БЕЗОПАСНОСТЬ ДОРОЖНОГО ДВИЖЕНИЯ

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USE OF JSM-METHOD TO FIND REGULARITIES OF THE ROAD ACCIDENTS RISING

O. Poletaykin, Assoc. Prof., Ph. D. (Eng.), Siberian State University of Telecommunications and Informations sciences, A. Kostenko, Assoc. Prof., Ph. D. (Eng.), Donetsk Academy of Motor Transport

Abstract. *The use of the JSM-method for problem solving of determining regularities of traffic accident occurrance resulting in injured participants is considered. As a solution of the problem they proposed the cause-and-effect relationship system, which makes it possible to develop solutions directed to impove the traffic safety on the motorroads of Ukraine.*

Key words: *registration card of an accident, cause-and-effect relationship, data extraction, generation of hypotheses, intelligent analysis of accidents.*

ЗАСТОСУВАННЯ ДСМ-МЕТОДУ ДЛЯ ПОШУКУ ЗАКОНОМІРНОСТЕЙ ВИНИКНЕННЯ ДОРОЖНЬО-ТРАНСПОРТНИХ ПРИГОД

О.М. Полєтайкін, доц., к.т.н., Сибірський державний університет телекомунікацій та інформатики, А.В. Костенко, доц., к.т.н., Донецька академія автомобільного транспорту

Анотація. *Розглянуто застосування ДСМ-методу для розв'язання задачі визначення закономірностей виникнення ДТП із постраждалими учасниками. Як вирішення задачі передбачається система причинно-наслідкових зв'язків, що дозволяє здійснювати вироблення рішень з підвищення безпеки дорожнього руху на автошляхах України.*

Ключові слова: *карта обліку ДТП, причинно-наслідковий зв'язок, збір даних, визначення закономірностей виникнення ДТП, інтелектуальний аналіз аварійності.*

ПРИМЕНЕНИЕ ДСМ-МЕТОДА ДЛЯ ПОИСКА ЗАКОНОМЕРНОСТЕЙ ВОЗНИКНОВЕНИЯ ДОРОЖНО-ТРАНСПОРТНЫХ ПРОИСШЕСТВИЙ

А.Н. Полетайкин, доц., к.т.н., Сибирский государственный университет телекоммуникаций и информатики, А.В. Костенко, доц., к.т.н., Донецкая академия автомобильного транспорта

Аннотация. *Рассмотрено применение ДСМ-метода для решения задачи определения закономерностей возникновения ДТП с пострадавшими участниками. В качестве решения задачи предполагается система причинно-следственных связей, которая позволяет осуществлять выработку решений по повышению безопасности дорожного движения на автодорогах Украины.*

Ключевые слова: *карта учета ДТП, причинно-следственная связь, извлечение данных, определение закономерностей возникновения ДТП, интеллектуальный анализ аварийности.*

Introduction

The problem of road traffic injuries is of current importance. The Transport Research Results [1] in 2001–2011 defined the European transport policy for the next Decade of road safety. The results of this study highlight four main directions of strategic development:

1) improving the drivers safety;
2) creation of the safer vehicles;
3) the road infrastructure safety improving;
4) accumulation of databases of the accidents and statistic estimation of road safety.

The fourth direction includes the preparation and maintenance of joint database of road accidents and the use of methodologies and tools for risk analysis and evaluation of various road traffic safety aspects.

Analysis of publications

We should pay your attention to the identification methodology and in-depth study of causal relationships and identifying the regularities of the accidents rise. One of the well-known such methodologies is the JSM-method, named after John Stuart Mill [2], which is widely used now in the analysis of sociologic data. This research method of the regularities is based on induction methods proposed by this scientist. The JSM-method is based on Mill's idea that common effects are likely to be due to common causes. The JSM-method is being developed since the 1980s and is used for realization of a causal analysis technique.

At the moment, an intelligent system such as JSM is created for different subject areas: pharmacology, medical diagnostics, sociology, criminology, robotics, and others. The creation of intelligent systems that implement cognitive reasoning in the study of road traffic accidents is caused by the need of the qualitative analysis of large number of collected data about accidents, and qualitative interpretation which allow to make conclusions about the effectiveness of economic sectors associated with the operation of road transport and road networks, such as the automotive industry, road construction and repair and maintenance services, legislative, health, social services and education sector [3].

The aim of the article

Study of the JSM-method use during the causal analysis to determine the regularities of traffic accidents rising.

Causal study to road accident

The essence of the JSM method is as follows. Three finite sets are introduced: as a set of reasons $A=\{a_1, a_2, \ldots, a_p\}$, consequences $B=\{b_1, b_2, \ldots, b_m\}$ and estimates $Q=\{q_1, q_2, \ldots, q_l\}$. Expression $a_i \Rightarrow b_j$; q_k is called *positive hypothesis*. It is associated with the statement «a_i is the reason of b_j, with of the reliability estimation of q_k». Expression $a_i \not\Rightarrow b_j$; q_k is called *negative hypothesis*. It is associated with the statement «a_i is not the reason of b_j, with the reliability estimation of q_k».

To reduce the notation the positive hypothesis is denoted as h_{ijk}^{+} and negative hypothesis is denoted as h_{ijk}^{-}. Among the meanings of qi there are two special meanings, which can be denoted as 0 and 1. A value of 0, attributed to positive or negative hypothesis means that the corresponding statement is false. Attributing hypotheses value of 1 means that this hypothesis is identically true. Thus, the hypothesis with a score of 0 and 1 can be regarded as statements whose truth and falsity firmly established. All other estimates differ from 0 and 1 are denoted by rational numbers of the s/n form, where s runs from 1 to n–1. The value of n characterizes the «granularity» of used reliabile estimation.

We suppose that while the registration of road traffic accidents among technical faults of one of the car- offender, defective steering is found. In some time again in the vehicle that is involved in traffic accident, it is detected broken steering. It raises the positive hypothesis as «If there is broken steering in a moving vehicle, it is potentially responsible for an accident». Evaluation of the reliability of this hypothesis with these two observations will be small. However, if during further study of this question it'll occur that the cars involved in the accident, had broken steering system, the estimation of this hypothesis will grow all the time, but this estimation will never be equal to 1. In this regard, we'll introduce two types of truth: empirical and theoretical truth. In this example, the statement about the potential involvement in the accident is set as empirical truth, because all observations were in favor of this hypothesis. However, it can be assumed that there are a small number of vehicles with the same faults that have not provoked the accident, and therefore they do not atract the researcher's attention. Quite a different position would be in the cases when in traffic rules it will be said that «further movement of vehicles is prohibited if the steering does not allow the driver to carry out the maneuver driving with a minimum speed» [4]. With this information statement about involvement in the accident moving car

with faulty steering will be evaluated as a theoretical truth.

The given example illustrates the estimation process of validity degree of the hypothesis when the alleged cause (in this case it is the car defect) is already selected from a variety of possible causes. In JSM method not only this stage is formalized, but the preceding stage of finding a candidate for reasons that could cause the interest of the investigation (in this case – the involvement in the accident). In this example, this corresponds to the next. Looking at the flow of vehicles in the streets and separating cars with steering defects, it is necessary to «understand» that such cars can provoke an accident. All these arguments suggest, «The reason is different» that is, the causes may vary according to the type and importance of relative influences with the investigation. We will consider this problem in detail.

The object model of causality

The causes may be different according to the type. Fig. 1 shows the different types of causes and their inheritance relationship according to the superclass of Causes. The necessary and sufficient causes are the rarest. If a_i is the cause of this type, then b_j always happens, and if b_j takes place, it certainly is a_i. The examples of such «hard» connection between the two phenomena may serve as falling body, if there is no support for it. More often the sufficient causes occur which always cause the appearance of b_j. But appearance of b_j is not the fact that before it was a_i. Consequence of b_j could be caused by some other sufficient reasons. For example, a possible cause of the accident can be vehicle firing while motion, because it is quite enough that the situation will be as an accident, which is given in article 1.10 in Traffic Rules of Ukraine, but it is likely that there could be other causes of this accident.

Additional causes have the property that their presence does not cause b_j. To appear b_j, we need a well-defined set of additional reasons, which acts as a generalized sufficient cause of b_j. It is easy to imagine a set of these reasons that lead, for example, to involve the car in an accident while moving in the city at rush hour in conditions of poor visibility. Enumeration and discussion of additional factors that led to the accident is ordinary occupation for participants or witnesses of the incident. Among the additional causes additional causes may be necessary. Their entry into the set, generalized sufficient cause, nessecary for b_j to be realized (Fig. 1, this ratio is displayed with composition icon). Other additional causes are optional. In the final set they may include a combination of these or other required and elective reasons. Thus, when the accident occurs such as «striking the absticle» two additional reasons are obviously necessary: 1) the vehicle and 2) the intersection of its motion trajectory with an obstacle. The rest of the additional reasons are optional. Finally, the possible causes a_i have the property that the appearance of a_i is not necessarily leads to b_j, but increases the possibility of b_j appearence.

Except of the a_i reasons the important role in the realization of causal relationships brakes do. The brake with the reason causing b_j under conventional conditions leads to the fact that there is no b_j. Thus, the above mentioned accident such as «striking the absticle» do not occur if the driver keeps extreme attantion while driving at a minimum speed.

After that it is clear that the determination of the causes-candidate for hypotheses generated is not a trivial task. In the positive and negative examples of these reasons are hidden in the descriptions of real objects, with or without interesting properties for researchers. From these descriptions we should highlight the causes – candidates, and then make sure that the choice was not accidental.

The use of JSM-method for solving this problem is as follows. We consider the group of positive examples. We find some of the objects descriptions common to a particular set of examples of this group. For example, we find a large part of the accidents like «running over a pedestrian» because of the illumination absence on the road in the dark. Then there's reason to believe this cause as candidate to causes. Such candidates may be several. We form the matrix M^+, in which the rows correspond to the selected candidates a_i, and columns to interesting for us b_j consequences. At the intersection of rows and columns we'll write q_k validity assess of $h_i^+{}_{jk}$ hypotheses. About their finding we will discuss. For a set of negative examples other matrix M is constructed in same way which contains validity assess of negative $h_i^-{}_{jk}$ hypotheses. Candidates for the reasons in the matrices M^+ and M^- may partly coincide, as positive and negative examples do not form a complete sample of many possible examples.

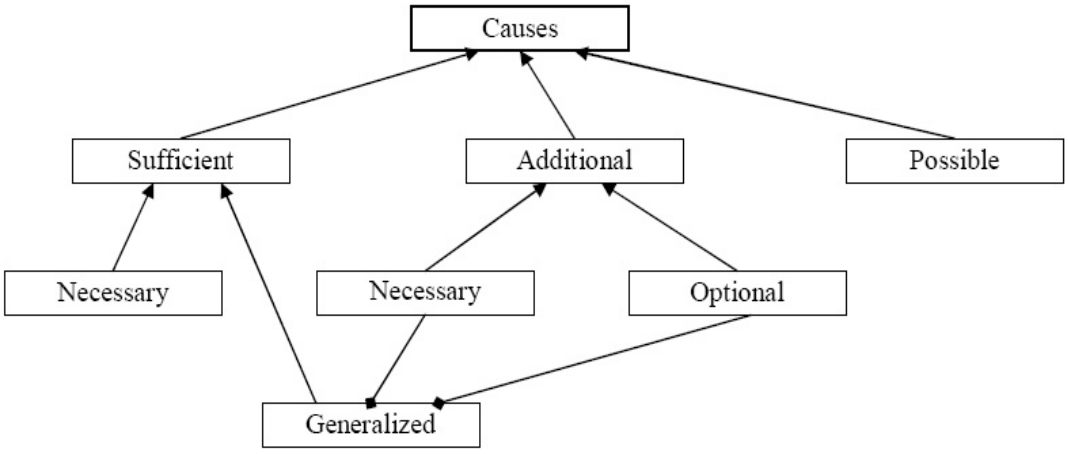

Fig. 1. The relationship between the cause types in UML notation

At each step of the JSM method using the new observations are supplied the set of positive and negative examples. These new observations may either confirm the hypothesis of $h_i^+{}_{jk}$ and $h_i^-{}_{jk}$ generated, or contradict them. In the first case, validity assessment of the relevant hypotheses is increasing, while the second is decreasing. The mechanism of assessment changes of q_k may be different. In JSM-method it is arranged as follows. The value of n coincides with the number of currently available positive and negative examples. Thus, for M^+ and M^- to n may be different. With n rising discreteness of the estimates reliability increases. The estimation of $1/n$ has a special role. It corresponds to the total ignorance of the hypothesis validity. Therefore, in the initial moment M^+ and M are only filled with zeros, ones and estimation of $1/n$. The values of truth and false may have a hypothesis in which as the reasons complete objects description is given that formed a set of examples.

If a positive or negative hypothesis of $h_i^-{}_{jk}$ had k/n assessment, then when a new example (n in this case is replaced by n+1) is checked, confirmed or not confirm as a new example of this hypothesis. During confirmation of k/n estimation is replaced by $(k+1)/(n+1)$, and for example if is not confirmed by the new hypothesis its estimation varies from k/n at $(k-1)/(n+1)$. Thus, in the accumulation of new information of hypothesis evaluation approach to 0 or 1, or a range between the boundary values. In the first case, the hypothesis may disappear from the M^+ or M^- at some stage. In the second case, when a certain upper threshold hypothesis reliability can obtain an estimate that reflects empirical truth. In the third case, if estimation of fluctuation is strong enough exception can also occur of earlier hypotheses generated described in the M^+ and M^-.

New hypotheses are formed not only on the basis of allocation of a certain similarity in the examples (in the general part of the description). They can use the method of differences, that is formulated by Mill [2] and adapted to problems of automatic generation of hypotheses in intelligent systems [5]. The difference is detected for examples of groups of positive and negative examples. The obtained difference is a candidate for the hypotheses included in the M^+ or M^-.

Except identification of candidates in a_i reasons for positive and negative hypotheses in the described method and also brakes are researched, the presence of which removes the effect of a_i to appearance of b_j. In new versions of the method [6] as a_i there are very complex statements, in which separate parts of the objects descriptions can be linked with arbitrary logical expressions, for example: «If in the object there is a' and a'' and no a''', or the object has a'''' the property of b takes place.»

As already mentioned, in the JSM-method except direct implementation of Mill's ideas it is used some conclusions by analogy [5, 6]. If, for example, it is structural formulas of the chemical compounds, the measure of similarity for them may be in coincidence of the structures themselves, or the positions of different fillers, or conversely, the presence of some fixed positions structures of identical elements. If attitude similarity is determined, in the JSM-method conclusion is made by analogy. It works in the following manner. If the hypothesis h_{ijk} has k/n essesment, and the sence is that the reason it is used is similar to the reason in the hypothesis of

h'_{ijk}, available in the same matrix M and it is evaluated in terms of the value reliability of $1/n$. the evaluation hypothesis of h_{ijk} is transferred to hypothesis of h'_{ijk} and it gets authenticity assessment of k/n. Such procedure in JSM-method is called *the rule of positive analogy*. There is in this method and *the rule of negative analogy*, as well as the gradition of those and other rules taking into account the strength of similarities. Thus, the JSM-method demonstrates the conducting possibility of plausible discussing of very wide spectrum.

Studies of road transport accidents using the JSM-method. To conduct applied research data was used that extracted from the 510 cards of traffic accidents with victims, registered in Donetsk in the period from January 1 to July 31 2013. As many additional and possible causes (set A) and effect (set B) it is adopted a set that includes a full set of values in selected fields of accounting accidents cards (Fig. 2), which in some way determine the causal picture of the accident.

There the fields are marked with single contour data which give a single value from its possible values field. The fields of data is marked with double circuit which give a set of values (e.g., field $A7$ suggesting entering up to 3 different elements of the road or field $A14$ in which the number of values in this case corresponds to the number of accident participants), relatevily to the particular case corresponds to «many-to-one» connection. The list of accounting cards of accidents is classified as sources of cause data ($A1$–$A27$) and consequences ($B1$–$B8$) during the accident, are presented in Table. 1.

Thus, according to the data in table. 1, all potential candidates in accidents causes (except degraded set $A3$) are 426, and the consequences of characterizing the causal picture of the accident are 44. For the study sample of 510 cases, they are all loaded data elements, taking into account the multiplicity of most symptoms (22 of 35) 15728 characteristic values of A and 4786 feature values of B.

We should note the almost complete lack of data on the basis of the $A6$, $A9$ and $A11$ concerning technical condition of the road. This circumstance is beyond common sense, as it creates the impression of perfect condition of Ukrainian roads. So, the official statistics of the Department of Traffic Police [7] states that in 2013 from 191 thousand of accidents in Ukraine only 114 accidents are committed because of the road owners fault. It is not true. In fact, every twentieth accident in Ukraine happened due to violations of the technical road condition and road maintenance errors [8].

Also, $A21$ and $A25$ are not popular with their case multiplicity. It expanse the imperfection of procedural proceedings to accident victims where conclusions about the actual violation of Traffic Rules and defects of vehicles can only be done at auto technical examination, and sometimes only when the investigation of an accident is complete.

This state of affairs is due in particular to the activities of insurance companies, which, according to the current legislation, have right to refuse in insurance payment to accident participant when the data in map of accident records and conclusion of autotechnical examination and the court's decision are not coordinated. Except the rules such as in 1.5, 8.1 paragraphs and others the violation of which is not in doubt, as well as paragraphs which showed offenders themselves (e.g., 10.2, 4.10 and others).

In this case, the inspector registrating the accident has the righ to write this information in $A21$ field. As for the technical faults (field $A25$), to put them in an accident card is possible provided that fault is obvious, and it is in the practice of accident registration is rare phenomenon.

Thus, the data in the fields $A6$, $A9$, $A11$, $A21$ and $A25$ due to their scarcity will not be taken as an additional possible causes- candidate. The other data is quite abundant and even at surfacial analysis reveals some patterns, which, however, require proof of their accuracy and reliability.

The further research of the intilectual analisis of an accident to some modern modifications of this method should be directed to, such as JSM-method of automatic generating hypotheses by G. Finn [5], the theoretic set of JSM-method [9], and others. This requires the creation of a software system, which algoritmize as classic JSM-method and its modifications described above. And to obtain a more complete picture of accidents in the annual period it should be supplement with information obtained data of accidents during 8–12 months in 2013 and all months in 2014.

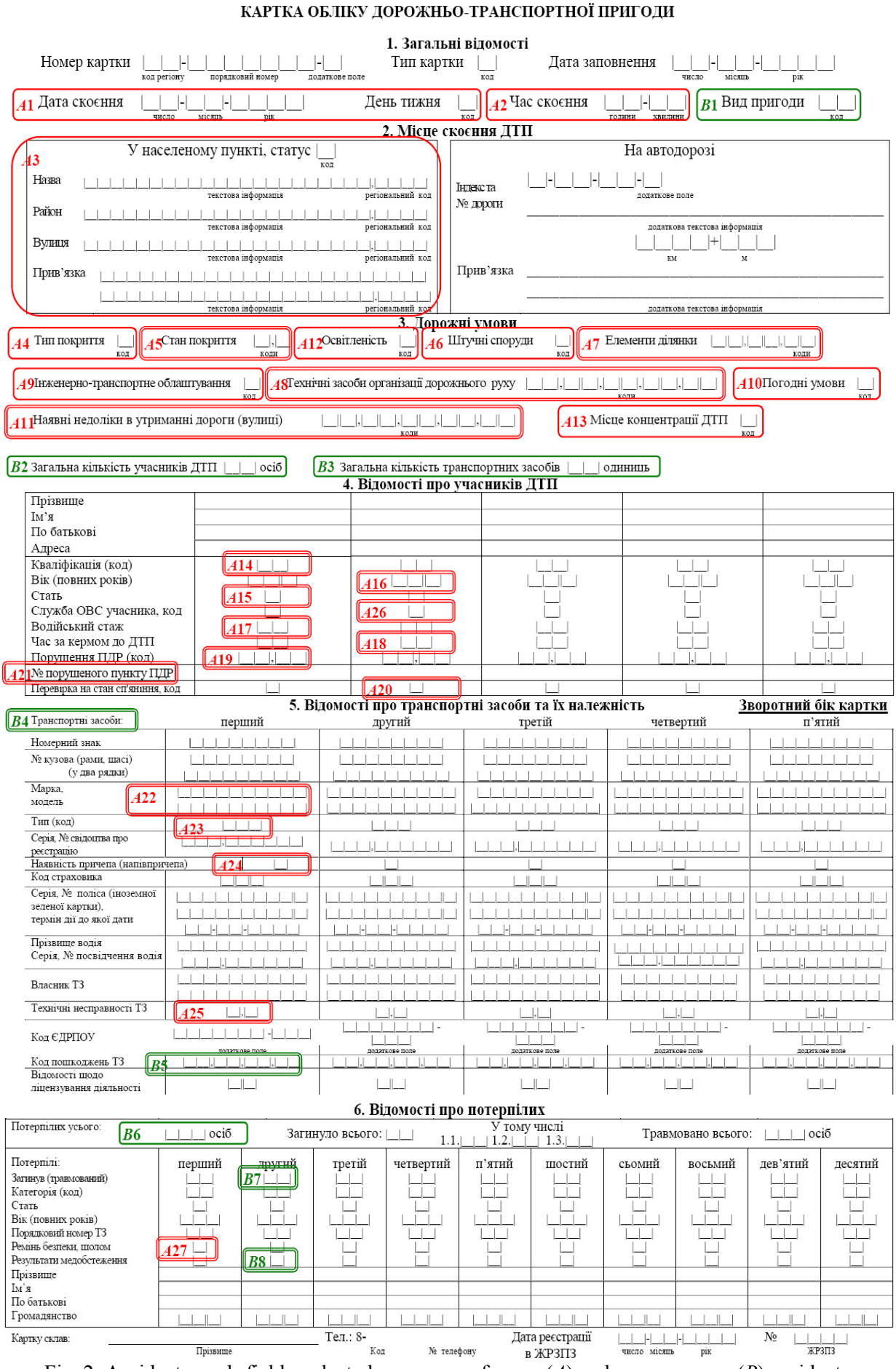

Fig. 2. Accidents cards fields, selected as sources of cause (*A*) and consequences (*B*) accident

Table 1 Fields-sources of data of cause and consequences during the accident

Name	Title	Part number of card	Multiplicity comparatively accident	Power of data elements ensembles	Total loaded data elements
*A*1	Day of week	1	1	7	510
*A*2	Time of day	1	1	7	510
*A*3	Place of accident	1	1	–	510
*A*4	Type of road surfacing	3	1	5	510
*A*5	Condition of road surfacing	3	M	3	510
*A*6	Artificial buildings	3	1	5	1
*A*7	Elements of road area	3	M	13	455
*A*8	Traffic management technology	3	M	10	361
*A*9	Engineering-transport equipping	3	1	5	0
*A*10	Weather conditions	3	1	6	510
*A*11	Defect in the maintenance of the road	3	M	22	2
*A*12	Luminosity	3	1	2	510
*A*13	Place of accident concentration	3	1	2	510
*A*14	Qualification of participant	4	M	10	1196
*A*15	Sex	4	M	2	1175
*A*16	Age group	4	M	7	1175
*A*17	Driver's experience	4	M	6	708
*A*18	Drive time before accident	4	M	7	686
*A*19	Traffic violation	4	M	28	499
*A*20	Alcohol intoxication check	4	M	5	1175
*A*21	Break article number of traffic regulations	4	M	179	8
*A*22	Classes of transport facilities (make of car / model)	5	M	52	698/692
*A*23	Types of transport facilities	5	M	22	730
*A*24	Trailor availability	5	M	2	729
*A*25	Technical troubles of transport facilities	5	M	9	1
*A*26	Sort of occupations	6	M	2	1172
*A*27	Passive car safety facilities	6	M	2	877
Total in ensembles causes *A*:				**426**	**15728**
*B*1	Accident type	1	1	10	510
*B*2	Total participation	3	1	4	510
*B*3	Total transport facilities	3	1	4	510
*B*4	Location of transport facilities	5	M	6	749
*B*5	External damages of transport facilities	5	M	9	731
*B*6	Total victims	6	1	4	510
*B*7	Victims	6	M	4	648
*B*8	Injureds	6	M	3	618
Total in ensembles consequences *B*:				**44**	**4786**

Conclusions

The using of JSM-method permits to solve problems of determining reasons of traffic accidents.

It is made the system representation of input data for using JSM-method. It is shown the relation with the registration card of accident, the analisis of input data is made.

For further research it is necessary to create a software system that makes algoritm of classic JSM-method, and some modern modifications of this method.

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Рецензент А.В. Рябушенко, доцент, к.т.н., ХНАДУ.

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