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USE OF SIMULATION MODELLING FOR SUPPORT OF DECISION MAKING FOR THE PURPOSE OF INTRODUCING NEW PRODUCT TO THE MARKET

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This article describes the simulation model, which could be used by the company's management to support the process of decision-making for the purpose of identifying necessary resources and risks in the course of introducing a new product to the market. The object of this research is business process of the company that prevents emergency situations in the radius of 50 km around Riga. While forming the model two approaches have been used: agent modelling and discrete-event approach. As a result of synthesis of these approaches it is possible, on the one hand, to describe in details business process of emergency elimination but on the other hand to specify individual characteristics of the company's customers. The package of simulation modelling AnyLogic 6.3 is used as a tool.

***Keywords**: modelling, decision making, discrete-event approach, agent modelling, hybrid modelling*

1. Introduction

Modern business exists in the circumstances of intense competition that especially increases in the period of economic crisis together with general decrease of consumer demand. In such circumstances the search for new possibilities of business development for many companies remains the only way of keeping their business. One of the ways of such development can be offering to the consumer new goods or services.

From the very beginning of the company's activity one of the main priorities is maintenance of engineering networks and constructions of buildings and facilities. On the basis of the company's priorities and tendency for constant development, the management took the decision to introduce to the market a new product. This product is the provision of services in elimination or localisation of accidents within a radius of 50 km around Riga. Introduction of new products to the market is always connected with risk because we can speak about high level of uncertainty. To reduce this risk the company should have the tools which could allow its management to take reasonable administrative decisions on an operational basis. To solve this task we have used the simulation modelling device.

One of the most important tasks in assessment of efficiency of future business is evaluation of necessary resources (employees, equipment, vehicles, etc.). Therefore, the aim of such modelling is creation of tool for support of decision-making in evaluation of necessary resources, for introduction of a new product to the market [1].

In the model we used only human resources, i.e. direct participants of the business process (dispatchers, workers and experts). The personnel's technical equipment and economic component were not subject to research within the framework of this model; however, they can be calculated on the basis of the results of such modelling.

2. Description of Business Process

The subject of this research is to simulate the business process of the company that eliminates emergency situations within a radius of 50 km around Riga. The process will consist of the following basic stages:

- call acceptance;
- customer identification;
- analysis of customer information;
- departure of the team;
- way to the serviceable facility;
- access to the facility;
- accident identification;
- elimination or localisation of the accident;
- provision of information to the customer and dispatcher.

On Figure 1 the main stages of this business process and the resources are represented that may be required for their implementation.

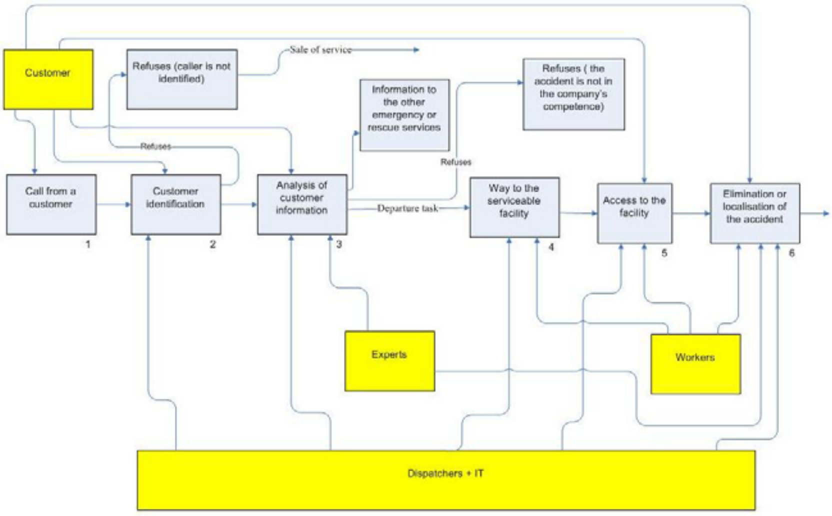

Figure 1. Stages and resources of the process

We would consider the procedure of implementing all the stages of accident elimination. The process begins with a message (call) from a customer who informs about the accident.

The dispatcher accepts the call, documents it in the database and identifies the customer. At the end of this stage the following variants of further development are possible. In the case of the customer's identification the dispatcher continues with analysis of information. But if the caller is not identified and is not the company's customer the dispatcher refuses to send the team to the caller's accident. From this moment the other business process related to the sale of service may start. But this paper does not consider such process.

In the course of analysing the customer's information about the accident the dispatcher first of all determines if elimination of this accident is in the company's competence. Then the category of accident complexity is determined. In the case when the dispatcher is not qualified enough to determine the complexity of the accident, he/she may consult with the experts of the team. Moreover, in a number of cases when the accidents are very serious (there is a danger of destruction, fire, danger to life and health) the dispatcher should transmit this information to the other emergency or rescue services.

After the above-mentioned steps have been taken in the case when the accident is in the company's competence the dispatcher transmits the departure task to the emergency team. In the case when the accident is not in the company's competence the dispatcher refuses the caller to send the team to this accident.

After the emergency team receives the departure task it goes to the facility and informs the dispatcher about all its further activity so that the dispatcher could place this information into the database. The time of the team's arrival to the facility is a random variable and depends on territorial location of the facility, traffic jams on the way as well as possible breakdowns of the vehicle or accidents on the way to the facility.

After the team arrives at the facility it may face the situation of limited access to the facility. In such a case with the support of the dispatching service and keeping contact with the customer the team must be provided with access to the place of accident.

After the access to the facility has been found the emergency team starts the stage of accident elimination or localisation. This stage will consist of the following steps: emergency diagnostics, elimination or localisation of the accident, provision of information to the customer and dispatcher. In the case when the team needs help in diagnostics of the origination of accident it can receive consultation of the team of experts. After the accident has been eliminated but the customer and the dispatcher have been informed the team leaves the place of accident.

3. Conceptual Model

In the beginning of this work the conceptual model of the process (see Figure 2) has been formed to make the description of simulated business process clearer. Development of this conceptual model allowed visualisation of the structure of the simulated business process and cause-effect relationships of its elements.

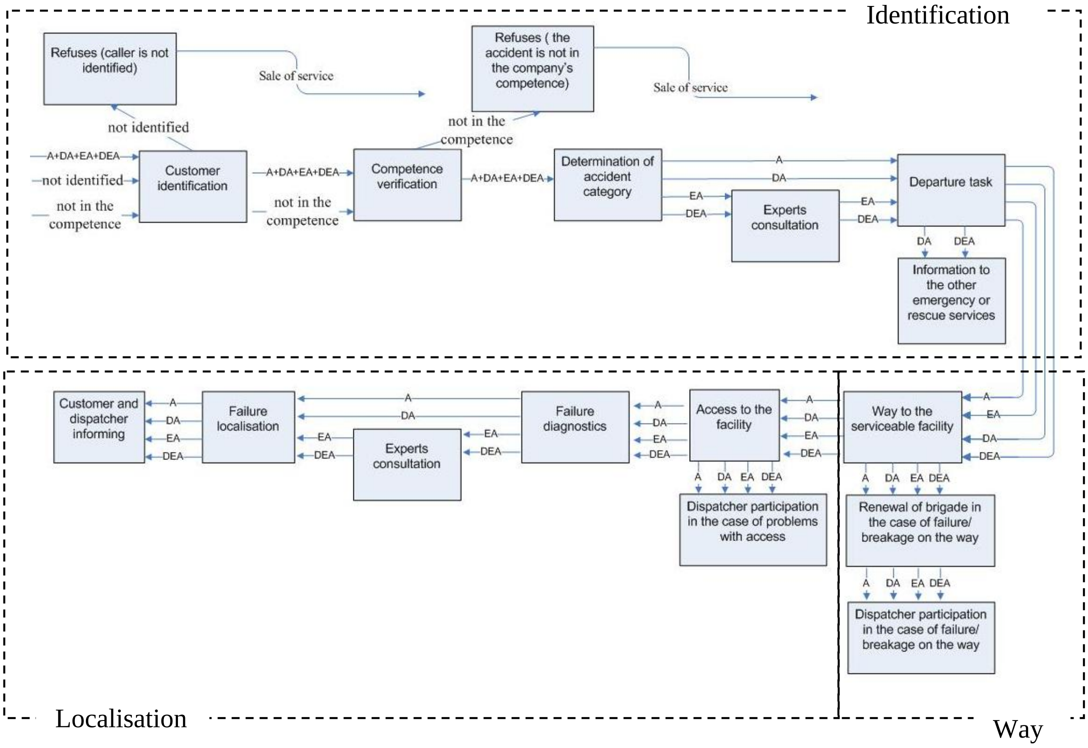

Figure 2. Conceptual model of the process

The business process of accident localisation can be presented as three interrelated stages: “Identification”, “Way” and “Localisation”. We will consider each of the stages in detail.

The peculiarity of the stage “Identification” is the fact that at the initial stage the dispatching service accepts calls not only from the company’s customers but also from incidental callers. Aside from that, a part of accidents is beyond the company’s competence. Such calls require screening out and additionally load the resources (the dispatching service).

The accidents that get localised by the employees of the company can be divided into five categories of complexity; they are presented in Table 1.

Table 1. Categories of accident complexity

Category of accident complexity	**Description**
A	Simple accident (the dispatcher sets the departure task, all the other tasks are executed by the team)
DA	The dispatcher’s work is complicated by additional participation in the process (either calling to other services or solution of problems with access, etc.)
EA	Accident with involvement of the expert
DEA	The most complicated accident when all the participants take part in it.
NC	The accident is beyond the company’s competence

It should be noted that each category of accidents has its own intensity of origination. After the dispatcher determines the category of accident, each category will have its own specific features of the process. So, for example, at the stage of accident “identification” EA and DEA will require expert’s consultation but accidents DA and DEA will need transmission of information to the other services (fire fighting service, emergency medical aid service, etc.).

The stage “Way” describes the team’s way to the facility. The specifics of this stage is the possibility of breakdown on the way and need for recovery of resources for continuation of work. However, at this stage the differences of categories are not taken into account because every breakdown is accidental and can arise in any category of accidents.

The peculiarity of the stage “Localisation” is the fact that at the moment of the team’s arrival to the site in a number of cases the access to this facility can be problematic. This problem arises irrespectively of the category of accident. The time for diagnostics and localisation is a random variable and depends on the category of accident complexity. The specifics of this stage is that the accidents of categories EA and DEA in the course of their localisation may require additional expert’s consultation and it increases the time of their elimination.

The most important input parameters that are to be taken into account in the course of modelling are the following:

- the time of executing all the steps of the business process;
- probability of accident distribution according to the categories of complexity (see Table 2);
- intensity of accidents.

Precise estimation of input parameter values of the model is one of the most significant tasks that ensures adequacy of the model. Since we have been modelling a new business process the company could not have any historic data for estimation of the parameters of this model. So to solve this problem the method of expert estimation is applied. As a result all input parameters have been estimated by experts on the basis of the company’s previous work experience and expert’s suppositions.

Table 2. Probability of accident distribution according to the categories of complexity

Category of accident’s complexity	Probability
A	0.64
DA	0.08
EA	0.04
DEA	0.04
NC	0.20

One of the suppositions that have been used in the model is the fact that the intensity of accidents depend on the time of the day and the day of week. It has been assumed that from Monday to Friday from 8 a.m. to 6 p.m. the intensity of accidents would amount to 80% of their total quantity. The change flow chart of the intensity of accidents in accordance with the time of a day and day of a week is presented on Figure 3.

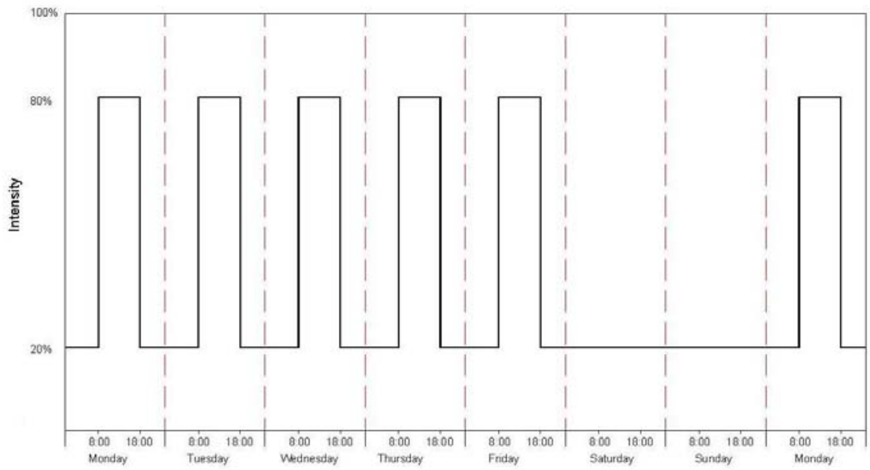

Figure 3. The change flow chart of the intensity of accidents in accordance with the time of a day and day of a week

4. Development of Simulation Model

When the task has been set the following requirements to the model are advanced: clearness, visualisation, possibility of different experiments and change of parameters of work of such experiments. Taking into account all these requirements the package of simulation modelling AnyLogic 6.3 has been chosen. The reason for choosing this package is as follows:

- availability of large inbuilt library of standard blocks;
- the use of different modelling approaches in one package;
- extension of possibilities of the package due to inbuilt programming language Java;
- possibility of creating interactive animation for improving the clearness of the model;
- possibility of creating Java applets [2].

In the course of forming the model two approaches have been used: agent-based modelling and discrete-event approach. As a result of synthesis of these approaches it is possible, on the one hand, to describe the process of accident elimination but on the other hand, to specify individual characteristics of the company's customers [3]. In the course of model's development the authors used as follows:

- 61 block from the Enterprise Library;
- 69 connectors;
- 2 types of agents;
- 14 blocks for collection and depiction of statistical data.

The process of model development can be conventionally divided into five stages:

the 1st stage – development of discrete-event model;
the 2nd stage – allocation of individual characteristics to the customers with the use of agent-based approach;
the 3rd stage – development of the page for experiment management;
the 4th stage – development of functions for acquisition of statistical indexes;
the 5th stage – development of animation.

Firstly, the discrete-event model has been formed. Each of the stages of business process – "Identification", "Way" and "Localisation" – is described with the help of the elements of the Enterprise Library. Such blocks as seize, delay, select Output, release, sink, split, etc. have been used in development of a discrete-event model. The use of these blocks helps to implement the logic of executing the business process in the course of modelling. All details of business process have been taken into account: the time for implementation of every step by the employees, probability of events, priorities etc. The developed discrete-event model is presented on Figure 4.

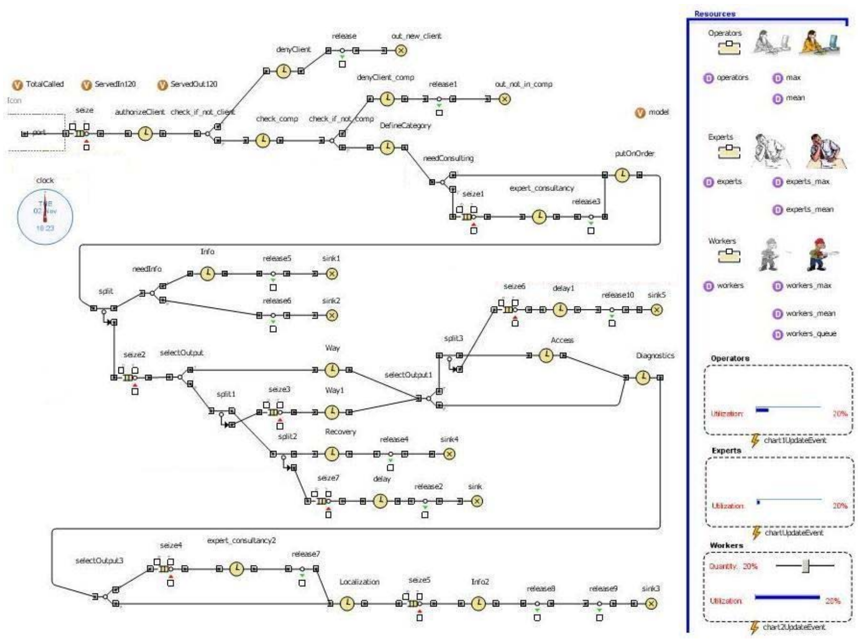

Figure 4. The discrete-event model

Since the supposition that the intensity of accidents is depending on the time of the day and day of week is being used in this model it has been necessary to include into this model the possibility of changing the intensity of customers’ calls. This service is provided through development of schedule that took into account the intensity of customers’ calls. Apart from that it is possible to create the work schedule for different resources. A separate work schedule has been created for each type of resources.

At the second stage with the use of agent-based approach the customers are allocated individual characteristics. Each customer and incidental caller has generated features and receives the following characteristics:

- personal identifier;
- Role (Customer or Spammer);
- coordinates (X and Y), which determine his/her location and affect the time of the team’s arrival;
- customer’s status.

All characteristics are generated incidentally and are attached to the object in the course of all time of modelling.

The significance of the third stage is the development of convenient user interface that could allow flexible management of the input parameters of the experiments. The layout of the page for managing the parameters of experiments is presented on Figure 5.

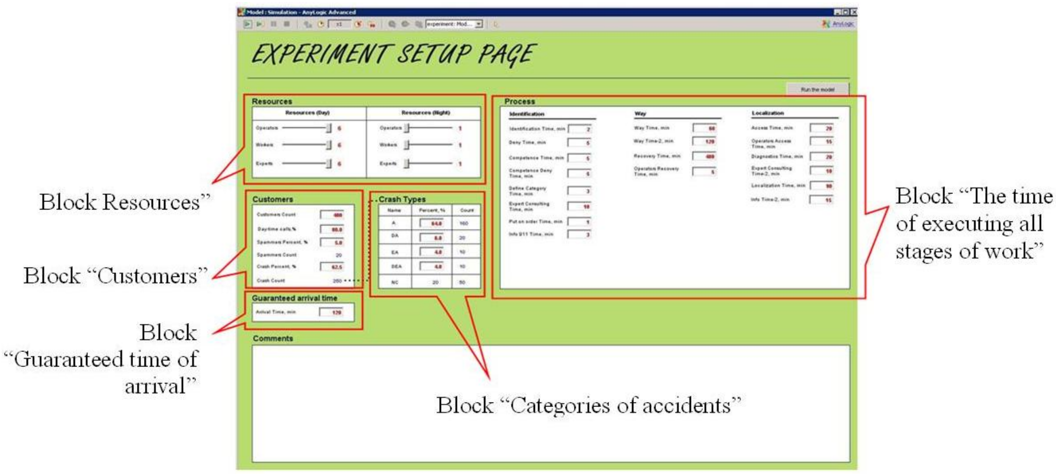

Figure 5. The layout of the page for managing the parameters of experiments

As a result of the performed work the page for experiment management allows the user to set 33 manageable parameters independently.

To make the work of the page for experiment management more convenient it has been divided into seven functional blocks: resources, customers, types of accidents, guaranteed time of arrival, time of executing all the stages of work. We will consider the most important manageable parameters of the model:

1. Block “Resources”:
   - the amount of resources (dispatchers, experts, working teams) in day and night time.
2. Block “Customers”:
   - number of customers;
   - intensity of calls in daytime;
   - the number of incidental callers;
   - the number of accidents (according to 5 different categories).
3. Block “Categories of accidents”:
   - the number of accidents of the category A;
   - the number of accidents of the category DA;
   - the number of accidents of the category EA;
   - the number of accidents of the category DEA;
   - the number of accidents of the category NC.
4. Block “Guaranteed time of arrival”:
   - guaranteed by the contract time of arrival to the place of accident

5. Block “The time of executing all stages of work”, subsection “Identification”:
- time from call acceptance and documentation to customer identification;
- time that is required for estimation if the accident is in the company’s competence;
- time that is required for estimation if it is necessary to transmit the information to the other services;
- time that is required for the experts’ consultation;
- time that is required to hand over the departure task.

6. Block “The time of executing all stages of work”, subsection “Way”:
- time from the moment of departure to arrival at the site and provision of information to the dispatcher;
- time for team recovery (in the case of accident/breakdown on the way);
- time for the dispatcher’s participation (in the case of accident/breakdown on the way).

7. Block “The time of executing all stages of work”, subsection “Localisation”:
- time that is required for access to the facility (in the case of access problems);
- time that is required for accident diagnostics;
- time that is required for the expert’ s consultation (in the case of accident localisation);
- time that is required for localisation or elimination of the accident;
- time that is required for provision of information to the customer and dispatcher.

At the fourth stage of work the author collected statistical data for results of modelling. First of all the data on work load of resources as well as the average and maximum length of queue is collected. The statistical data has been collected individually for each resource.

As the accidents are connected with the loss of function of the facility but in some cases even with risk to human life, one of the most significant parameters of efficiency is the time of accident elimination. To assess this parameter we collect statistical data which is necessary for building the histogram of the time of the team’s arrival at the site.

The other criterion of efficiency which has been used in the model is the proportion of duly executed orders. This index has been calculated on the basis of comparing actual time with the time which has been set at first.

All statistical data which is collected as a result of modelling has been visualised in animation. As a result of animation which has been developed at the fifth stage the authors develop the page of the model and output results. The page of the model allows the user to see the dynamics of a simulated process. The layout of the simulation model is presented on Figure 6.

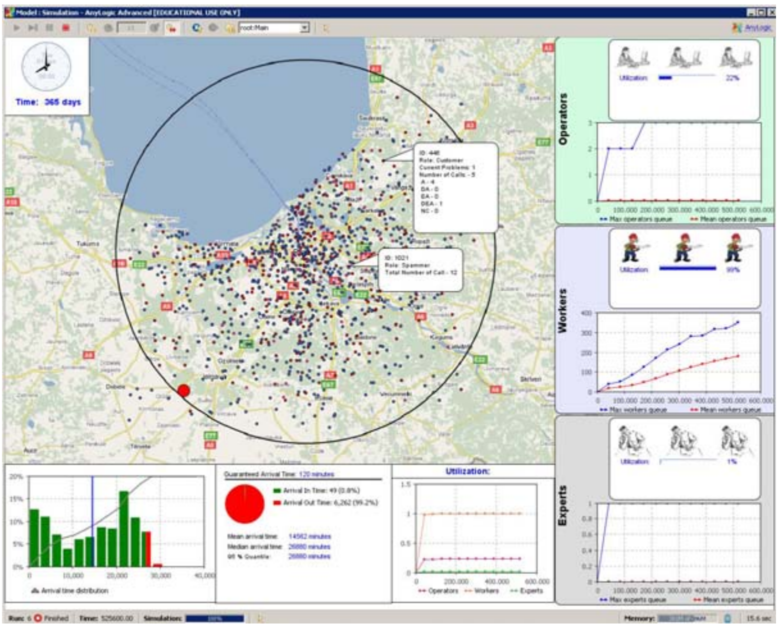

Figure 6. The layout of the simulation model

The model is graphically presented as the map of Latvia. The black circle marks the region with the radius of 50 km within which the company eliminates the accidents. The company’s customers and incidental callers are marked as the points on the map. The customers are marked by blue points but the incidental callers are marked by blue points with red border. If the customer experiences emergency situation the point changes its colour into red. After the accident is eliminated the point becomes blue again.

With every start of the model the customers and incidental callers are placed on the map at random. In the course of modelling you can get information about the customer or incidental caller by clicking the left button of the mouse on its graphical image. Thanks to the use of agent-based approach we have implemented the possibility of obtaining the following information about the caller:

- personal identifier;
- Role (Customer or Spammer);
- total number of calls from this customer;
- number of accidents of each category which occurred to this particular customer during the time of modelling.

As we can see from Figure 6 the user can receive the report on the use of the company’s resources in the right part of the page. The report contains the following positions:

- the amount of each type of resources;
- work load coefficient for each type of resources;
- the average length of queue for each type of resources;
- the maximum length of queue for each type of resources.

At the bottom of the page the statistical data on performance of the model is presented in the way of diagrams and charts. On the basis of this data the user can receive the following information:

- histogram of distribution of the time of arrival to the place of accident;
- proportion of accidents to which the company arrives in time prescribed by the contract;
- the average time of arrival to the place of accident;
- the median of the time of arrival to the place of accident;
- 95% quantile of the time of arrival to the place of accident;
- summary schedule with work load coefficients for each type of resources.

Conclusions

1. The simulation model was developed on the basis of the package AnyLogic 6.3, it allows the company’s management to take more well-thought and reasonable administrative decisions and to reduce the risk of introducing a new product to the market.
2. While working with the package AnyLogic 6.3 some drawbacks of this package have been found. One of the drawbacks is unavailability of several inbuilt statistical functions, for example, the function of median and quantile. To eliminate this drawback the calculation of statistical function has been performed through development of Java code.
3. A hybrid approach was used in the modelling, it combined the discrete-event and agent-based modelling. As a result, it was possible not only to describe all steps and branching of the business process in detail but also to specify individual characteristics of the company’s customers. Such approach allows not only analysing the indexes of the system in the course of modelling but also investigating the statistics of individual work with every customer.
4. As a result of the performed work it has been possible to develop convenient user interface which allows flexible management of 33 input parameters of experiments.
5. The following parameters of the model were used as criteria for efficiency of business processes: coefficient of work load of resources, length of queues, time of arrival to the place of accident, the proportion of accidents to which the company arrived in time prescribed by the contract, etc. Depending on the aims which were set by the company, at different stages of development the priority could be given to different criteria of efficiency.
6. The use of this simulation model allows the company’s management to try different scenarios of business development on this model and to analyse how the results change in accordance with input parameters of experiments.

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