration of similar zones selected in the so-called clusters/groups.

Stage 2 - Determination of the proximity measure of high risk areas.
We can call a proximity measure such a function, which assigns - to each of Z zones - numeric values that meet the following conditions:
– proximity measure does not adopt negative values, but it can be nil, $\mu(X1) \geq 0$,
– proximity measure of an empty set is always 0, i.e. $\mu(\emptyset) = 0$.
We formalize the notion of proximity measure:

$\mu(X1) = 1$, when $X1 \in Y \vee$
$\mu(X1) = 0$, when $X1 \notin Y$, (2)
where:
$X1$ – is an identified high-risk zone,
Y – is the cluster of similar high risk zones.

This stage is based on the procedure of sorting information contained in a disordered set. It has an analytical function, whereby it is possible to determine the factors shaping emergency situations in road traffic. In analyzed case, the sorting is carried out in order to distinguish the elevated risk zones located on routes of sensitive cargoes transports. The threat level of liquidity of supplies in such zones is measured by an integral indicator "threat level" with its basic variable in form of the degree of imperfection of road infrastructure. This level takes into account the lack or excess of road signs, limited visibility fields, too-tight corners, high road curvature, steep descents, lack of emergency belts, low number of parking bays, difficulties when changing direction or lane, etc. Two additional factors may also be taken into account:
1) The degree of working order of road transport means. According to the report of Polish General Police Headquarters, in 2017 there were 40 road accidents in Poland, in which the technical failure of HGVs was direct cause. Six people died and 49 were wounded in these. It should be emphasized that technical inspections at the scenes of accidents revealed vehicle defects. A total of 121 defects were found in the report. The most noted defects were in lighting system (45.5% of the total) and improper condition of the tires (25.6%). There were also cases where more than one defect was found (KGP, 2018).
2) The impact level of human factor. In the "*driver-vehicle-road*" interactions, technical progress is directed primarily at increasing the driving comfort, which may contribute to the emergence of new threats. Let us quote several examples:
– soundproofing HGV leads not only to noise reduction (comfort), but also reduces the information on lane departure - crossing the white line on road surface (*and thus creates a new threat*),
– improved suspension combined with high quality of roads, increases driving comfort, but also gives the opportunity to increase the speed of cars (*new threat),*
– reduction of fuel consumption makes it possible to travel longer, which increases the negative impact of monotony, and consequently increases the likelihood of driver fatigue (*new threat*),
– increasing the number of information directed to driver while driving increases the distraction of his attention (*new threat*), etc.

Stage 3 - Development of cluster groups using the proximity measure function of different high risk zones. At this stage cluster groups are developed using the proximity measure function of different high risk zones $M = [\mu(X)_{ij}]$. Therefore, one needs to find two zones $X1$ and $X2$, which are closest to each other due to similarity of their characteristics:

$M[X1, X2] = \min[\mu(X)_{ij}]$, (3)
where:
i – are factors that increase the risk of an accident as a result of design miscalculations on the examined road infrastructure segment, $i = 1, \ldots, I$,
j – are factors that increase the risk of an accident as a result of negligence in operating the examined road infrastructure segment $j = 1, \ldots, J$.

Stage 4 - Creating the metric space. Creating the metric space should meet the following principles:
1) Each and any zone of increased risk $X1$ belongs to the cluster Y as part of the set of studied fragments of road infrastructure Z, however $Y \subset Z$, because otherwise this zone would belong to another cluster.
2) If two zones $X1$ and $X2$ are disjoint ($\mu = 0$), then only one of them can belong to the Y cluster. If none of the zones belong to the Y cluster, then the cluster is empty ($Y = \emptyset$).

As a result of the tests we found that the use of clustering procedure allowed for a radical reduction of information required to generate new knowledge about the methods of ensuring required level of safety during transport of sensitive cargoes. The conclusion results from the fact that each of separated clusters can be replaced by one of its representatives (the rest is similar).

Stage 5 - Analysis of developed clusters. Two cluster analysis techniques can be used in practical applications:
- use of Partitioning Algorithms. They are based on the assumption that there is an optimal division of the set of information into a respective number of clusters.
- use of Density-Based Algorithms. They divide information sets into clusters, using the probabilistic model for predetermined clusters.

When analyzing the location of characteristics of increased risk zones, two proximity parameters can be taken into account:
- R_{max} – maximum neighbouring radius of two HRS,
- $\min n$ – minimum number of zones in vicinity R of each cluster.

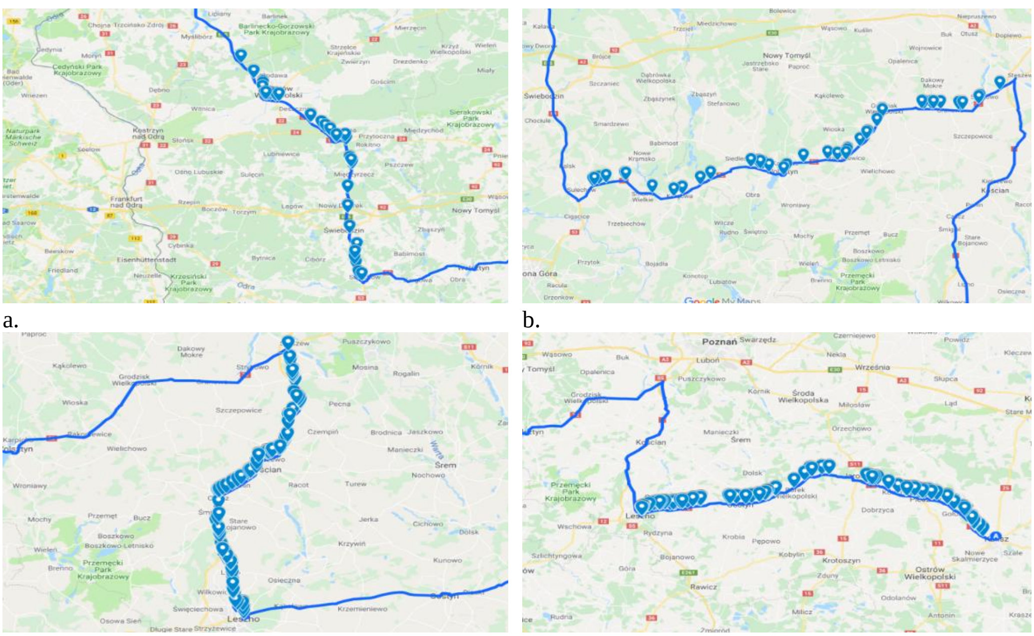
– The vicinity of two zones can be described as:

$$M\,[X1, X2] = [1.0 \geq \mu(X1, X2) > 0, \text{ when } R_{max} < R_{dop} \text{ and } \min n > 0], \quad (4)$$

Based on the formulated approach, different sets of information on the safety of sensitive cargo transport can be analyzed and evaluated.

4. Results

In order to verify the suggested methodology of information analysis we analyzed a selected route in Poland, running from Kalisz to Szczecin. This route was selected because there is a concentration of 71 manufacturers of sensitive products, i.e. meat and milk products, in its vicinity, which sets 25% of all manufacturers located in Poland. For the selected route we conducted road accident analysis (see Fig. 1) and performed an audit in October 2018, which allowed for segregation and grouping of information on its safety.



a. b. c. d.

Fig. 1. Mapping road accidents on Kalisz to Szczecin route (reported crashes from 2015 to 2017), where: a-b-c-d - are the sections of analyzed route (own elaboration based on (KGP, 2018))

The total length of the route was 460 km. In order to conduct the analysis the route was divided into 92 sections, the length of each section was 5 km. Particular sections were analysed separately regarding the risk of accidents occurrence considering available statistical information on road accidents and information collected during the road audit. Then it was possible to set the clusters with similar levels of risk occurrence.

In the result of route examination we achieved the segregation of information on zones of higher risk of accidents within the limits of a relatively small number of clusters. During the cluster grouping process:

- we included information on road accidents from three years (2015-2017),
- we eliminated irrelevant information,
- we ordered fragments of the tested route with increased risk according to measures of proximity of sections with a high probability of accidents.

During the audit of selected route, it was found that a number of incorrect design solutions were applied on its separate sections, which may lead to high values of the severity factor for potential collisions and indicator of possible post-accidental losses (death or health impairment, destruction of goods, loss of profits or income, missing a ride, property damage). In the result of the research 20 types of errors in infrastructure were identified. The most common errors were:

- poor visibility on curves of infrastructure elements (occurs on 31% of the route sections),
- proximity to technical infrastructure elements (occurs on 15% of route sections),
- too small curve radius (occurs on 11% of route sections),
- incorrect road marking (occurs on 9% of route sections),
- invalid road geometry (occurs on 9% of route sections) etc.

The areas of the route, where high-risk zones threaten the traffic safety of vehicles carrying sensitive loads were identified in the result (see Fig. 2). These zones will form the basis for designation and analysis of clusters of separated risk zones, which will be the subject of further scientific research conducted by the authors.

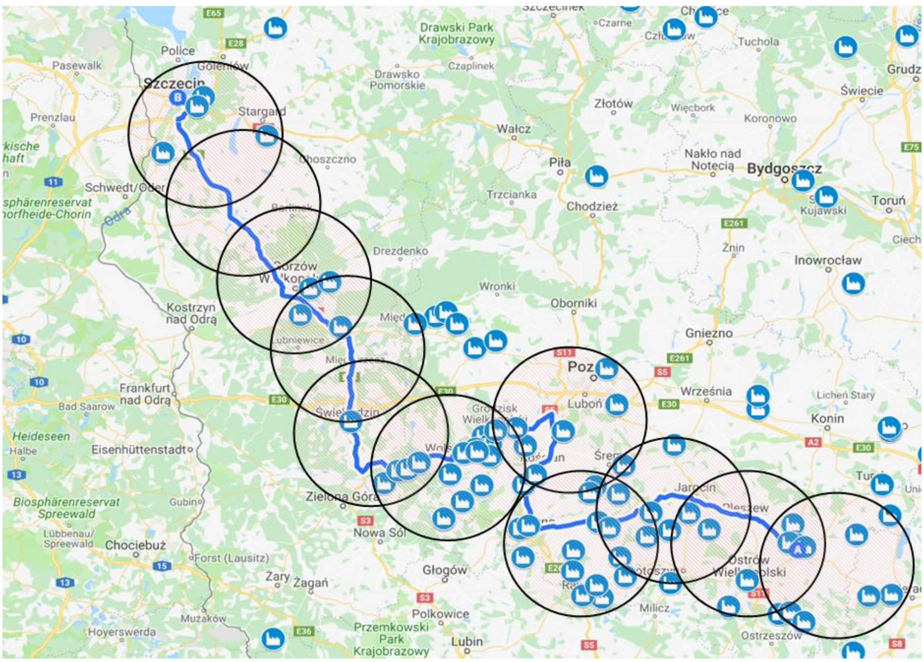


Fig. 2. The high-risk zones located on Kalisz to Szczecin route (own elaboration).

5. Conclusions

The article presents an integrated approach to analysis and application of information relevant to transportation planning of sensitive cargo. The application of the results of present research creates the possibility for:

– assessing the information on accident rate of road transport on selected routes of distribution of sensitive cargo in a more appropriate manner,
– performing preliminary tests in field of ensuring the safety of conveying sensitive cargo along selected routes,
– separation of zones with an increased risk of safety loss using two methods - descriptive method (qualitative analysis) and experimental method (quantitative analysis),
– development of clusters of separated risk zones on the selected route of sensitive cargo transportation,
– adaptation of preventive emergency situations technologies to selected transport route of sensitive cargo, etc.
– Based on our research, it can be concluded that:
– drawing conclusions from the history of already existing emergency situations is useful in the case of developing a plan for sensitive cargo transport, the implementation of which is planned on the same route, and in very similar environmental (e.g. atmospheric) conditions,
– ordering data sets and discovering knowledge of the characteristics of clusters of high risk zones allows for earlier identification and diagnosis of possible issues of loss of safety of sensitive cargo transport, already at the initial planning stage, and that regardless of the type of transported cargo or environmental conditions.

Hazardous fragments of road infrastructure should be identified by analyzing the number of accidents in relation to particular fragments of road infrastructure. Such identification should be made for all fragments of road infrastructure with a length of up to 2-10 km. Selected fragments can be classified to homogeneous groups of HRS, as for example to group (cluster) of poorly visible road curves, intersections, motorway exits, etc. The selection process should be carried out by means of appropriate procedures that will be capable of forecasting the future number and consequences of road accidents in analyzed of road infrastructure fragments.

Research within the subject matter may be of interest to entities involved in planning and organizing transports of sensitive cargo. Continuation of the research will include, among others, development of methods for grouping and clustering information on Polish road transport infrastructure in context of sensitive cargoes transportation.

References

[1] BARCIK, J., & CZECH, P., 2010. Wpływ infrastruktury drogowej na bezpieczeństwo ruchu – część 1. *Zeszyty Naukowe. Transport /Politechnika Śląska* 67, 13-21.
[2] BRANNOLTE, U., & MUNCH, A., 2009. Software-based road safety analysis in Germany. *4th IRTAD Conference Seoul*, South Korea, 16-17 September.
[3] CSISZÁR, C., & FÖLDES, D., 2018, System Model for Autonomous Road Freight Transportation. *Promet-Traffic & Transportation* 30(1), 93-103.
[4] European Transport Safety Council (ETSC), 1997. Road safety audit and road safety impact assessment. Brussels.
[5] GACA, S., & POGODZIŃSKA, S., 2017. Speed management as a measure to improve road safety on Polish regional roads. *Archives of transport*, 43 (3), 29-42.
[6] GALKIN, A., DAVIDICH, N., MELENCHUK, T., KUSH, Y., DAVIDICH, Y., & LOBASHOV, O., 2018, Modelling truck's transportation speed on the route considering driver's state. *Transportation Research Procedia* 30, 207-215.
[7] GHADI, M., & TOROK, Á., 2017. Comparison different black spot identification methods. *Transportation Research Procedia 27*, 1105–1112.
[8] Guidelines for competent authorities on the application of the Directive *2008/96/EC on road infrastructure safety management*. 19th December EU 2011.
[9] ISO 39001, 2012. *A management system standard for road traffic safety*. Requirements with guidance for use, October.
[10] JAMROZ, K., BUDZYŃSKI, M., KUSTRA, W., MICHALSKI, L., & GACA, S., 2014.

Tools for road infrastructure safety management – Polish experiences. *Transportation Research Procedia* 3, 730–739.

[11] KHAN, F. I., & ABBASI S.A., 1999. Major accidents in process industries and an analysis of causes and consequences. *Journal of Loss Prevention in the Process Industries* 12(5), 361-378.

[12] KOMENDA GŁÓWNA POLICJI (KGP), 2018. *Wypadki drogowe w Polsce w 2017 r.*, Warszawa.

[13] KOSTRZEWSKI, M., & VARJAN, P., 2018, The issue of parking areas conditions in surrounding of logistics and production facilities in Slovakia and Poland. *Transport Means - Proceedings of the International Conference 2018*, 791-796.

[14] LAMR, M., 2018. Big Data and Its Usage in Systems of Early Warning of Traffic Accident Risks. *In 2018 Sixth International Conference on Enterprise Systems*, pp. 154-157. IEEE.

[15] LAWSON, S., 2011. Crash rate – Star Rating comparisons. Review of available evidence. Working Paper 504.2, EuroRAP, Brussels.

[16] LI, T., YANG, Y., WANG, Y., CHEN, C., & YAO, J., 2016. Traffic fatalities prediction based on support vector machine. *Archives of Transport*, 39 (3), 21-30.

[17] MACIOSZEK, E., 2015. The road safety at turbo roundabouts in Poland. *Archives of Transport*, 33 (1), 57-67.

[18] MADSEN, O., 2005. From crash prevention of loss reduction in the Danish, Ph.D. thesis, Traffic Research Group, Department of Development and Planning, Aalborg University, Aalborg.

[19] MASHROS, N., HASSAN, S., HARYATI, Y., AHMAD, M. S. A., SAMAT, I., PUAN, O. C., HASSAN, N.A., YUNUS, N.Z.M., HARON, Z., 2018. Road traffic accidents on Senai-Desaru expressway. *In MATEC Web of Conferences*, vol. 250, p. 02002. EDP Sciences.

[20] MORIN, D. A., 1967. Application of statistical concepts to accident data. *Highway Research Record* 188, 72–80.

[21] MUSLIM, N. H. B., SHAFAGHAT, A., KEYVANFAR, A., & IAMAIL, M., 2018. Green Driver: driving behaviors revisited on safety. *Archives of Transport*, 47 (3), 49-78.

[22] NORDEN, N., ORLANSKY, J., & JACOBS, H., 1956. Application of statistical quality-control techniques to analysis of highway accident data. *Highway Research Board Bulletin* 117, 17–31.

[23] PATANKAR, A., WALUNJ, S.G., PIMPLE, A., & KADHANE, D., 2017. Blackspot warning system identification and analysis. *Vishwakarma Journal of Engineering Research* 1 (4), 201-206.

[24] PIARC, 2007. *Road Accident Investigation Guidelines For Road Engineers*.

[25] RAMOS, L., SILVA, L., SANTOS, M.Y., & PIRES, J., 2015. Detection of road accident accumulation zones with a visual analytics approach. *Procedia Computer Science* 64, 969 – 976.

[26] RZECZPOSPOLITA, 2017. Przewóz towarów wrażliwych pod kontrolą Służby Celno-Skarbowej, URL: https://www.rp.pl/Firma/304119984-Przewoz-towarow-wrazliwych-pod-kontrola-Sluzby-Celno-Skarbowej. 11.04.2017.

[27] SKRODZKA, I., 2015. Development of knowledge-based economy in European union in 2000-2014. *Quantitative Methods in Economics* XVI (2), 113 – 122.

[28] SORENSEN, M., & ELVIK, R., 2007. *Black spot management - best practice guidelines and implementation steps.* Report 919.

[29] SORENSEN, M., & ELVIK, R., 2007. *Black spot management and safety analysis of road networks - best practice guidelines and implementation steps.* The Institute of Transport Economics, Oslo, Norway, 118 p.

[30] SORENSEN, M., & PEDERSEN, S., 2007. Injury severity based black spot identification. *Annual Transport Conference at Aalborg University*, 1-10.

[31] THE WORLD BANK, 2013. *Przegląd potencjału w zakresie zarządzania bezpieczeństwem drogowym w Polsce*. Report 78319.

[32] TM, 2011. *Technical guidelines for the preparation of road safety audits, Road Safety Impact Assessments and Road Safety Inspections*, October. URL: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/topics/infrastructure/national-guidelines/pdf/malta-national-guidelines.pdf.

[33] VIVEK, & SAINI, R., 2015. Identification and improvement of accident black spots on N.H.- 3 district Una, Himachal Pradesh - A Case Study. *International Journal of Core Engineering & Management* 2(3), 155-177.

[34] WHO, 2018. *Road traffic injuries*. URL: http://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries. 19.02.2018.