UDC 004.9
DOI: 10.15587/1729-4061.2022.255839

DEVELOPMENT OF AN INFORMATION SYSTEM AND SOFTWARE FOR EFFECTIVE BUILDING EVACUATION PLAN

Ainur Kozbakova
Corresponding author
PhD, Associate Professor, Leading Researcher*
E-mail: ainur79@mail.ru
Yedilkhan Amirgaliyev
Doctor of Technical Sciences, Professor, Chief Researcher, Head of Laboratory *
Aliya Kalizhanova
PhD, Associate Professor
Department IT - Engineering
Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeyev
Baitursynov str., 126/1, Almaty, Republic of Kazakhstan, 050013
Zhalau Aitkulov
Research Associate*
Aygerim Astanayeva
Doctoral Student, Researcher*
Guldana Kabidolliyeva
Master's Student, Methodologist
Department of Methodological Support and Career
Almaty Technological University
Tole bi str., 100, Almaty, Republic of Kazakhstan, 050012
*Laboratory of Artificial Intelligence and Robotics
Institute of Information and Computational Technologies
Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan
Shevchenko str., 28, Almaty, Republic of Kazakhstan, 050010

The main goal of the work is to create the optimal emergency evacuation plan in general education institutions according to the schedule at a certain time. The work developed an information model of the evacuation system, taking into account the schedule of classes and classrooms. The methodology of the system approach, which ensures the compatibility of heterogeneous devices to find an operationally optimal evacuation plan in real time, was developed. A conceptual scheme of an evacuation system using heterogeneous sources of receiving and transmitting information about emergencies is proposed. Determined the input and output sources of receiving and transmitting information about the number of people in the building. Developed software for the rapid and most effective evacuation of people from the educational institution and can be used for other types of buildings.

The importance of this work is the creation of an integrated evacuation information system based on mathematical modeling of multi-criteria optimization problem of flow distribution and design, construction technology receiving and transmitting data and information notification systems for the selected type of building. in order to adopt an operational evacuation plan.

The results of this paper allow the systematic organization of evacuation training, preparing resources so that in the event of an emergency it is possible to quickly respond and conduct the evacuation process to avoid major consequences. The use of information technology greatly increases the efficiency of evacuation systems, so the development of new integrated and intelligent info-communication approaches to solve the problem of evacuation is currently very relevant

Keywords: evacuation, information modeling, software system design, data transfer, operational plan

Received date 19.02.2022
Accepted date 03.04.2022
Published date 30.04.2022

***How to Cite**: Kozbakova, A., Amirgaliyev, Y., Kalizhanova, A., Aitkulov, Z., Astanayeva, A., Kabidolliyeva, G. (2022). Development of an information system and software for effective building evacuation plan. Eastern-European Journal of Enterprise Technologies, 2 (2 (116)), 36–50. doi: https://doi.org/10.15587/1729-4061.2022.255839*

1. Introduction

The practice of modern life shows that the population is increasingly exposed to hazards as a result of natural disasters, accidents and disasters in industry and at nuclear power plants, earthquakes, floods, avalanches, mudflows, landslides, massive forest fires, spills of chemicals and biologically harmful substances, large fires at petrochemical and oil refineries. In these cases, it is almost always necessary to resort to evacuation. The task of building effective evacuation measures is important and urgent, since people's lives and the preservation of material assets depend on it.

Disadvantages of forecasting natural disasters, untimely delivery of vital funds require the improvement of methods for managing the evacuation process in emergency situations.

Evacuation models are mainly designed to determine the time of evacuation of people. Very often, such models allow to determine the possible areas of congestion during evacuation.

Many models include features such as visualization of the flow of people, modeling of human behavior, determining the best evacuation routes, etc.

Scientists from many countries consider life safety a new science at the first stage of development – the systematization of knowledge. Only recently, attempts to explain and predict have appeared and formed, so various issues of the theory and practice of life safety were scientists.

The theoretical foundations of the mathematical modeling of the movement of people flows inside buildings and assessment of evacuation plans of buildings were developed [1]. In [2], a graphic-analytical method for calculating the total evacuation time was developed, in which empirical dependences of the speed of movement of people on the density of the human flow were revealed.

At the present stage, the most effective tool for research and optimization of the evacuation process are computer evacuation models. By the present time, a large number of similar computer models have been created [3].

The work [4] contributed to the development of computer evacuation simulation models (CESM).

Modern CESM allow to simulate to some extent the dynamics of human flow parameters during the evacuation of a building, estimate the total duration of the evacuation and solve the problem of selecting evacuation routes. However, the vast majority of modern CESM do not adequately account for the possibility of flow stratification by velocity [5]. In addition, there is virtually no consideration of the specifics and architectural features of educational institutions and enterprises in modern CESM. The main feature of flow formation in the buildings of educational institutions is non-stationary distribution of people in the inner rooms of the building, related to the schedule of classes [6]. This leads to the dependence of evacuation plans on the time of day, and also requires an assessment of the training schedule in terms of organizing the unobstructed movement of people during evacuation. The solution of these problems for educational buildings is complicated by the presence of moments of time when people move from one room to another, for example, during breaks between classes [7].

Thus, the development of new models and methods for evacuating people in educational buildings under conditions of nonstationarity and variability in the distribution of people in the premises of the building at different points in time, allowing to evaluate the educational schedule in terms of the unobstructed evacuation is an urgent task [8].

The timeliness and unobstructed evacuation in emergencies requires scientifically sound and technically supported evacuation plans. The application of a dynamic model for solving the problem of maximum flow for evacuating people has become possible with the use of wireless sensor technology, which allows to capture data from the object of study by observation with high-resolution video cameras or sensors of information acquisition. There are no restrictive conditions on the subject and mode of operation. Wireless sensor networks have great commercial potential, which are currently being implemented by many countries.

Undoubtedly, one of the important components of the successful implementation of evacuation measures is a public address system. Notification system ROXTON-8000 – a wide range of devices made on the basis of modern digital (microprocessor) technology and components, functioning both independently and under the control of software [9]. And the development and application of mobile applications for cell phones, monitors in classrooms and other means of notification are also provided for notification.

Therefore, science-based real-time evacuation arrangements are a very important task. This is facilitated by evacuation measures for separately selected buildings and educational buildings, which must be strictly organized and implemented.

The significance of the proposed system for solving evacuation problems on a global scale is also very important because in countries with developed economies, due to political disagreements, terrorism and conflict situations that lead to evacuation tasks often appear. The densely populated urban areas, natural disasters and industrial accidents also justify the need for an effective solution to the problems of evacuation. And in this case, the methods and technologies of evacuation proposed by the performers are significant, because in the literature review of evacuation problems we have not found similar comprehensive solutions to evacuation problems.

The use of mathematical methods [10] and information technologies significantly increases the efficiency of evacuation systems, so the development of new integrated and info communication approaches to solving the problem of evacuation is currently relevant.

2. Literature review and problem statement

An overview of intelligent evacuation management systems is provided in [11], covering aspects of crowd monitoring, disaster prediction, evacuation modeling, and evacuation route recommendations. This review will assist researchers in developing robust automated evacuation systems that will help ensure the safety of evacuees, especially during emergency evacuation scenarios. The uncertainty of crowd behavior is inevitable in any evacuation scenario, especially during an emergency evacuation. Similarly, during an emergency evacuation scenario, finding the safest exit route is imprecise and inaccurate.

The article [12] presents a comprehensive and systematic review of existing research in the field of emergency management, both in terms of system design and algorithm development. New challenges and opportunities related to system optimization, modeling and optimization of evacuee behavior, computational models, data analysis, energy and cybersecurity aspects are proposed. But evacuation tasks depend on building architecture or population density. During an emergency, if the power goes out, organizing a comprehensive evacuation will be difficult.

The paper [13] presents a comprehensive review of research on emergency evacuation and wayfinding, focusing on algorithmic and system design aspects. [14].

For the evacuation planning process, a variety of methods and algorithms have been presented, in paper [15], evacuation planning was considered directly on dynamic issues related to time-varying and volume-dependent.

The article [16] distinguishes between macroscopic and microscopic models of evacuation, which are able to record the movement of evacuees in time.

The article [17] considers a mathematical model describing the motion of dynamic flows in a directed graph. The model parameters include the undirected graph as the building model, the initial flow values, the flow sources, and their receivers.

In this paper [18] present a new mathematical model of rescue-evacuation and develop a method for a quick solution for emergency response in real time for various population groups and various means of evacuation, based on the iterative use of a modification of the planning algorithm.

This article [19] describes the maximum flow in a bipartite dynamic network. The main idea behind these improvements is the rule of pushing out two arcs in the case of maximal algorithms.

In this article [20] proposed and analyzed an algorithm for Dynamic Real-Time Bandwidth Sharing Routing (DRTCCR). Such an algorithm would investigate the capacity constraints of the evacuation network in real time by modeling capacity based on time series to improve current solutions to the emergency route planning (ERP) problem.

The article [21] presents a highly polynomial time algorithm for calculating an approximate solution to the fastest partial contraflow problem on two terminal networks, which is justified by numerical calculations that consider the Kathmandu Road network as an evacuation network.

Articles [11] and [12] present an intelligent information system with monitoring of general evacuation plans, but do not consider the flow of people during evacuations, because managing the flow due to human behavior is difficult without mathematical modeling.

The essence of evacuation is to organize the rapid removal of people to a safe place. This method is used during fires, natural disasters, military actions. Any situation in which there is a danger to the life of the population requires immediate evacuation. But evacuation tasks and operational evacuation plan is not the same everywhere.

Emergencies are divided into local, local, territorial, regional, federal, etc.

The evacuation problem is related to the architecture of buildings and depends on the types of people in them, such as university-students, schools-students, hospitals-doctors and people receiving treatment, retail spaces-people of all types, etc. In this paper, the evacuation problems related to the architecture of closed buildings university is considered as a facility and distributes the flow of people and create an optimal evacuation plan. The integrated approach to creating an operational evacuation plan and implementing the evacuation process proposed in the article involves the implementation of several alternatives to the evacuation process. One solution to the evacuation process proposes the use of a database of class schedules and occupancy of classrooms by faculty and staff with the issuance of an operational hourly evacuation plan. A mathematical and information model of the Grinshield distribution network in enclosed spaces is built according to the plan of the Kazakh National Research Technical University named after K. I. Satpayev. Built a mathematical model of Grinshield distribution network in enclosed spaces, taking into account the architectural features of the building [10]. Development of new models and methods for evacuating people in the buildings of educational institutions under conditions of non-stationarity and variability in the distribution of people in the rooms of the building at different points in time, allowing the evaluation of the educational schedule in terms of the unobstructed evacuation. Universities and educational institutions are the future of the country, first and foremost the safety of the younger generation.

3. The aim and objectives of the study

The aim of the study is to create an integrated information evacuation system based on mathematical modeling of multicriteria optimization problem of flow distribution [1] and design, build technology for receiving-transfer data and information notification systems for the selected building type in order to adopt an operational evacuation plan.

To achieve this aim, the following objectives are accomplished:

– develop an information model of the evacuation system, taking into account class schedules and classrooms;

– model and design the evacuation information system;

– develop a database and implement a software and hardware evacuation system, test the system.

4. Materials and methods

The most commonly used methods for modeling human movement are the representation of human movement in the form of fluid flows (hydroanalogy), cellular automata, and network models.

Network models involve the representation of building components in the form of nodes connected by arcs. Each arc is compared to some crossing time. The movement of people is calculated from node to node. In some network models, each individual person is matched with a certain route within the network and a certain arc crossing time. With this approach, it is fundamentally possible to simulate the movement of people with different speeds. Thus, network models allow the individual characteristics of individuals to be taken into account. In addition, it is possible to represent the building as a network with such a number of constituent elements, which would not greatly complicate the modeling algorithm. The main difficulty in the construction of such models is the labor intensity of forming the structure of the network.

The main methods for calculating the parameters of human flow are:

– the method of calculating the total evacuation time and flow parameters using the formulas of GOST 12.1.004-91;

– calculation of the total evacuation time and flow parameters by grapho-analytical method;

– calculation of flow parameters, taking into account the influence of the density of the flow and the emotional state of the people on the speed of their movement.

The grapho-analytical method calculates the speeds of flow reshaping, the speed of the head and the main part of the flow, etc. The obtained data is plotted on the graph. Using special constructions, the total evacuation time is determined. The main advantage of grapho-analytical method is that it takes into account the reformation of the flow, and therefore gives a more accurate result. At the same time, the graph-analytical method is rather labor-intensive for practical implementation.

Developed mathematical model [10] to build an information model for the network of people flux distribution in enclosed spaces, taking into account the architectural features of the building. Models for multi-criteria optimization of flow distribution over Grinshield network with analysis of flow formation and characteristics of people paths in the building in real time. Computer simulation of the flow distribution in the integrated network taking into account the wireless sensor network of receiving and transmitting information.

Let's suppose that an emergency has happened in an educational institution bringing to the necessity to evacuate people. There are 24 classrooms with 30 students in each, and 10 stair wells and 2 exits (Fig. 1). It is necessary to calculate the time, speed and direction of students' evacuation from the educational institution. Let's specify a graph $G=<E, V, H>$, in which direction of every arc $v \in V$ identifies direction of flow motion, flow capacity of each arc equals to dv. Auditoriums are in E vertexes multiple. There identified two vertexes "start" and 'end' in E vertexes multiple. Vertex 0 is the stream source, 35 flowing. For i from E there given 2 numbers: amount of people sitting there and amount of people rushing out of there per time unit. Arcs are corridors and stir wells between the nodes.

Let's describe people's flow movement along a corridor and staircase by means of Grinshield formula. Let's introduce following designations: L – network section length, T – time of moving along the section, x – flow having passed the road section for time unit, P – flow density, S – number of lanes, W – speed of flow, λ – average corridor length.

As defined, the density is $\rho=1/\lambda$. Assume W – student's speed, W_{max} – maximum speed. Time, which gets a man to travel a route section of λ length equals to $\tau=\lambda/v$. Amount of students per time unit will be equal to $k=1/\tau$. Therefore, $x=ks=(1/T)S=w/\lambda=wps$. Let's consider that the flow speed and density are interconnected due to linear dependence $w/w_{max}+p/p_{max}=1$ (Grindshiels formula).

Therefrom $w=w_{max}(1-p/p_{max})$, or $p=p_{max}(1-w/w_{max})$. Let's insert it, and obtain $x=swp_{max}(1-w/w_{max})$. Obtained function is a parabola with branches downward directed, maximum is achieved at $w=w_{max}/2$, and accordingly $x_{max}=s(w_{max}p_{max})/4$ [10].

In the work let's consider the design of the information system, dynamic and static models of the information system. Database on sources of flux and architectural features of the building.

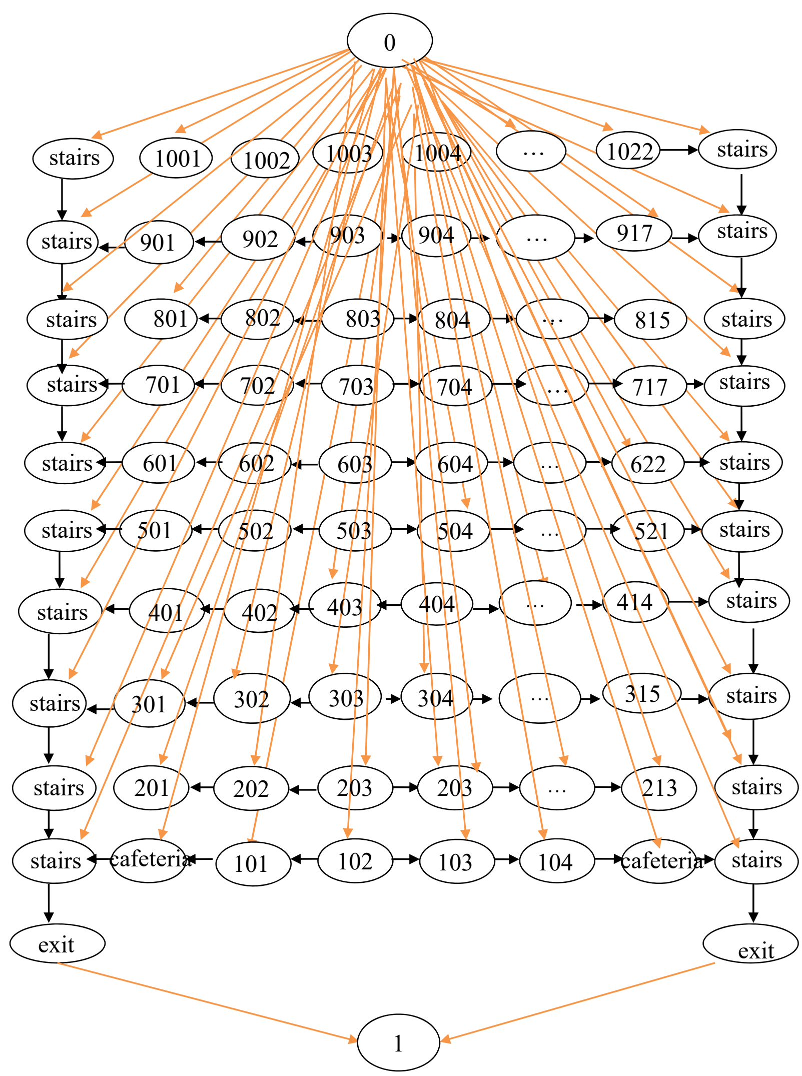

Fig. 1. The building of the main educational building of Kazakh National Research Technical University named after K. I. Satpayev in the form of a graph

CASE refers to a set of methods and tools for designing information systems with integrated automated tools that can be used in the software development process.

A programming model is a set of programming techniques corresponding to the architecture of an abstract computer designed to perform a certain class of algorithms. The programming model is based on a certain notion of the logical organization of the computer, its architecture.

Using CASE tools Rational Rose is made:

– a model of the subject area, the description of the subject area using UML is well perceived by subject matter experts and does not require any special training to understand the models presented to them for consideration;

– dynamic modeling of information system (sequence and interaction diagram) The sequence diagram (Fig. 8) shows the process of the Administrator's actions sequentially when the program code changes;

– static modeling of the information system (class diagram). Class diagrams also depict class attributes, class operations, and constraints that are imposed on the relationships between objects. A class diagram is shown in Fig. 9.

On the part of mathematical modeling will be investigated effective coverage zones for the selected type of building (university). As a result of research on finding the optimal coverage will be installed sensors receiving information transfer, defined information flows, the technology of processing information from sensors, will be proposed methods of notification of evacuation processes, both in the mode of educational and training mode, and in cases of emergency situations requiring an evacuation.

5. Results information system and software for building evacuation

5. 1. Develop an information model of the evacuation system, taking into account class schedules and classrooms

Let's propose a conceptual scheme of the evacuation task based on heterogeneous systems of receiving and transmitting information (Fig. 2). The development of a computer model of the information system will be carried out according to the proposed conceptual schemes shown in Fig. 2, 3.

The use of mathematical methods and information technologies significantly increases the efficiency of evacuation systems, therefore, the development of new integrated and info communication approaches to the evacuation problem is currently relevant.

A ten – story educational institution is presented. Suppose that people need to be evacuated from a building due to an emergency. Since the alarm is announced during the class, all classrooms will accordingly be occupied. Each classroom has a certain number of students. There are 1 to 22 classrooms on each floor. There are 2 stairways between the floors. There are 2 exits in the building, two of them are the main exit, two are the emergency exit.

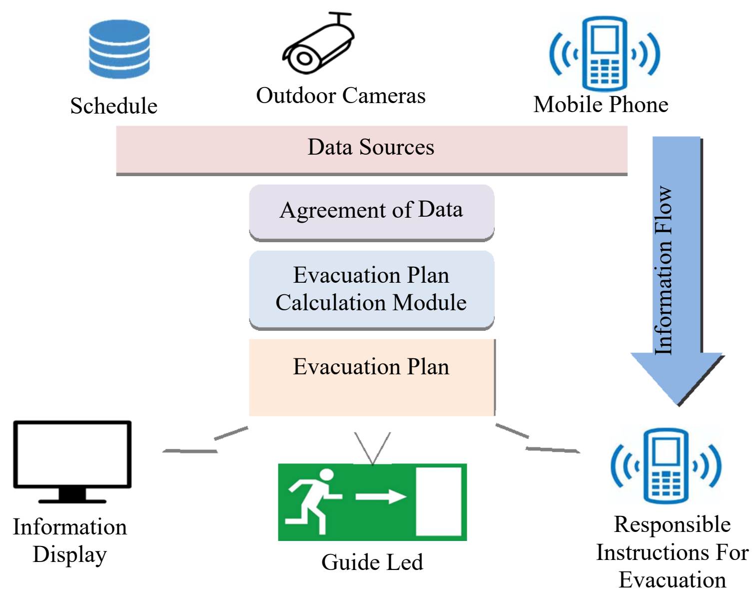

Fig. 2. Operational Plan

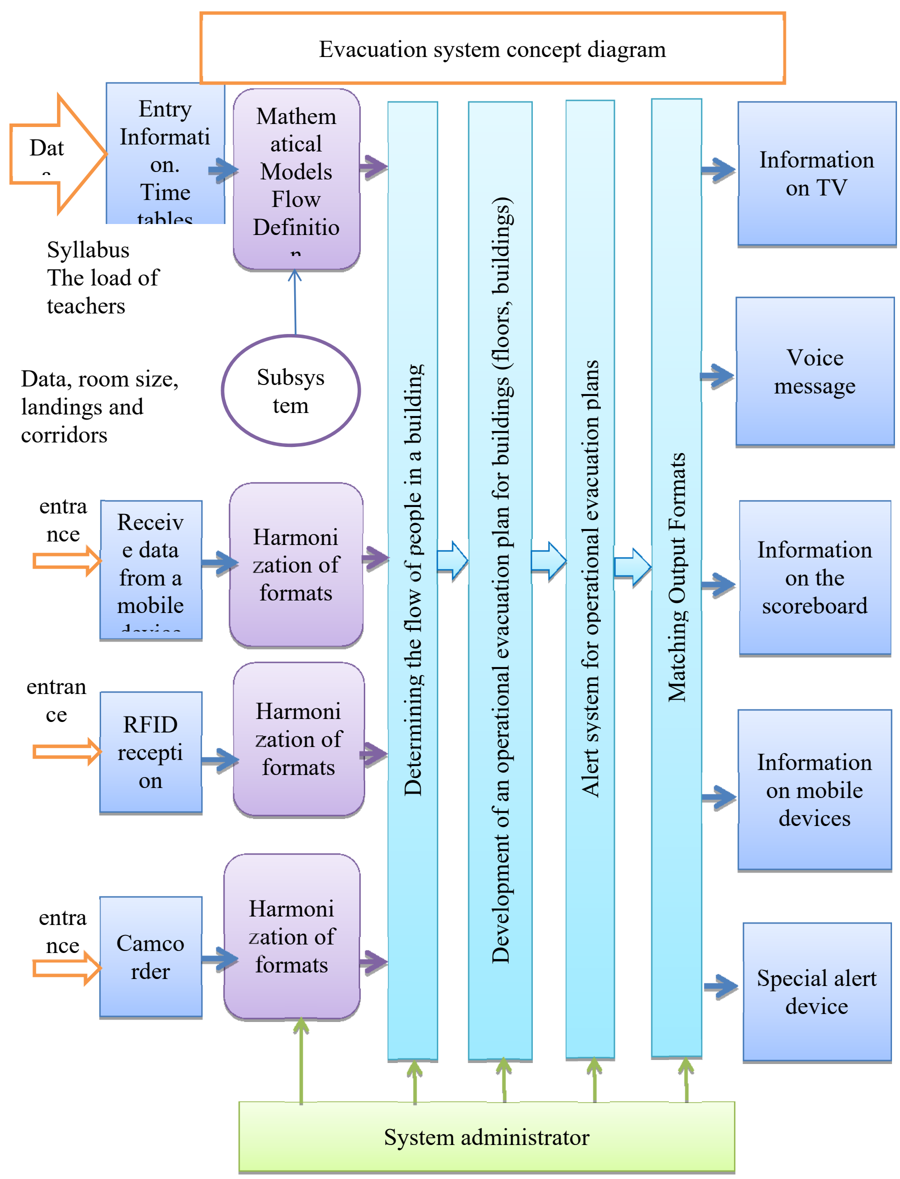

Fig. 3. Conceptual diagram of the evacuation system

Based on the timetable in educational institutions, it is possible to say that there are different numbers of people in different rooms. Since the number of people in the classroom varies, the evacuation plan must be appropriate.

It is very important for people in emergency situations (fire, earthquake, etc.) to quickly leave the building in which they are located.

The objective of the project is to develop the most effective evacuation plan, which will be based on the following data.

Model (object) – Kazakh National Research Technical University named after K. I. Satpayev. The model of the university interior in the AutoCAD program is shown in Fig. 4.

Data on the distribution of people in the interior of the building, obtained from the database of the class schedule Fig. 5, 6.

The module for modeling and optimizing the distribution of human flows uses the following input data:

1) data about the distribution of people in the internal rooms of the building, obtained from the database of class schedules;

2) range of horizontal projection areas of a person, specified by the user;

3) range of speeds of free movement of people, taking into account the level of psychological tension of the situation, specified by the user.

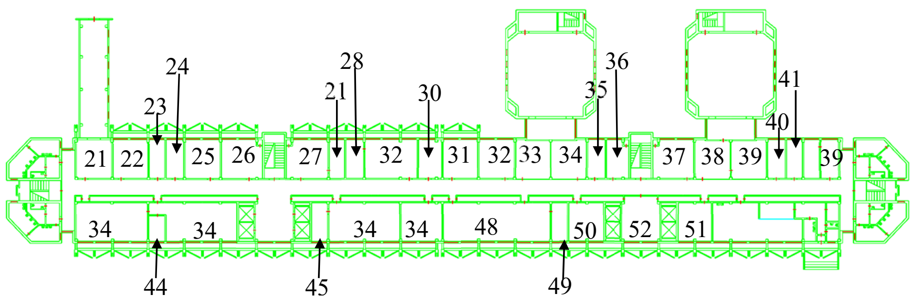

Fig. 4. Plan of the Kazakh National Research Technical University named after K. I. Satpayev building (main educational building, 2^{nd} floor) [10]

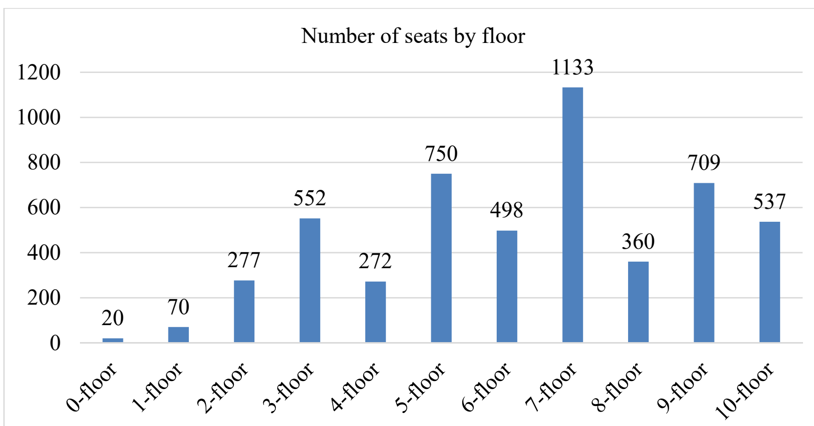

Fig. 5. Number of seats by floor

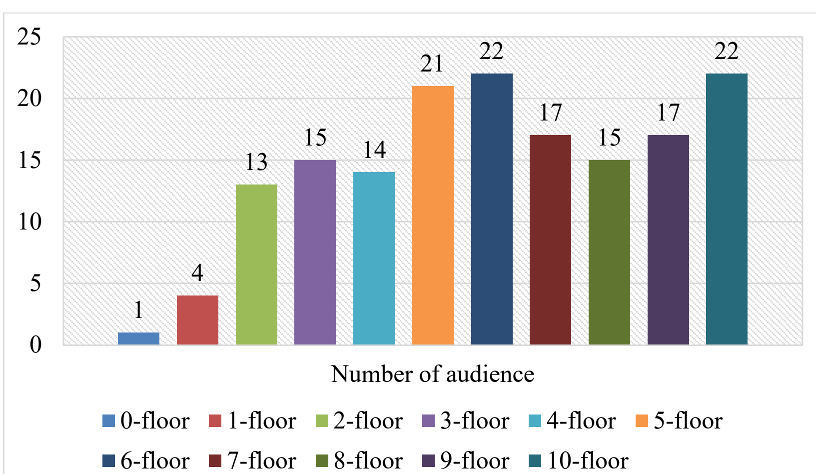

Fig. 6. Number of audience by floors

Outputs of the module of modeling and optimization of the distribution of human flows include:

1) a near-optimal evacuation plan for the considered distribution of people in the interior of the building (indicating evacuation routes for each room);

2) the total duration of evacuation when the near-optimal evacuation plan is implemented;

3) the density of the human flow on each floor at certain points in time (when the program runs in simulation mode).

Data on the distribution of people in the interior of the building, obtained from the schedule database Fig. 5, 6.

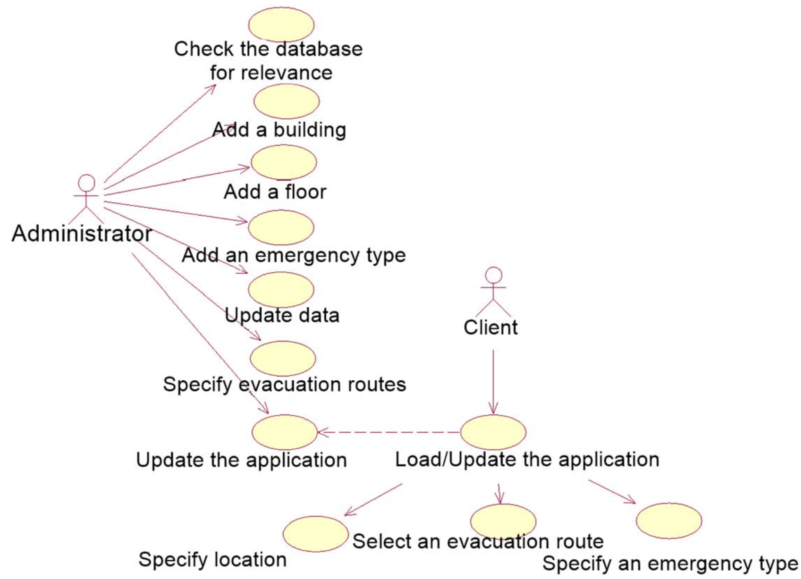

Fig. 7. Subject Area Model

5. 2. Model and design of the evacuation information system

UML is a unified graphical modeling language for describing, visualizing, designing, and documenting object-oriented systems. UML is designed to support the process of modeling software based on an object-oriented approach, to organize the relationship of conceptual and software concepts, to reflect the problems of scaling complex systems.

With the help of CASE tools Rational Rose made model of the subject area (Fig. 7).

The administrator adds the building to the application code. After adding a building, the administrator adds the floor plans of the building or checks their relevance. If the database is out of date, the Administrator updates the data. The administrator adds emergency types and escape routes for each floor.

After changing the application, the Administrator updates the application and adds it to an external resource.

All use cases, one way or another, are related to external requirements for the functionality of the system. If the Accounting System requires a file, then this requirement must be satisfied. Use cases should always be analyzed in conjunction with the actors in the system, while defining the real needs of the users and considering alternative ways of solving these problems.

Actors can play different roles in relation to a use case. They can use its results or can directly participate in it themselves. The significance of the different roles of an actor depends on how its connections are used.

External events are a good source for identifying use cases. It is possible to start by listing all the events taking place in the outside world to which the system must react in some way. Any specific event can cause a system reaction that does not require user intervention, or, conversely, cause a purely user reaction. Identifying the events to react to helps highlight use cases.

Dynamic modeling of the information system (sequence and interaction diagram).

The sequence diagram Fig. 8 shows the process of sequentially performing the Administrator's actions when changing the program code.

Class diagrams also depict class attributes, class operations, and constraints that apply to relationships between objects. The class diagram is shown in Fig. 9.

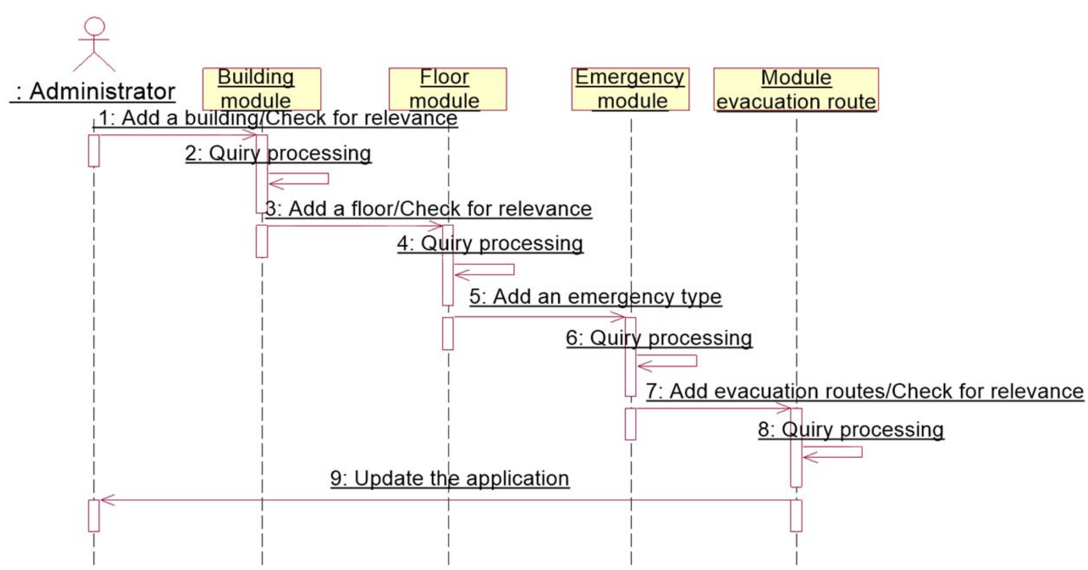

Fig. 8. Diagram of sequences of actions of the Administrator

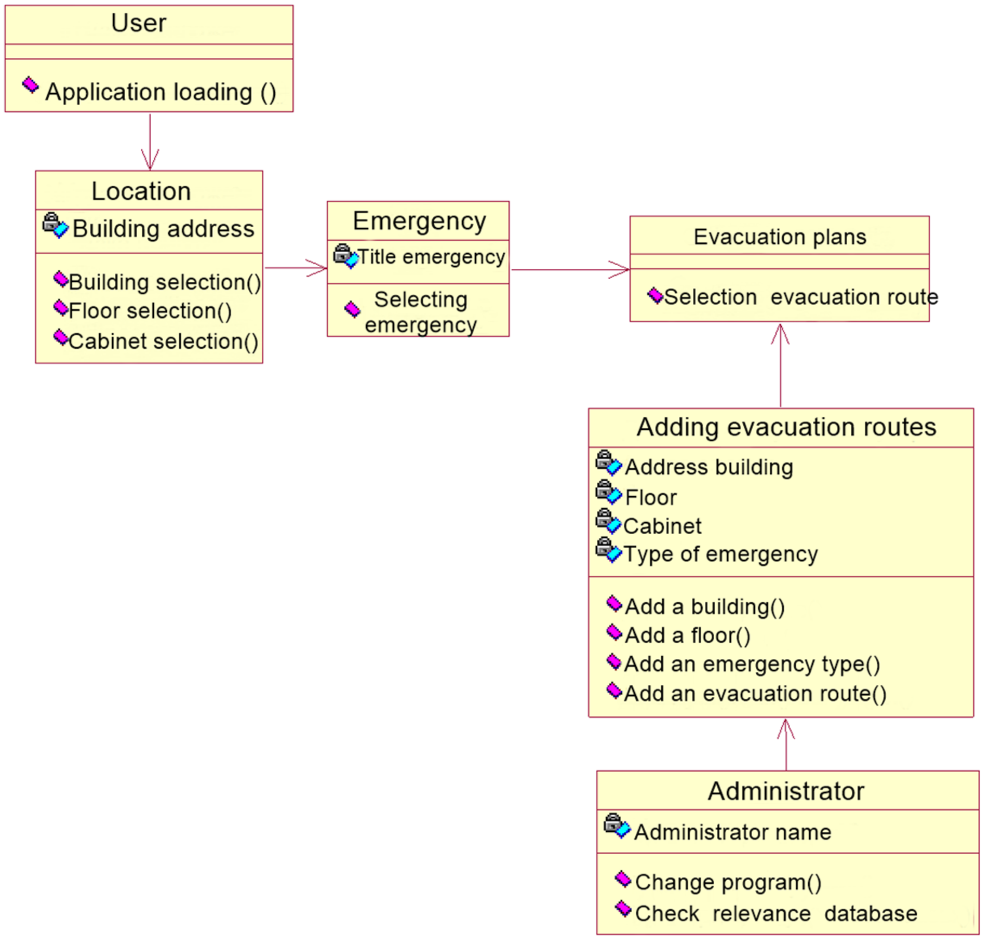

Fig. 9. Class diagram

Class diagrams are the centerpiece of object-oriented methods. A class diagram defines the types of objects in the system and the various kinds of static relationships that exist between them. There are two main types of static links:

– associations (for example, a customer can make an order);

– subtypes (private client is a type of client).

The main goal of the project is to create the most optimal plan for emergency evacuation in educational institutions according to the schedule at a certain time.

5. 3. Development of a database and implementation of a software and hardware evacuation system, test of the system

The evacuation should be based on the number of people in the auditors, which differ depending on the time and schedule, in order to avoid any crowding during the evacuation process. This approach provides a quick evacuation without any crush and density, which in the future will help save a lot of time and reduce the risk of human life.

The main tasks are:

– calculate the distance from each classroom to each exit;

– calculate the transmittance of the outputs;

– according to the schedule, count the number of people in each classroom;

– organize each exit (if more than 2) according to the priorities of each classroom;

– create an algorithm taking into account the flow of people. Find the optimum and most efficient way to avoid crowds and quickly evacuate.

The shortest path problem. Dijkstra's algorithm.

In graph theory, the shortest path problem is to find a path between two vertices (or nodes) in a graph in such a way that the sum of the edge weights is minimal.

Dijkstra's algorithm is a graph algorithm invented by the Dutch scientist Edsger Dijkstra in 1959. Finds the shortest paths from one of the vertices of the graph to all the others. The algorithm works only for graphs without edges of negative weight. The algorithm is widely used in programming and technology, for example, it is used by the OSPF and IS-IS routing protocols.

The NetBeans IDE is a free, open source, integrated development environment (IDE) that allows to develop desktop, mobile, and web applications. The IDE supports application development in a variety of languages, including Java, HTML5, PHP, and C++. The IDE provides integrated support for the full development cycle, from project creation with debugging, profiling, and deployment. The IDE runs on Windows, Linux, Mac OS X and Unix based systems.

The IDE provides comprehensive support for JDK 7 technologies and the latest Java enhancements. It is the first IDE to provide support for JDK 7, Java EE 7, and JavaFX 2. The IDE fully supports Java EE using the latest standards for Java, XML, Web Services, SQL, and fully supports GlassFish Server, a reference implementation in Java EE.

Data on the distribution of people in the interior of the building, obtained from the schedule database Fig. 10.

```
08.00 204 31
08.00 201 23
09.00 204 32
09.00 201 33
09.00 213 21
10.00 204 21
10.00 209 34
10.00 201 30
10.00 213 26
11.05 204 21
11.05 225 35
11.05 209 29
11.05 201 35
11.05 202 22
11.05 213 22
12.05 204 22
12.05 209 21
13.05 209 36
13.05 204 27
13.05 202 31
13.05 201 37
14.10 202 31
14.10 201 37
```

Fig. 10. New txt file

Since the program will show the optimal emergency evacuation plan, it is necessary to have a building plan. The building plan of KazNRTU must be in JPEG or PNG format in order for it to appear at the beginning of the program. This floor plan shows each floor separately (1st to 10th floor).

By extracting data from the file list, it is possible to restore a new txt file that will contain the following information:

– lecture hall No;

– lecture (start time);

– the number of people in the hall.

As it is possible to see, in Fig. 11, the chart is organized according to these three aspects and is divided by day of the week.

```
201-210,420,210,450
202-190,560,190,590
204-300,560,300,590
209-350,420,350,450
213-555,420,555,450
215-645,420,645,450
221-925,420,925,450
225-975,420,975,450
```

Fig. 11. Coordinates of the lecture halls

Since the program is Java based and has the ability to draw a path from auditorium to exit, it is obvious that it is necessary to use Canvas. In order to show the number of people in lecture halls and draw lines between objects, we are dealing with coordinates. This results in another text file with the following information:

– lecture hall No;

– coordinates along the *X* axis;

– coordinates along the Y axis.

As yit is possible to see in Fig. 12, there are 8 lecture halls on the second floor. Next to the lecture hall number are numbers, which are the *X* and Y coordinates, separated by commas.

```
201-11.5
202-19
204-9.5
209-5.5
213-4
215-2
225-1.5
```

Fig. 12. Exit priority

In order to develop an optimal evacuation algorithm, it is necessary to have information about the «exit priorities» for each classroom, based on distance. Since there are 4 main outputs, where there will be a stream of people, there are 4 different files that show the distances from each classroom.

The file should contain the following:

– lection (number of people),

– the distance from each lecture hall to the exits (Fig. 12).

These files will be used to distribute people from the hall to the exits in the best way to avoid collisions. Based on this distance, this algorithm will calculate the number of people from each hall to the exit. This amount will vary depending on the distance to the exit.

The final product should contain an image of the floor plan and paths for each exit. Which means, if to work in Java, our Canvas has 2 layers:

– JPEG images (building plan);

– created path with label.

In order to show a picture of the KazNITU plan, it is necessary to add it to our Canvas. it is necessary to create a GraphicsContext object, images (Fig. 13).

```
//************************************************
    Image image = new Image("guk.jpg");
    ImageView iv2 = new ImageView();
     iv2.setImage(image);
     iv2.setFitWidth(1200);
     iv2.setFitHeight(800);
     iv2.setPreserveRatio(true);
     iv2.setSmooth(true);
     iv2.setCache(true);
```

Fig. 13. Creating an image object

Then, setting its width, height and other parameters in imageView, let's add it to the Canvas. In order to create a Canvas, it is necessary to create an object of the Canvas class and give it a specific width and height. Then let's add this Canvas to create the object's graphics context (Fig. 14).

```
Scene s = new Scene(root, 1300, 800, Color.BLACK);
final Canvas canvas = new Canvas(1300, 800);
gc = canvas.getGraphicsContext2D();
         gc.clearRect(0, 0, 1300, 800);
gc.setFill(Color.GREEN);
```

Fig. 14. Creating a Canvas object

Based on the current date and time, let's extract information from the files. If the day of the week is 2, let's use the monday.txt file and so on (Fig. 15).

```
if(day==2){
    path = "/Users/demo/Desktop/monday.txt";
    System.out.println(path);
} if(day==3){
    path = "/Users/demo/Desktop/tuesday.txt";
    System.out.println(path);
} if(day==4){
    path = "/Users/demo/Desktop/wednesday.txt";
    System.out.println(path);
} if(day==5){
    path = "/Users/demo/Desktop/thursday.txt";
    System.out.println(path);
} if(day==6){
    path = "/Users/demo/Desktop/friday.txt";
    System.out.println(path);
} if(day==7){
    path = "/Users/demo/Desktop/saturday.txt";
    System.out.println(path);
}
```

Fig. 15. Determining the target file

The next step is to get the current number of people in your classroom. To do this, it is necessary to extract the data from monday.txt and add all the lines to arroutList (Fig. 16).

```
try {
    InputStream instream = new FileInputStream(path);
    InputStreamReader isr = new InputStreamReader(instream,Charset.forName("UTF-8"));
    BufferedReader bufread = new BufferedReader(isr);
     String line = "";
    while((line=bufread.readLine() )!=null){
       schedule.add(line);
    }

} catch (Exception ex1) {

}
ArrayList<String> ttt = new ArrayList<>();
for(int i=0;i<schedule.size();i++){
    ttt.add(schedule.get(i).split(" ")[0]);

}
```

Fig. 16. Extracting data from monday.txt

Then let's add the present tense and sorting to the same arrayList. Based on the current index in the selection list, the previous one will become the beginning of time, and this line will show the flow density in the classrooms (Fig. 17).

```
ttt.add(time);
Collections.sort(ttt);
for(int i=0;i<ttt.size();i++){
   //  System.out.println(ttt.get(i));
}
begin_time = ttt.get(ttt.indexOf(time)-1);
```

Fig. 17. Adding the current time

The algorithm starts with a for loop, which is executed 4 times, since there are 4 main outputs, if i is zero, it is possible to consider lecture halls with priority output «a», and if i is equal to one, let's consider that output «B " and so on (Fig. 18).

```
for(int i=0;i<4;i++){

    if(i==0){
        negative_number=0;
        temp_array = new ArrayList<>();
        for(int j=0;j<rooms_priority_people.size();j++){
            if(rooms_priority_people.get(j).charAt(3)=='a'){
            temp_array.add(rooms_priority_people.get(j));
            }

        }
```

Fig. 18. Given the output «a»

Each exit has a certain number of people who are acceptable in order to avoid some collisions. This number is 60. Which means, when the sum of people in each lecture hall with priority «a» is more than 60, they must use a method that organizes the exit of a certain number of people from the classroom, which is exactly 60. That is why the first sum must be calculated (Fig. 19).

```
 //calculate sum of students
 for(String line : temp_array){
// System.out.println(line);
 sum = sum + Integer.parseInt(line.substring(7, line.length()));
 }
 System.out.println("sum is!-!_!_!_!_!_!"+sum);
 //check if its more that 60
```

Fig. 19. Calculation of the amount of people

If the sum is less than 60, let's take all the people from the classroom and direct them to this exit, storing them in a selection list called final_results_for_a (Fig. 20).

If the sum is more than 60, then by executing the getDistances method, which selects the classroom parameter and the priority exit (Fig. 21).

As soon as to execute the getDistance method, using the second parameter, let's define the corresponding file in txt format. For example, if the priority is «a», it is necessary to define the file a_exit.txt (Fig. 22).

```
if(sum<=60){
System.out.println("less that 60");
for(int k=0;k<rooms_priority_people.size();k++){
    for(String line2 : temp_array){
        if(rooms_priority_people.get(k).contains(line2.substring(0, 4))){
            rooms_priority_people.remove(k);
            final_result_for_a.add(line2.substring(0,3)+"/"+
                    line2.substring(7, line2.length()));
        }
    }
}
```

Fig. 20. If the amount is less than 60

```
if(sum>60){
    System.out.println("more that 60");
       ArrayList<String> distances = getDistances(temp_array, 'a');
       rooms_priority_people = replace(rooms_priority_people,distances);
       System.out.println("***********After 1*************");
       if(negative_number<0){
           System.out.println("7777777777777777777777777777777777777777");
       }
       rooms_priority_people = remove_zeros(rooms_priority_people);
       for(String in : rooms_priority_people){

           System.out.println(in);
       }
```

Fig. 21. If the amount is more than 60

In order to count the exact number of people from each classroom, it is necessary to focus on the content of the txt file. As mentioned above, it has already determined the distance from the hall to the exits (Fig. 23).

By determining each distance, it is possible to calculate the exact number of people from each classroom (Fig. 24).

The next step is to subtract the percentage that was calculated earlier from the original amount. If the result is a negative number, it means that some people will be drawn from the next lecture hall. If the result is a positive number, it means that some people stay in this lecture, they will be directed to a different exit (Fig. 25).

The next step is to save the result to an array list. Each output has its own array list (Fig. 26). By adding a percentage of the amount to the lecture hall, there is one line that looks something like this:201/15, 202/3, 204/19, 209/15, 213/14, 215/20, 221/31, 225/25.

After saving the result in the appropriate selection list, it is necessary to replace the global array list (rooms_priority_people), which contains all the information, with a new array list using the replacement method (Fig. 27).

The next step is to check if no one is left in the lecture halls. If there are 0 people in the picklist rooms_priority_people, it is necessary to delete it. In order to do this, wit is necessary to use the remove_zeros.

The last step is to delete the priority method (Fig. 28).

After exiting with 60 people, it is necessary to move forward with the other exits, which means "a" exit switches to the last place and "B" exit will stand on the first (Fig. 29).

This lasts until the cycle reaches the last exit. Each output repeats the above steps and saves them to bring them to the appropriate selection list. Finally, the last result will be as shown in Fig. 30.

The developed software is designed to quickly and efficiently evacuate people from the school and can be used for other types of buildings.

The practical significance of the work consists in the development of models and methods for solving the problem of evacuation, modeling the information model of the evacuation system taking into account the minute-by-minute recording of the number of people in the classroom using sensor sensors, getting hourly optimal operational evacuation plan. The use of this system will reduce the evacuation time and reduce the flow of people out of the building. The results and main provisions of the work can be used for educational purposes, as training in emergency situations.

```
public ArrayList<String> getDistances(ArrayList<String> temp_arrays,char exit){

    double sum_of_percentage = 0;
    ArrayList<String> dist = new ArrayList<>();
    ArrayList<String> ff = new ArrayList<>();

    String pat = "";
    if(exit=='a'){
        pat = "/Users/demo/Desktop/a_exit.txt";
    }
    if(exit=='b'){

        pat = "/Users/demo/Desktop/b_exit.txt";
    }
    if(exit=='c'){
        pat = "/Users/demo/Desktop/c_exit.txt";
    }
    if(exit=='d'){
        pat = "/Users/demo/Desktop/d_exit.txt";
    }
```

Fig. 22. Define the corresponding txt file

```
 try {
InputStream instream = new FileInputStream(pat);
InputStreamReader isr = new InputStreamReader(instream,Charset.forName("UTF-8"));
BufferedReader bufread = new BufferedReader(isr);
 String line = "";
while((line=bufread.readLine() )!=null){

            for(int i=0;i<temp_arrays.size();i++){
                if(temp_arrays.get(i).substring(0, 3).equals(line.split("-")[0])){
                    //System.out.println("$$$$$");
                    //System.out.println(line);
                    sum_of_percentage = sum_of_percentage +
                            Double.parseDouble(line.split("-")[1]);
                    dist.add(line);
                }
            }
```

Fig. 23. Extracting content from a_exit.txt file

```
for(int i=0;i<dist.size();i++){
    double perc = (Double.parseDouble(dist.get(i).split("-")[1])/
            sum_of_percentage)*60;
    System.out.println("Percentage of "+perc);
    double origin = Double.parseDouble(temp_arrays.get(i).substring(7,
            temp_arrays.get(i).length()));
    System.out.println(origin+"----------"+perc);
```

Fig. 24. Calculation of percentage

```
    int subtr = (int)(origin - Math.round(perc))+negative_number;
    int temp=0;
     if(subtr==0){
        temp = (int)(Math.round(perc));
    }
    if(subtr<0){
        negative_number = subtr;
        System.out.println("It is negative!!");
        System.out.println("negative number:"+negative_number);
        temp = (int)origin;
        subtr=0;

    }
    if(subtr>0){
        System.out.println("It is positive!!");
        System.out.println("negative number:"+negative_number);
      temp = (int)(Math.round(perc))-negative_number;
      negative_number=0;
    }
```

Fig. 25. Working with unnecessary people

```
if(exit=='a'){

    final_result_for_a.add(temp_arrays.get(i).substring(0, 3)+"/"+temp);
    System.out.println(temp_arrays.get(i).substring(0, 3)+"/"+temp);
}
if(exit=='b'){
  final_result_for_b.add(temp_arrays.get(i).substring(0, 3)+"/"+temp);
    System.out.println(temp_arrays.get(i).substring(0, 3)+"/"+temp);
}
if(exit=='c'){
   final_result_for_c.add(temp_arrays.get(i).substring(0, 3)+"/"+temp);
    System.out.println(temp_arrays.get(i).substring(0, 3)+"/"+temp);
}
if(exit=='d'){
   final_result_for_d.add(temp_arrays.get(i).substring(0, 3)+"/"+temp);
    System.out.println(temp_arrays.get(i).substring(0, 3)+"/"+temp);
}
```

Fig. 26. Saving the result

```
rooms_priority_people = replace(rooms_priority_people,distances);
System.out.println("***********After 3*************");

 if(negative_number<0){
    System.out.println("7777777777777777777777777777777777777777");
    System.out.println("NEgatiiiiive numbeeer--"+negative_number);
}
for(String in : rooms_priority_people){

    System.out.println(in);
}
```

Fig. 27. Using the replace method

```
for(int k=0;k<rooms_priority_people.size();k++){
 if(rooms_priority_people.get(k).charAt(6)!='d'){
 String some = remove_priority(rooms_priority_people.get(k),'d');
    rooms_priority_people.remove(k);
    rooms_priority_people.add(k, some);
 }
```

Fig. 28. Using delete priority method

```
private String remove_priority(String get, char c) {
    String sub_get = get.substring(3, 7);
    System.out.println("what about meeee!!!1 "+
            sub_get.substring(0, sub_get.indexOf(c+"")));
    String f = sub_get.substring(0, sub_get.indexOf(c+""));
    System.out.println("what about meeee!!!2 "+
            sub_get.substring(sub_get.indexOf(c+"")+1,sub_get.length()));
    String s = sub_get.substring(sub_get.indexOf(c+"")+1,sub_get.length());
    String changed_priority = f+s+c;

    String n_strint = get.substring(0, 3)+changed_priority+
            get.substring(7, get.length());
    System.out.println("what abut meee!!3 "+n_strint);
    return n_strint;
}
```

Fig. 29. Remove Priority Method

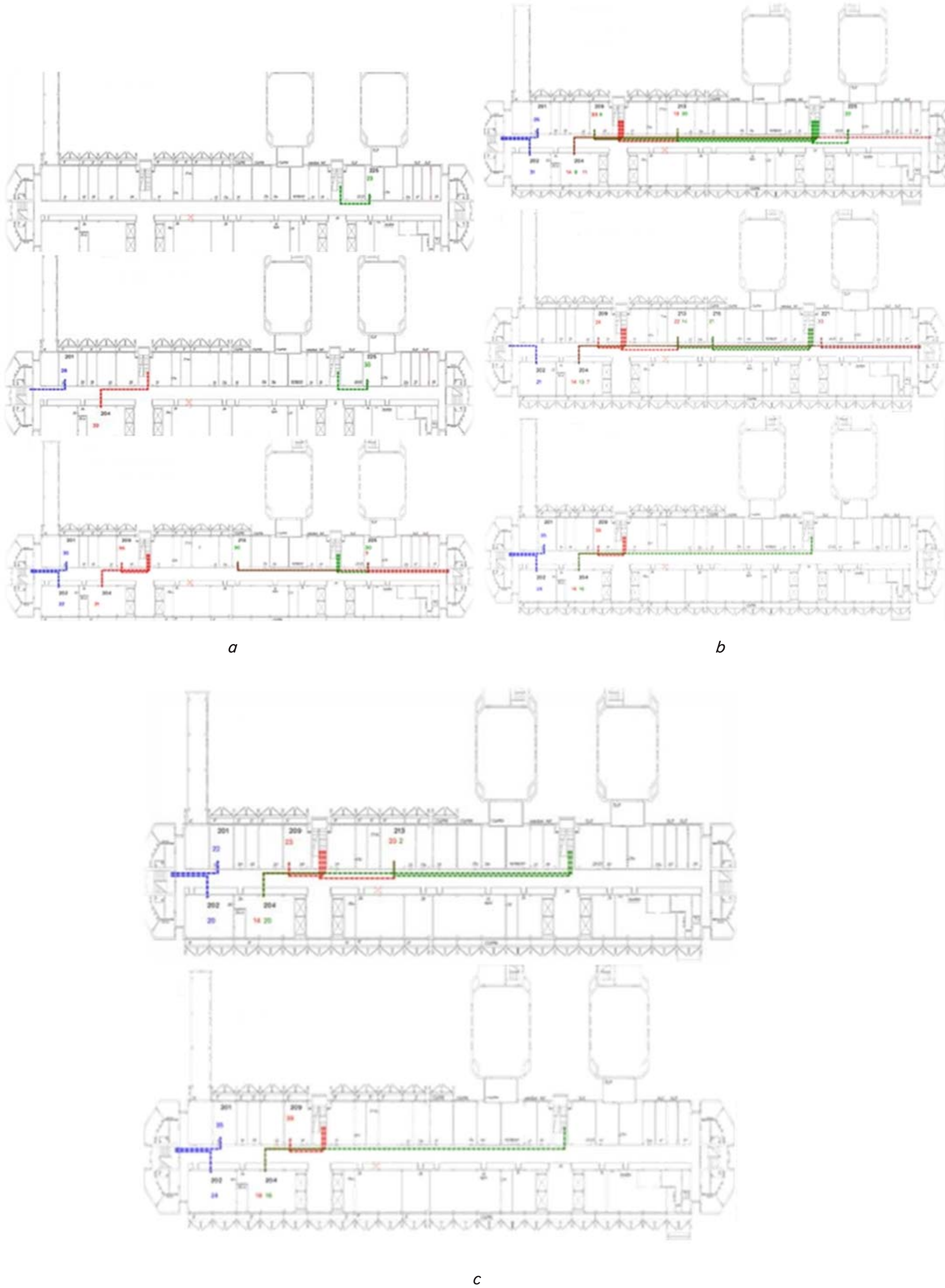

Fig. 30. Flow distribution of people according to the schedule of classes: *a* – time 08.50–09.00, time 09.50–10.00, time 10.50–11.00; *b* – time 11.50–12.00, time 12.50–13.00, time 14.50–15.00; *c* – time 15.50–16.00, time 16.50–17.00

6. Discussion of the results infocommunication approaches to solving the problem of evacuation and the effectiveness of evacuation systems

Creating an integrated evacuation information system is based on mathematical modeling of multicriteria optimization problem of flow distribution and design, building technology of data reception-transmission and information notification systems for the selected type of building in order to adopt an operational evacuation plan.

The use of mathematical methods and information technology significantly increases the efficiency of evacuation systems, so the development of new integrated and intelligent info-communication approaches to solving the problem of evacuation.

The developed information model and info–communication approach allows to quickly organize the evacuation of people in enclosed spaces, taking into account the architectural features of the building. Using Rational Rose built diagrams, the model of the subject area is shown in (Fig. 7), dynamic modeling information system sequence diagram (Fig. 8) shows the process of sequential administrator actions and static modeling class diagram is shown in (Fig. 9).

The developed software is designed (Fig. 10–29) to quickly and efficiently evacuate people from the school (Fig. 30) and can be used for other types of buildings.

In the republic there is almost no systematic monitoring of evacuation systems for different regions and types of buildings at possible natural and man-made risks. In this connection, accidents and disasters are not predicted, comprehensive measures for their prevention, preparedness for them are not fully implemented. In many buildings, evacuation plans are fixed in schemes that have not been changed for years. The parameters and conditions of evacuation are not taken into account in real time.

The results and main provisions of the work can be used for educational purposes, as training in simulating the occurrence of emergencies.

Critical points may also be all technical means of receiving and transmitting information, notification systems of evacuation processes.

7. Conclusions

1. An information model of the evacuation system is developed, taking into account the schedule of classes and classrooms, and a conceptual scheme of the evacuation task proposed based on heterogeneous systems of receiving-transmitting information of the main educational building of the Kazakh National Research Technical University named after K. I. Satpaev with a total capacity of 4,500 seats and 4 stairwells and 2 exits in the city of Almaty.

2. Using means and modules for the successful solution of the evacuation task with the constructed operational plan it is proposed a conceptual scheme of the evacuation task on the basis of heterogeneous systems of receiving-transmitting information. The development of a computer model of the information system is carried out according to the proposed conceptual diagrams. The university's evacuation information system is modeled and designed, built a UML use case diagram, an action sequence diagram, and a class diagram.

3. The developed software is designed for quick and maximally effective evacuation of people from the educational institution in conditions of non-stationary distribution of people in the premises of the building, allowing to evaluate the educational schedule in terms of the unobstructed evacuation in ensuring human safety.

Acknowledgments

This work is supported by grant from the Ministry of Education and Science of the Republic of Kazakhstan within the framework of the Work №AP08855903 «Development of intelligent information technology for the real-time evacuation task», Institute Information and Computational Technologies CS MES RK.

References

1. Belyaev, S. V. (1938). Evakuatsiya zdaniy massovogo naznacheniya. Moscow: Izdatel'stvo «Vsesoyuznoy Akademii Arkhitektury», 72.
2. Predtechenskiy, V. M., Milinskiy, A. I. (1979). Proektirovanie zdaniy s uchetom organizatsii dvizheniya lyudskikh potokov. Moscow: Stroyizdat, 375.
3. Kholschevnikov, V. V. (1983). Lyudskie potoki v zdaniyakh, sooruzheniyakh i na territorii ikh kompleksov. Moscow: MISI.
4. Kholschevnikov, V. V., Samoshin, D. A., Isaevich, I. I. (2009). Naturnye nablyudeniya lyudskikh potokov. Moscow: Akademiya GPS MCHS Rossii, 191.
5. Cappuccio, J. (2000). A Computer-Based Timed Egress Simulation. SFPE Journal of Fire Protection Engineering, 8, 11–12.
6. Fahy, R. (1996). EXIT89: High-Rise Evacuation Model – Recent Enhancements and Example Applications. International Interflam Conference «Inter– flam '96». Cambridge, 1001–1005.
7. Weinroth, J. (1989). An adaptable microcomputer model for evacuation management. Fire Technology, 25 (4), 291–307. doi: https://doi.org/10.1007/bf01040378
8. Fahy, R. (1996). Enhancement of EXIT89 and Analysis of World Trade Center Data. NIST GCR. Available at: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=909241
9. Stepantsov, M. E. (2003). Model' napravlennogo dvizheniya tolpy s elementami analiza situatsii. Issledovano v Rossii, 89, 991–995.
10. Amirgaliyev, Y., Kalizhanova, A., Kozbakova, A., Aitkulov, Z., Astanayeva, A. (2021). Development of a systematic approach and mathematical support for the evacuation process. Eastern-European Journal of Enterprise Technologies, 3 (4 (111)), 31–42. doi: https://doi.org/10.15587/1729-4061.2021.234959

11. Ibrahim, A. M., Venkat, I., Subramanian, K. G., Khader, A. T., Wilde, P. D. (2016). Intelligent Evacuation Management Systems. ACM Transactions on Intelligent Systems and Technology, 7 (3), 1–27. doi: https://doi.org/10.1145/2842630
12. Bi, H., Gelenbe, E. (2019). Emergency Management Systems and Algorithms: a Comprehensive Survey. MDPI Submitted to Electronics. Available at: https://arxiv.org/pdf/1907.04136.pdf
13. Bi, H., Gelenbe, E. (2019). A Survey of Algorithms and Systems for Evacuating People in Confined Spaces. Electronics, 8 (6), 711. doi: https://doi.org/10.3390/electronics8060711
14. Hartama, D., Windarto, A. P., Wanto, A. (2018). Evacuation Planning for Disaster Management by Using The Relaxation Based Algorithm and Route Choice Model. IJISTECH (International Journal Of Information System & Technology), 2 (1), 7. doi: https://doi.org/10.30645/ijistech.v2i1.14
15. Hamacher, H. W., Tjandra, S. A. (2001). Mathematical Modelling of Evacuation Problems: A State of Art. Berichte des Fraunhofer ITWN. Available at: https://kluedo.ub.uni-kl.de/frontdoor/index/index/docId/1477
16. Malodushev, S. V., Rogov, A. A., Voronov, R. V. (2019). Mathematical model for evacuation people from corridor-type buildings. Vestnik of Saint Petersburg University. Applied Mathematics. Computer Science. Control Processes, 15 (3), 375–384. doi: https://doi.org/10.21638/11702/spbu10.2019.307
17. Ng, C. T., Cheng, T. C. E., Levner, E., Kriheli, B. (2020). Optimal bi-criterion planning of rescue and evacuation operations for marine accidents using an iterative scheduling algorithm. Annals of Operations Research, 296 (1-2), 407–420. doi: https://doi.org/10.1007/s10479-020-03632-6
18. Schiopu, C. (2019). Maximum flows in bipartite dynamic networks. Bulletin of the Transilvania University of Brasov Series III Mathematics and Computer Science, 61 (12 (1)), 177–198. doi: https://doi.org/10.31926/but.mif.2019.12.61.1.14
19. Abusalama, J., Razali, S., Choo, Y.-H., Momani, L., Alkharabsheh, A. (2020). Dynamic real-time capacity constrained routing algorithm for evacuation planning problem. Indonesian Journal of Electrical Engineering and Computer Science, 20 (3), 1388. doi: https://doi.org/10.11591/ijeecs.v20.i3.pp1388-1396
20. Pyakurel, U., Nath, H. N., Dempe, S., Dhamala, T. N. (2019). Efficient Dynamic Flow Algorithms for Evacuation Planning Problems with Partial Lane Reversal. Mathematics, 7 (10), 993. doi: https://doi.org/10.3390/math7100993
21. Feng, J., Wang, Q. (2019). Emergency safety evacuation decision based on dynamic Gaussian Bayesian network. IOP Conference Series: Materials Science and Engineering, 688 (5), 055076. doi: https://doi.org/10.1088/1757-899x/688/5/055076