INFORMATIONAL AND ANALITICAL ROUTE SAFETY ESTIMATION AND RISK CALCULATION SYSTEM FOR DANGEROUS OBJECT TRANSPORTATION

A. Agapov[1], A. Buchelnikov[1], A. Vaguine[2], A. Vikentjev[2], V. Mikheev[3], S. Poluektov[3]
[1]ROSATOM, Moscow, Russia, [2]MRTI RA, Moscow, Russia, [3] NPO Altey J S C, Moscow, Russia.

INTRODUCTION.

The problem of maintenance of nuclear and radiating safety of Russia demands the uniform approach to an estimation of radiation danger objects and development of criteria and technologies on maintenance of their safe functioning for the person and an environment.

Necessity of integrated parameters development for carrying out of the comparative analysis safety of various objects, systems and technological processes with the purpose of the subsequent forecasting and modeling of safety parameters behavior demands development and introduction of decision-making support system in the field of radiating and nuclear safety computer control.

The information-analytical decision-making support system (IAS) for safety control is intended for computer control of search, processing and display the information used in radiating and nuclear safety control. The system should promote decrease in breakdown susceptibility due to increase of administration knowledge level about a condition of safety at the enterprises and increases the decision validity accepted in the field of radiating and nuclear safety control.

Increase of a knowledge level means more operative results presentation of deeper initial information analysis, including opportunities of forecasting, planning and tracking the effect from accepted decisions and spent actions.

It is achieved due to application:

- multilateral quantitative and qualitative analysis of radiating and nuclear safety condition;
- complex quantitative estimation of a safety condition on the basis of the parameters set describing safety various aspects;
- effective forms of the analysis results report presenting to the making decision persons.

SYSTEM MAIN GOALS

-Granting to administration the operative access to the information on a condition of radiating and nuclear safety on objects and the duly warning about unfortunate trends occurrence.

-Granting to experts the effective means to analyze a safety condition on objects, enterprises, services, kinds of incidents, and also means for an estimation of tendencies in the safety basic parameters, modeling and forecasting of their values.

-Presenting reports in the table and graphic forms optimized for use in current processes development of operative and strategic decisions.

At the first stage of works it was used the concept of the system based on use of the knowledge based event-oriented approach developed by NPO Altey J S C in 1995-2000 [1, 2]. For the system pilot project realization and at definition of structure of data and the basic user interfaces, report forms, as well as the system basic scenario use the decision was taken to develop the information-analytical route safety estimation and risk calculation system for dangerous object transportation, using an existing Russian Railways transportation incidents database.

An approach to the problem decision

Specificity of the nuclear installations safety analysis is conditioned by an extreme rarity and, at the same time, exclusive danger of incidents in atomic engineering. The rarity of incidents allows at the certain level to do without the computer control system for data collecting and processing to search the information about a concrete case. Practically there is no opportunity for generalization of the information as way of new knowledge reception about internal mechanisms of incidents. At the same time, extreme danger of incidents, stimulates the analysts to carry out very deep investigation of everyone real or

possible incident. The safety objects analysis of the nuclear industry goes on a way of the real and possible trees of events analysis. The qualitative analysis of cause - consequence laws for area of nuclear safety is a beginning point of research. The basic purpose of application IAS is the quantitative analysis of cause - consequence structures on the basis of imitating modeling various processes, mistakes of the personnel, external influences. Result of the analysis is the figure of probability of the examined incident scenario and conclusion about its acceptability.

The key point of a new generation IAS is to increase of a level of data formalization of cause - consequence structures of the incidents opening essentially new opportunities for taking knowledge about internal mechanisms of incidents on the basis of the qualitative and quantitative analysis.

At the first stage of works on the information-analytical system it was necessary to develop criteria for an estimation and comparison safety of routes for dangerous objects transportation.

The main purpose of the system is to increase of reliability and safety of transportations, decrease the financial damage and reveal the" weak points" on various routes.

The event oriented approach in control system

Up to date the experts did not use the formal description of incidents as a source of the knowledge to make decision and used it mostly for statistic calculation.

The most suitable form for the incident description in complex control systems is the cause-consequence network which nods (event classes) are homogeneous and it is permitted to have a few possible sub-classes of each event. In the system we use cause-consequence network structure with unified for all the incidents scenario. The structure is realized as a tree structure of the unfavorable events, classified to one of the 5 classes:

-1. unstability factors of the system functioning;-2. technical means failures;-3. incorrect stuff actions;

-4. dangerous events;-5. final events.

The initial sources of the incidents lead to a technical means failures and cause an incorrect stuff actions, which successions and combination could cause some critical situation- dangerous events, then the final failure may happen as a result of a the «stored» functional deviations within the system. Inside the 5 classes the events is referred to the kind of events which joint the events in the independent groups.

The formal description of incident in network structure is three type of classifiers:

-classifier of safety violation (type of incidents already exist in industry);

-classifier of unfavorable events;

-classifier of cause-consequence relations of event.

The unit of the knowledge (and description) in relation-type data base about the subject is the quality information about the cause-consequence relations of one or a few cause-events with consequence-events. All the information about the cause-consequence relations taken from the incident descriptions is the homogeneous knowledge base about the ways of the incident start and progress.

At the moment our classifier of unfavorable events considered for more then 2000 incidents.

The cause-consequence relation classifier is a rectangular matrix the lines and columns correspond to the codes of events taken from the unfavorable event classifier (size about 10^7 elements of matrix). The special sign in some element of the matrix means that there is cause-consequence relation between the type of event in the title of the line and the type of event in the title of the column.

Incident formal description

The software of the expert interface for the incident formal description is very simple case technology to complete the unfavorable event tree structure. This interface is initializing the classifiers mentioned above offering suitable versions of event and relations. So the formal description of the incidents used earlier in the form of many attributes (place, time, type of incident etc.) and the cause unformalized description, obstacles, results of the incidents is added by the formal description of the incident as the cause-consequence network. The nods of the network are positioned in time and space of the unfavorable events, which took place either with the system objects or its media (technical means, stuff etc.). The

interface algorithm is not permitted the expert to go through a few levels of cause-consequence relations checking his inquiry.

Use of the information in safety route estimation system.

The knowledge collection and use technology is to use specialized interface to the existing information network to take the data about incidents each time when an inquiry team starts working. For the comparative calculations is used RF railways data base.

The data and knowledge of the incident investigation transmits to the joint knowledge base and through the central knowledge base to bring the experts the knowledge for helping in everyday work (investigation, prophylactic measures planning, etc.). Experts working on the central knowledge base are following the knowledge base editing and systematizing the fragment of the knowledge base (Fig.1).

Using the formalized description of the events and measures is permitted an expert to process the information in usual manner to use if for statistics, operative control and so on and it gives the " portability" of the information, but the new technology gives much more power in analysis and forecasting of the system functioning.

The formal description of incident described gives us the possibility to analyze the statistics of the accompanied hidden causes and the key events. At the time being in the system realized are:

- automatic seeking of the key events on the whole set of the cause-consequence incident structures;
- ranging of unfavorable events on the incident data base and calculation the percentage to the total number of incidents;
- determining the risk incident mean value of for any fixed structure on the base of the generalizing of the incident cause-consequence regularity of the incidents.

An imitation model is used to forecast the safety of the system. The object for imitation is the ties and transitions between the unfavorable events which leads to the incidents. The model uses the structural regularity from the knowledge base taking into account both the frequency of the events and the probability of the cause- consequence transfers. For that reason the system calculates in regular manner:

- probability of the events; - probability of the cause-consequence transfers; - correlation of probability of different cause complex of the event; - distribution of the types of unfavorable events in time and space; - effect estimate of the measures as a function of the cause- consequence probability.

Criteria of routes safety calculation.

At the first stage of the information-analytical system were solved the following functional problems.

- Railroads ranging.
- Laying the routs.
- Estimation and comparison safety of routes.
- Comparative estimation of incidents, events, stages of roads, etc.

The traffic safety violation data on the RF railway network appears as a result of the investigation with filling in the official form of incident description. In the case of crash or accident with serious consequences the form contains 34 positions. In the other cases the form contains: date, time, station, kind of work, kind and summary of spoilage, weather and conditions of visibility, consequences and reasons conclusion.

At the analysis of a safety violation the RF railways database were used. For the multilayer statistical analysis of safety estimation at transportation the analyzed incidents are filtered though the following basic attributes of incidents: time interval, current time, railroad (branch), facilities, kind of incident, reason of incident, kind of work, kind of transportation.

The system provides an opportunity of operative carrying out the multilayer analysis with detailed elaboration on the incidents attributes.

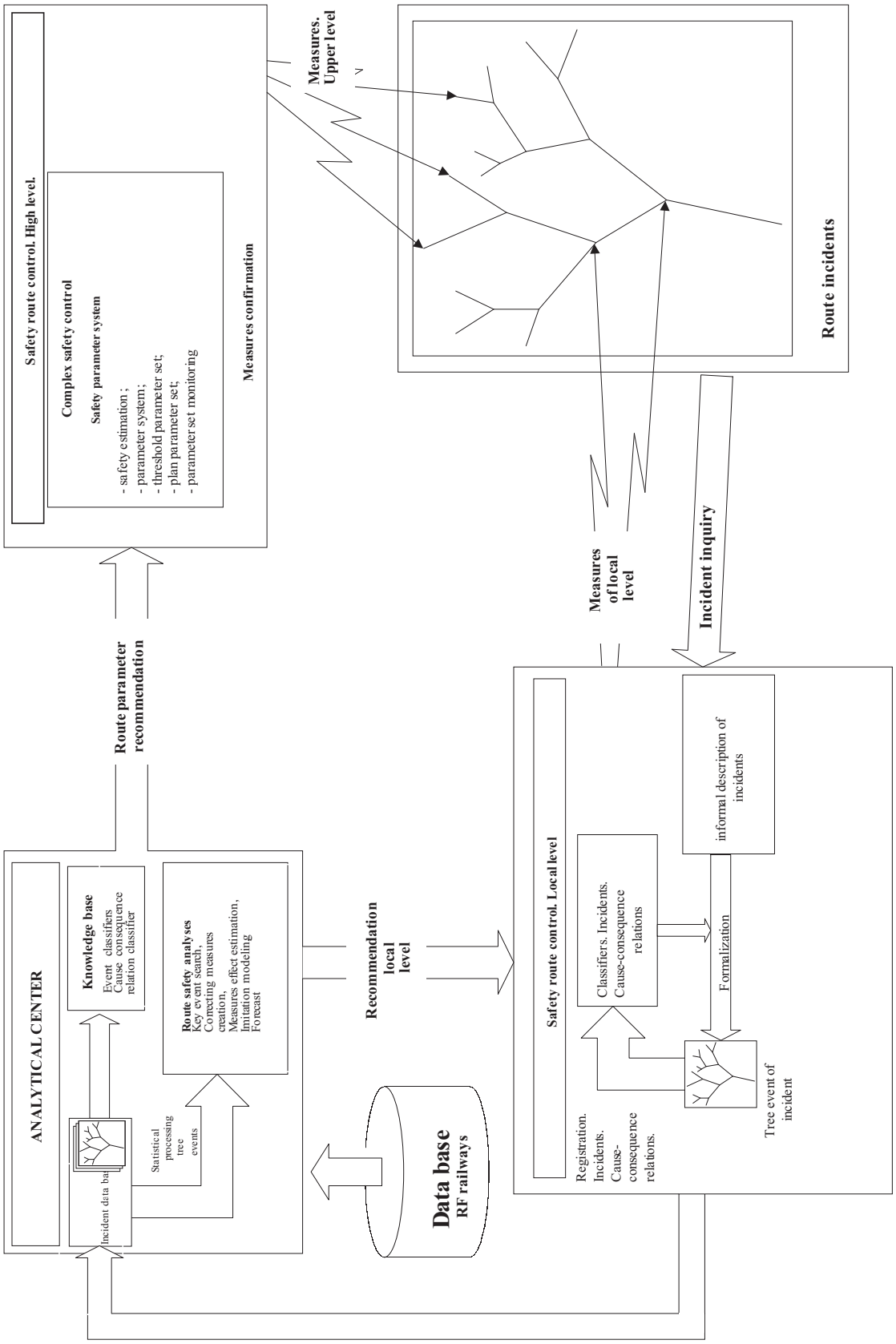

Fig.1. Structure of safety route estimation system

The analysis of tendencies of safety violation at transportation is made by comparison of values of the same parameters for the several comparable intervals of time.

Frequency characteristics of a transportation route.

For calculation of total number of incidents on a transportation route is used the transportation route incident information (stations and stages) taking into account various loading traffic on the route. Thus:

- The sites of a route running on territory of various railways, are estimated independently;
- Work on a site of the route belongs to the one particular railway are loaded equally;
- Total volume of work on a route are summarized on all sites of a route.

Under this condition the frequency of incidents on a route, consisting of k sites of various roads, is determined as:

$$F=W\,L\,I\,/\,P$$ incidents/one thousand years, where:

-W - frequency of concrete transportation on a route - trains in a year,

-$I=\sum_i I(s_i)+\sum_i I((s_i,s_j))$ - sum of incidents per year on a route (the sum of incidents on stages and at stations),

-$L=\sum_i L_{k\_}$ - length of a route,

-$P=\sum_i P_k$ - one million train / year - total work on a route.

At calculation of risk R on each stage and station of a route is used the information on a cost of damage D coming from this incident on this stage of the route:

$$R=F\,D\,/\,L_{ii}$$

Information-analytical system

The information - analytical system realizing the approach described above, allows:

1. To receive data on a condition of functioning and on deviations of parameters and safety violation in work of objects.
2. To transform the initial information into data about current probabilities of separate events and cause – consequence relations.
3. To distinguish tendencies of safety parameters change and to assess a condition of safety on objects.
4. To give to the supervising personnel the variants of forecast.

The technology of the analysis of a safety condition at transportation is constructed on a two-level basis. At the first stage the condition of safety on 17 RF railways is analyzed under the integrated characteristics calculated from the RF railways data base. The system allows to estimate the route safety using the incidents statistical data on route. Simultaneously the system makes the rating and graphic analysis of route stages and forms analytical tables for definition of the cause - consequence incidents data and to use it in the knowledge base for the subsequent profound analysis of processes and to create the forecasts in time scale.

The second level of informing is connected to the choice and the route estimation. The system allows to generate the route map and to estimate the differential characteristics of safety taking into account the incident cost of damage along the route for the safety comparative analysis (Fig. 2).

CONCLUSION

The report results the development of information technologies and information-analytical system for the route safety estimation over the transportation. The system provides the information for a management and experts in analysis of current tendencies and mechanisms of safety condition. Information from the system is used to analyze the next step models over the transportation.

The information-analytical system provides the quantitative analysis of cause - consequence structures on the basis of imitating modeling processes, the analysis of errors of the personnel, external influences and provides the possibility to accumulate the knowledge base. Result of the analysis is the probability figure of the examined scenario of transportations and conclusions about its acceptability, and also the size of risk expressed in uniform units for all incidents that allows to compare various routes.

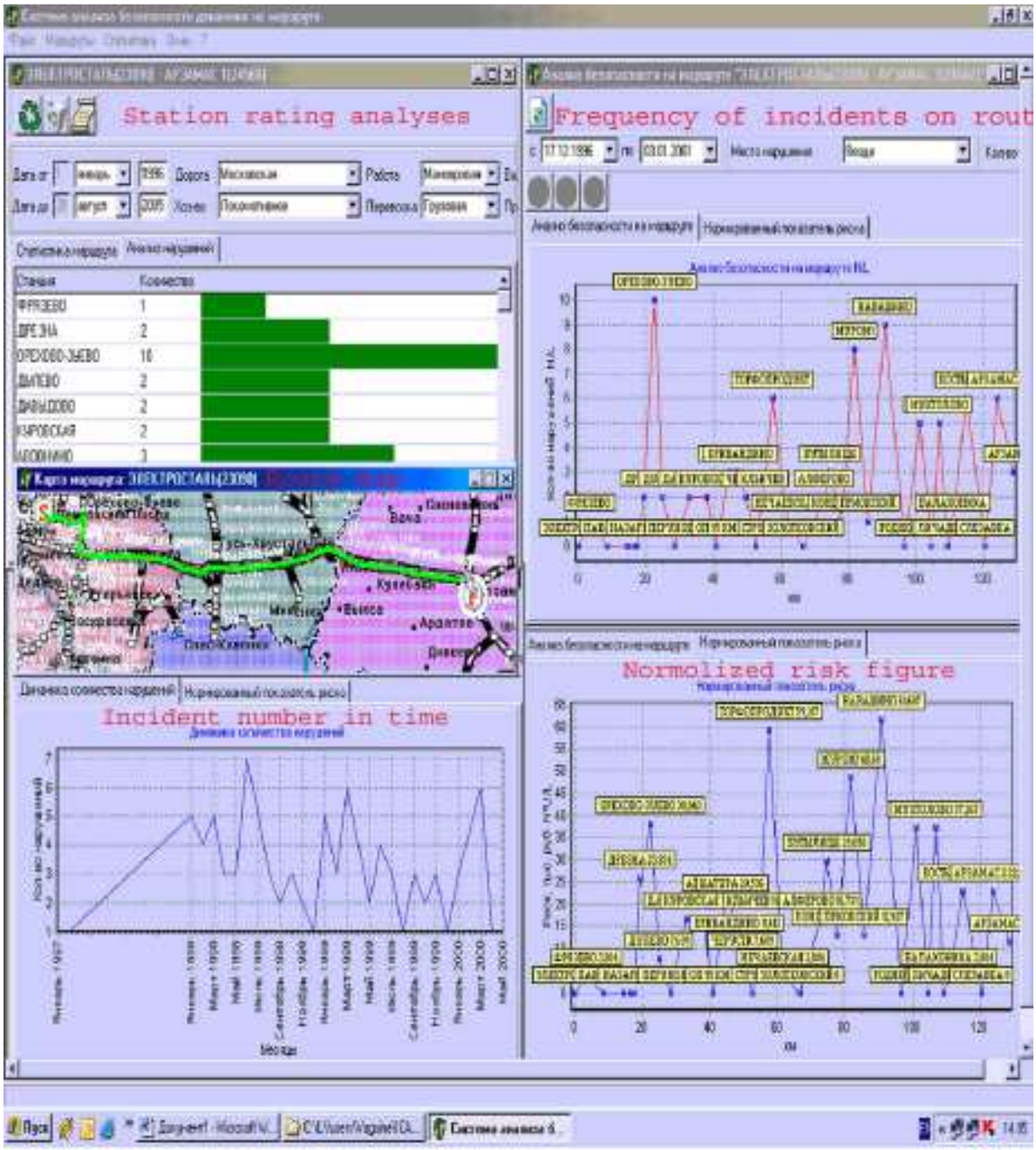

Fig. 2 Route safety analyses

Practical realization of the described information technology means gradual transition to development of decisions support system in the field of the objects safety management on the basis of exact quantitative calculations.

REFERENCES

[1] Knowledge-based event oriented approach in control system. ICALEPCS 97, Proc. 1997, p.400, Vikentiev A., Vaguine A., Poluektov S., Mikheev V.

[2] Knowledge-based event oriented approach in control system: Technologies and methodics. Vikentiev A., Vaguine A., Poluektov S., Mikheev V. ICALEPCS 2001, Proc. 2001, THAP044.