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Creatıng An Emergency Evolutıon Plan At A Unıversıty Usıng A Sımulatıon Model

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Research Article

Abstract-Many countries have experienced a lot of loss of life and material losses in many incidents due to natural or technological disasters. Planned and systematic action is required to manage emergencies. For this, a successful plan must be prepared. For emergency management to be successful, it is necessary to successfully evacuate people from the building in the event of a disaster. Emergency evacuation plans, evacuation drills and training should be provided. Simulations and models have often been one of the methods people use to study events. How solutions should be created for the events encountered were examined with simulations. With emergency evacuation simulations, an emergency management plan can be made close to reality. This study was carried out in a university building. In this 3-storey building, there are students, lecturers and working personnel. The best emergency evacuation plan to be applied in an emergency has been researched. It was aimed to create a plan with the shortest evacuation time by making experiments with the simulation program. A pathfinder simulation program was used in this study. In the first part, 11 scenarios related to the routing variability to the emergency exit doors were created. It is aimed to create a plan with the best evacuation time. In the second part, 5 scenarios were created about the situations where the emergency exit doors are locked and the doors are unusable for certain periods. The effects of these disruptions on the evacuation period were examined.

Keywords-*Emergency Evacuation, Emergency Plan, Pathfinder, Simulation*

Simülasyon Modeli Kullanarak Bir Üniversitede Acil Durum Tahliye Planı Oluşturulması

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Araştırma Makalesi

Öz-Birçok ülke doğal ya da teknolojik afetler nedeniyle birçok olayda fazlaca can kaybı ve maddi kayıplar yaşamıştır. Acil durumların yönetilmesi için planlı, sistematik hareket edilmesi gerekmektedir. Bunun için başarılı bir plan hazırlanmalıdır. Acil Durum yönetiminin başarılı olması için afet anında kişilerin binadan tahliyesinin başarılı bir şekilde yapılması gerekmektedir. Acil durum tahliye planlarının, tahliye tatbikatlarının yapılması ayrıca eğitimlerinin verilmesi gerekmektedir. Simülasyonlar ve modellemeler çoğu zaman insanların olayları incelemek için kullandığı yöntemlerden olmuştur. Karşılaşılan olaylar ile ilgili nasıl çözümler oluşturulması gerektiği simülasyonlar ile incelenmiştir. Acil durum tahliye simülasyonları ile acil durum yönetimi planı gerçeğe yakın yapılabilmektedir. Bu çalışma bir üniversite binasında yapılmıştır. Üç (3) katlı olan bu binada öğrenciler, öğretim elemanları ve çalışan personeller bulunmaktadır. Acil bir durumda uygulanacak en iyi acil tahliye planı araştırılmıştır. Simülasyon programı ile denemeler yapılarak en kısa tahliye süreli planın oluşturulması hedeflenmiştir. Bu çalışmada pathfinder simülasyon programı kullanılmıştır. İlk bölümde acil çıkış kapılarına yönlendirme değişkenliği ile ilgili on bir (11)adet senaryo oluşturulmuştur. En iyi tahliye süreli plan oluşturulması hedeflenmiştir. İkinci bölümde ise acil çıkış kapılarının kilitli olması ve belirli sürelerde kapıların kullanılamaz geldiği durumlarla ilgili beş (5) adet senaryo oluşturulmuştur. Bu aksaklıkların tahliye süresine olan etkileri incelenmiştir.

Anahtar Kelimeler-*Acil Durum Planı, Acil Durum Tahliye, Pathfinder, Simülasyon*

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1.INTRODUCTION

There are too many people in educational institutions during class hours. In higher education institutions, students, lecturers, civil servants and employees working in service work share the same working environment. In history, there have been many emergencies in educational institutions in Europe and America. Between 1908 and 1958, 755 people died in school fires in the United States (National Fire Protection Association,2021). In the United States, 298 people were killed in an explosion at a school in Texas Rusk County (Texas State Historical Association, 2021). In 2004, 93 students died in a fire caused by the explosion of a kitchen tube in a school in Tamil Nadu, India (Tuladharet all., 2014). Unplanned action in an emergency will increase the size of the disaster. An emergency evacuation plan should be made well and all people in the institution should be evacuated from the building without any harm. The created emergency plans should be tested with exercises. In places where the number of people is large, real exercises are difficult to implement and can be done in limited numbers. Accidents and injuries may occur during the exercise. By using simulation programs, the most appropriate evacuation plans can be prepared by carrying out unlimited studies with various scenarios. Studies can be done on real floor plans with realistic numbers of people. People's parameters can also be created with real values. Thanks to these programs in the computer environment, realistic results can be obtained.

Many scenarios designed in this study were examined and comparisons of evacuation times were made. The first episode scenarios were created as follows. Scenarios were designed, in which people knew the doors to exit, randomly headed to the exit doors, and were also directed to the exit doors with percentages and were randomly directed. Density maps were observed and escape routes were examined. Parameters such as the people's exit speed, the distance they took, and the stair densities were also reviewed. Evacuation plans were formed according to the simulation results and the most suitable escape routes were determined. An emergency evacuation plan with the shortest evacuation period has been created in the institution where the study will be conducted. In the scenarios of the second part, some negativities experienced at the emergency exit doors were simulated. Scenarios where the exit door is locked and the doors become unusable at various times were created and the delays of the plan with the best evacuation time were examined.

2.MATERIALS AND METHODS

2.1 Information on the Place of the Study

The university building where the study was conducted has three floors. In the building, which has a total construction area of 11750 m², three different colleges use this building, each floor being a separate unit. On the 1st floor of the building, there are 10 laboratories and 3 workshops, including computer, chemistry and R&D. 6 of the laboratories are 75 m², 1 of them is 85 m², 1 of them is 95 m² and 1 of them is 120 m². Workshops are 170 m² in size. There are 10 classrooms and 4 workshops on the second floor of the building. 5 classrooms are 75 m², 5 classrooms are 95 m², 3 workshops are 170 m² and the other workshop is 68 m². There are 10 classrooms and 7 laboratories on the 3rd floor of the building. 5 classrooms are 75 m², 5 classrooms are 95 m², 3 laboratories are 60 m² and 4 laboratories are 80 m². On each floor, there are offices, separate washbasins for students and academics, a tea room and restrooms. The sizes of the rooms in this section vary between 20 m² and 30 m². There are 2 fire and 3 normal exit stairs on each floor. The width of the fire stairs is 140 cm. The width of the main staircase is 190 cm, and the width of the other stairs is 150 cm. The total number of students, academicians and administrative staff of the three different colleges using this building is approximately 1730.

Figure 1: Floor plan top view

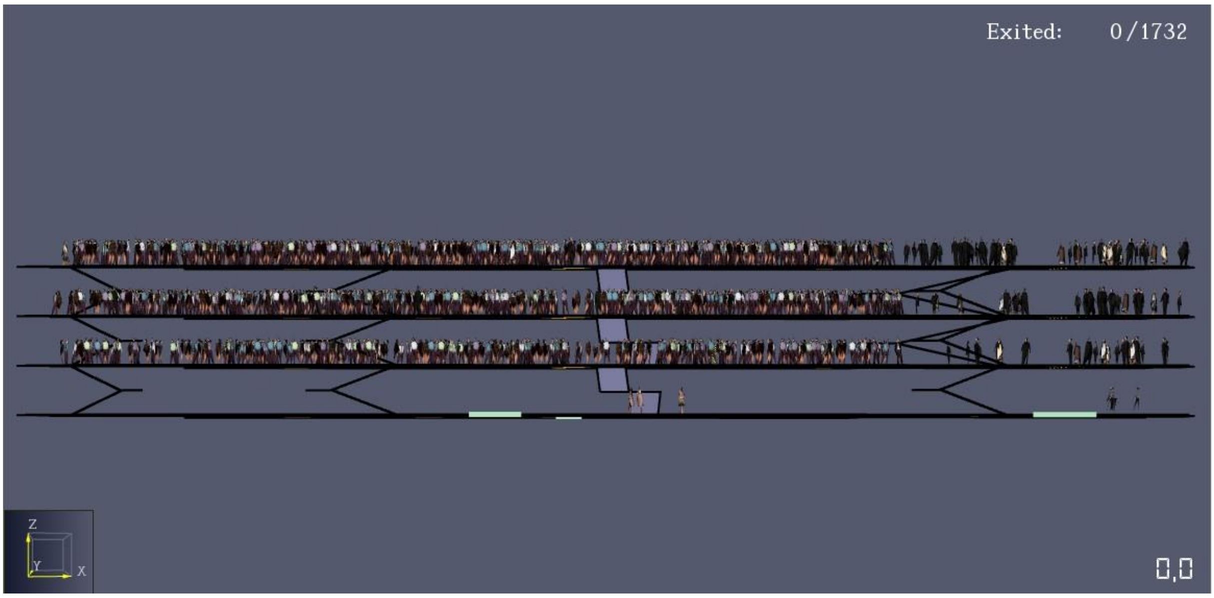


Figure 2: Floor plan side view

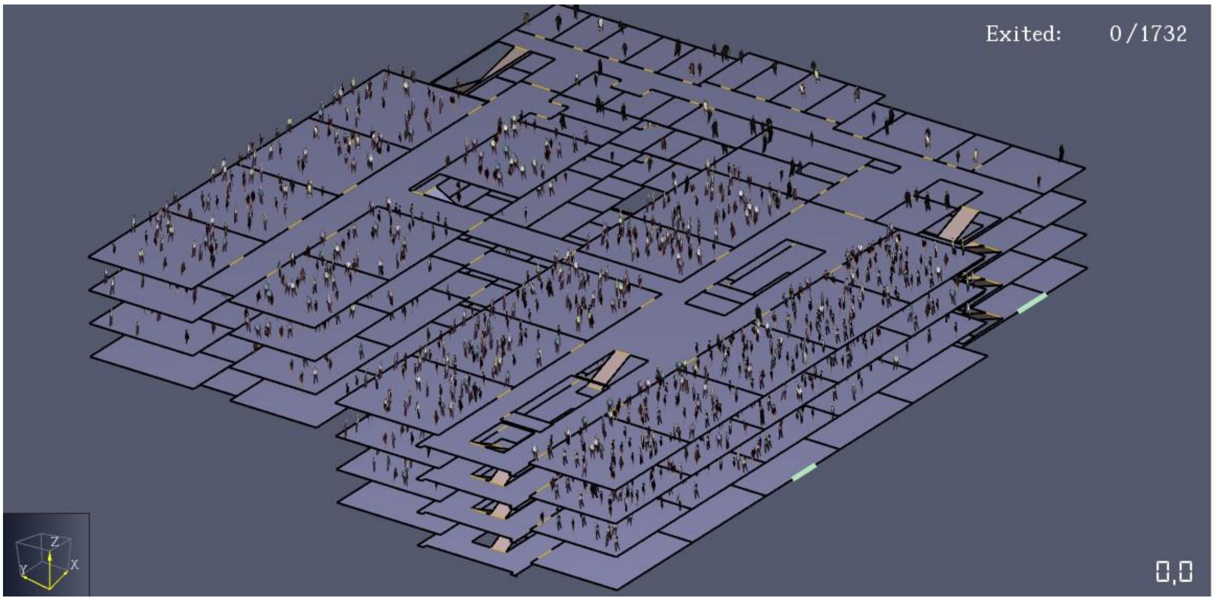


Figure 3: Floor plan 3D view

2.2 Pathfinder Simulation Program

Pathfinder Simulation Program was used in this study. This program is a three-dimensional and animated visual evacuation program. By drawing floor plans, stairs and exits are defined and distances are determined. The route is created. Modelling is done by determining the characteristics, gender and parameters of the people in the building. Floor plans can also be exported to the simulation in PNG, JPEG or GIF file format. The most important feature of the model is that it shows the evacuation visually. In this way, emergency escape routes will be observed during the evacuation with the analyses made (Thunderhead Engineering Consultants, 2019).

AutoCAD formatted DWG files can be transferred to the Pathfinder simulation program. It is possible to work on AutoCAD floor plans with real dimensions and obtain realistic results. It calculates the results with the use of artificial intelligence. In addition, this simulation model has been preferred because it has been widely used in recent studies and academic literature (Thunderhead Engineering Consultants, Inc., 2019).

We can express the working principles of the Pathfinder simulation program in two categories. The first is the use of Steering. In this use, it independently models the orientation of individuals in the face of obstacles. In another usage mode, it models possible actions using the guidelines of the fire protection engineer's association, which is expressed with the abbreviation SFPE (Society of Fire Protection Engineers). In the Pathfinder simulation, each coded person is called an agent. For this reason, the pathfinder simulation model is called agent-based modelling (The Society of Fire Protection Engineers, 2020).

2.3 Pathfinder simulation program literature review

There are many articles about Pathfinder simulation model studies. One of them is Hui Zhang and Hao-cheng Long's article, BIM and Pathfinder-based evacuation simulation in crowded places. In this article, the subject of discharge from the hospital is discussed. They have programmed the properties of the agents as persons who can be found in the hospital. Agents are categorized as children, adult women, adult men, and the elderly, with their speed and shoulder height adjusted. In the study, two scenarios related to the use and non-use of elevators were designed and programmed with people randomly turning to the exit. Children are given priority for evacuation. In this study, the evacuation time from the hospital building was examined with two scenarios (Zhang and Long, 2021).

In another article, a fire emergency evacuation simulation was made in a metro station. In this simulation, agents are divided into 7 categories. It is programmed as a child, young, middle-aged and old and female and male. Emergency evacuation speeds and shoulder widths are adjusted. Scenarios have been created for a single train or two trains to arrive at the station. By increasing the number of people, evacuation times in case of density were examined in 8 different scenarios. There is no restriction on routing to outputs (Qinet al., 2020).

In another reviewed article, an evacuation simulation was performed in a shopping mall. The study was carried out in a shopping centre consisting of 3 floors underground and 6 floors above ground. Hours of occupancy are considered. Realistic dimensions were used with the Pathfinder simulation program. In this study, the 5th floor, which is the most intense, was taken into account in the parameter calculation. In the simulation, gender discrimination was made and shoulder lengths were calculated. Dimensions and evacuation rates are adjusted for the country of study. As a result of random orientation without being directed to the exits, the behaviour styles of the people were examined (Han et al., 2021).

In another published article, a different study was made about the metro station. This study was conducted to examine evacuation behaviour in a crowded environment. Three venues, namely the platform, the station hall and the escalator, were examined. Evacuation times were investigated as a result of 200 people randomly heading to the doors (Wang, 2021).

In a study conducted in a high-rise educational institution building, simulation experiments were carried out in cases with and without obstacles in the classrooms. The effects of the two models on evacuation time were examined. The results were examined by changing the barriers and the number of people (Zang et al., 2021).

In addition, there are studies conducted with the pathfinder simulation model in hotels (Xinhai et al., 2021).

In our study, individual parameters such as age and gender were differentiated. Persons are coded according to reality. Emergency evacuation speed and shoulder widths are programmed. Anthropometric data were used. In this study, which was carried out by producing a large number of scenarios, it is a comprehensive study in which people know the way or do not know, and the situation of heading to the exit door at various percentages is programmed. Determining the best evacuation time and applying it to the actual emergency evacuation plan are discussed.

2.4Study Parameters and Methods

The emergency evacuation simulation was created with the worst case in mind. For this reason, a situation where all students are in the building is designed. Considering the situation where there are 6 people on the ground floor, 376 people on the first floor, 600 people on the second floor and 750 people on the third floor. The evacuation was simulated from a three-storey building with a total of 1732 people.

There are 2 fire escape stairs and 3 normal exit stairs in the building. These outputs are named in the simulation. The rear staircase, the rear fire staircase, middle staircase, middle fire staircase and main staircase. Exit directions were primarily programmed as heading towards the stairs.

There are 3 exits on the ground floor that open to the outside. It is named with the names of the rear exit, front right exit and front centre exit. Agents descending the stairs are programmed to direct them to these exits.

Figure 4: Programming exit stairs and exit doors

To obtain realistic results in the evacuation simulation, the anthropometric data, age groups and genders of the people in the building are designed to be realistic. Evacuation rates of people were also adjusted based on realistic data. 90% of 1732 people are young students. 7% are middle-aged people and 3% are elderly people. The ratio of men and women was applied as 50%. In this case, a distribution such as the following table was formed.

Table 1: Distribution of Persons in the Study

	3.floor	**2.floor**	**1.floor**	**Ground**	**Total**
Young Man	338	270	172	0	**780**
Young Woman	337	270	172	0	**779**
Middle Age Man	26	21	10	3	**60**
Middle Age Woman	26	21	10	3	**60**
Old Man	12	9	6	0	**27**
Old Woman	11	9	6	0	**26**
Total	**750**	**600**	**376**	**6**	***1732***

The shoulder widths and emergency evacuation speeds of the people used in the study are given in table 2 below (Qin et al., 2020).

Table 2: Profile and Parameters Table

Profile and Parameters	Young Man	Young Woman	Middle Age Man	Middle Age Woman	Old
Emergency Speed (m/s)	1,51	1,45	1,47	1,39	1,00
Shoulder Widths (m)	0,40	0,37	0,41	0,38	0,40

Emergency speeds and shoulder widths of agents can be adjusted in the Pathfinder simulation program. As indicated in Table 2, the emergency speed of the young male agent is 1.51 m/s and the shoulder width is 0.40 m (Qin et al., 2020).

In this study, it was possible to visually monitor the evacuation moment by using the features of the pathfinder simulation program. The people who were planned close to reality were selected in different visuals in line with parameters such as gender and age. Since the emergency speed and shoulder width parameters are the same in the elderly category, only one image was selected. The selected images are shown in the figure below.

Figure 5: Person Images Used in the Simulation

2.5Emergency Evacuation Scenarios First Part

In the first part of the study, 11 scenarios were created. The results have been observed. The contents of the scenarios are as in table 3 below.

Table3: Scenario-Based Movement Styles of Agents in Simulation

	Agents' Movement Styles
Scenario-1	Everyone heads for the exit at random.
Scenario-2	Direction is given according to the nearest exit. 10% of people know the door to the exit, and 90% of them randomly turn to the exit.
Scenario-3	Direction is given according to the nearest exit. 20% of people know the door to the exit, and 80% of them randomly turn to the exit.
Scenario-4	Direction is given according to the nearest exit. 30% of people know the door to the exit, and 70% of them randomly turn to the exit.
Scenario-5	Direction is given according to the nearest exit. 40% of people know the door to the exit, and 60% of them randomly turn to the exit.
Scenario-6	Direction is given according to the nearest exit. 50% of people know the door to the exit, and 50% of them randomly turn to the exit.
Scenario-7	Direction is given according to the nearest exit. 60% of people know the door to the exit, and 40% of them randomly turn to the exit.
Scenario-8	Direction is given according to the nearest exit. 70% of people know the door to exit, and 30% of them randomly turn to the exit.
Scenario-9	Direction is given according to the nearest exit. 80% of people know the door to the exit, and 20% of them randomly turn to the exit.
Scenario-10	Direction is given according to the nearest exit. 90% of people know the door to the exit, and 10% of them randomly turn to the exit.
Scenario-11	Direction is given according to the nearest exit. 100% of people know the door to the exit.

2.6Emergency Evacuation Scenarios Part Two

In this section, 5 scenarios of closing the doors were created based on the best scenario. In the event of an emergency evacuation, the case that the exit door is locked or an obstacle falls in front of it will be examined. The contents of the scenarios are as in the table below.

Table 4: Second part simulation scenarios

	Scenario Features
Scenario-12	The rear exit door closes at 20 seconds. Alternatives are offered to people who are directed to an emergency exit.
Scenario-13	The rear exit door closes at 50 seconds. Alternatives are offered to people who are directed to an emergency exit.
Scenario-14	The rear exit door closes at 100 seconds. Alternatives are offered to people who are directed to an emergency exit.
Scenario-15	The rear exit door closes at 200 seconds. Alternatives are offered to people who are directed to an emergency exit.
Scenario-16	The rear exit door closes in 200 seconds. No alternative is offered to people who are directed to an emergency exit.

3.FINDINGS

3.1 First Part Findings

According to the scenario programming, the results given in the tables and graphics below were obtained.

Table 5: Scenario-Based Evacuation Times (Seconds)

	Evacuation Times (s)
Scenario-1	454,5
Scenario-2	461,8
Scenario-3	463,3
Scenario-4	440,0
Scenario-5	461,8
Scenario-6	429,0
Scenario-7	484,5
Scenario-8	412,3
Scenario-9	417,0
Scenario-10	628,8
Scenario-11	581,8

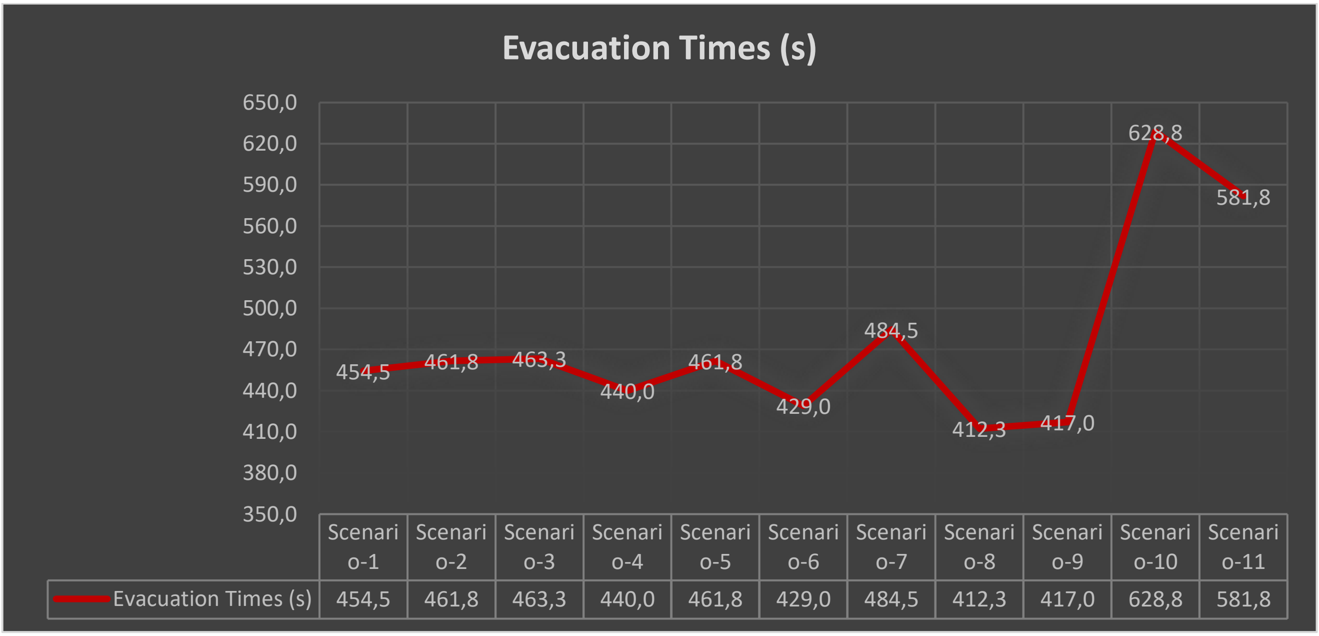


Figure6: Evacuation Times Chart

When the results of these scenarios are examined, it is seen that the best scenario with the shortest evacuation time is Scenario-8 with 412.3 s. It is seen that the worst scenario with the longest evacuation time is Scenario-10 with 628.8 s.

The number of people using the three separate exits on the ground floor is shown below.

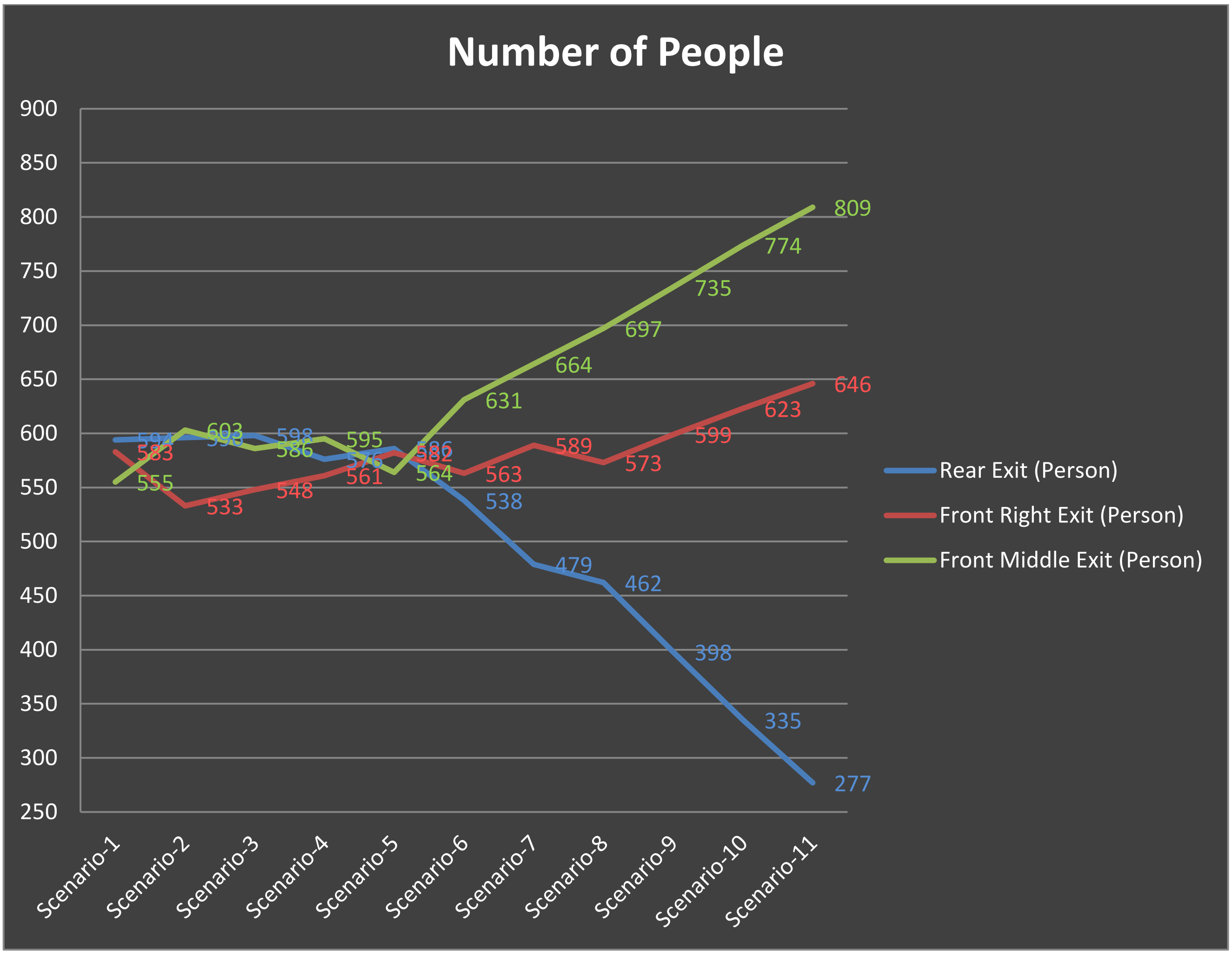


Figure7: Graph of People Using Exit Doors

There are three separate exit doors on the ground floor. These doors are accessed by stairs on each floor. 5 separate stairs on the 3rd and 2nd floors and 4 separate stairs on the 1st floor led people to these exits. Scenario-8 with the best evacuation time, scenario-10 with the worst evacuation time, scenario-1 where everyone randomly heads to the exit and scenario-11 where everyone knows the door to which they will go are examined in detail. The results are as follows.

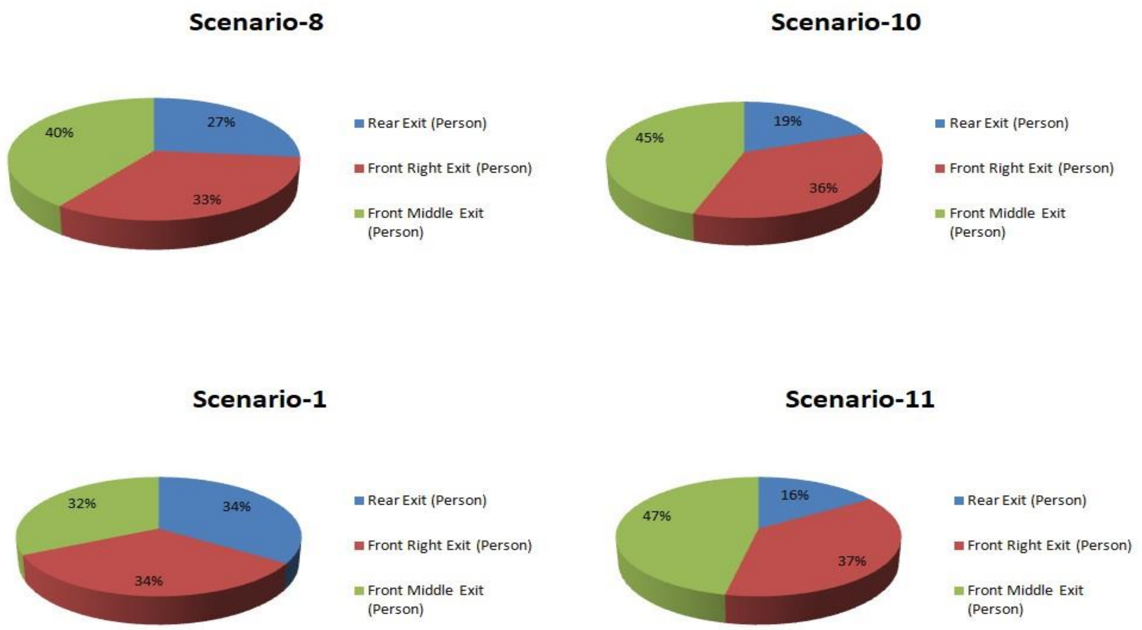


Figure 8: Exit Gates Percentage Distribution

As a result of the examination of 4 scenarios, it was seen that the front right exit door was used in similar percentiles. It has been observed that the change in evacuation time occurs with the use of the rear exit and front middle exit doors. The graphs of the number of people using the stairs are as follows.

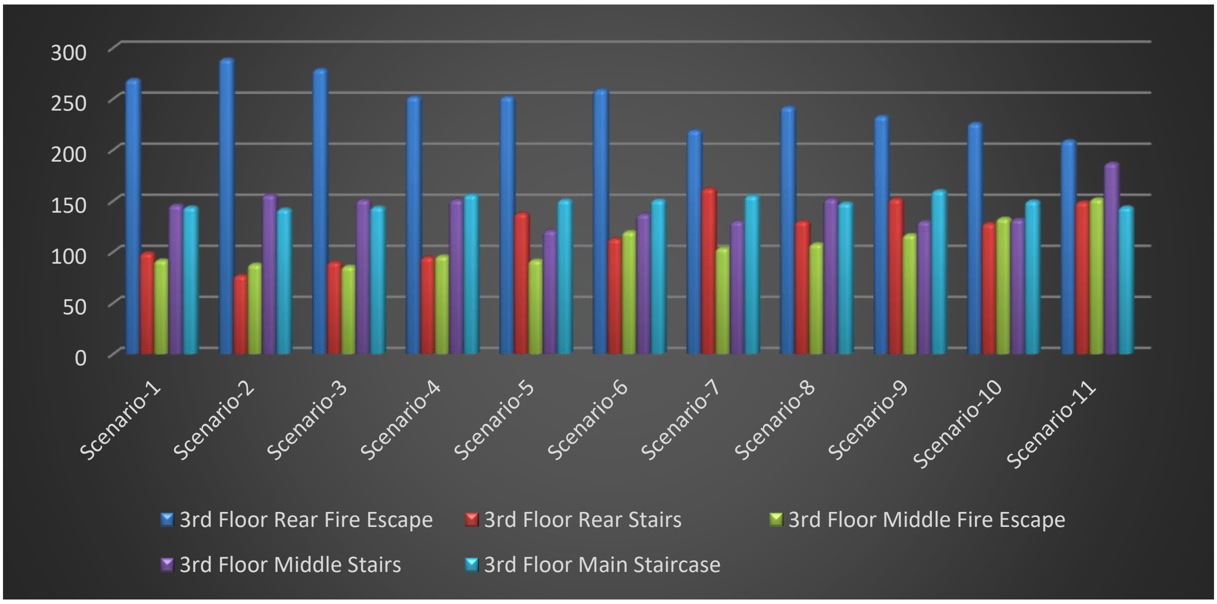


Figure9: Graph of People Using the 3rd Floor Stairs

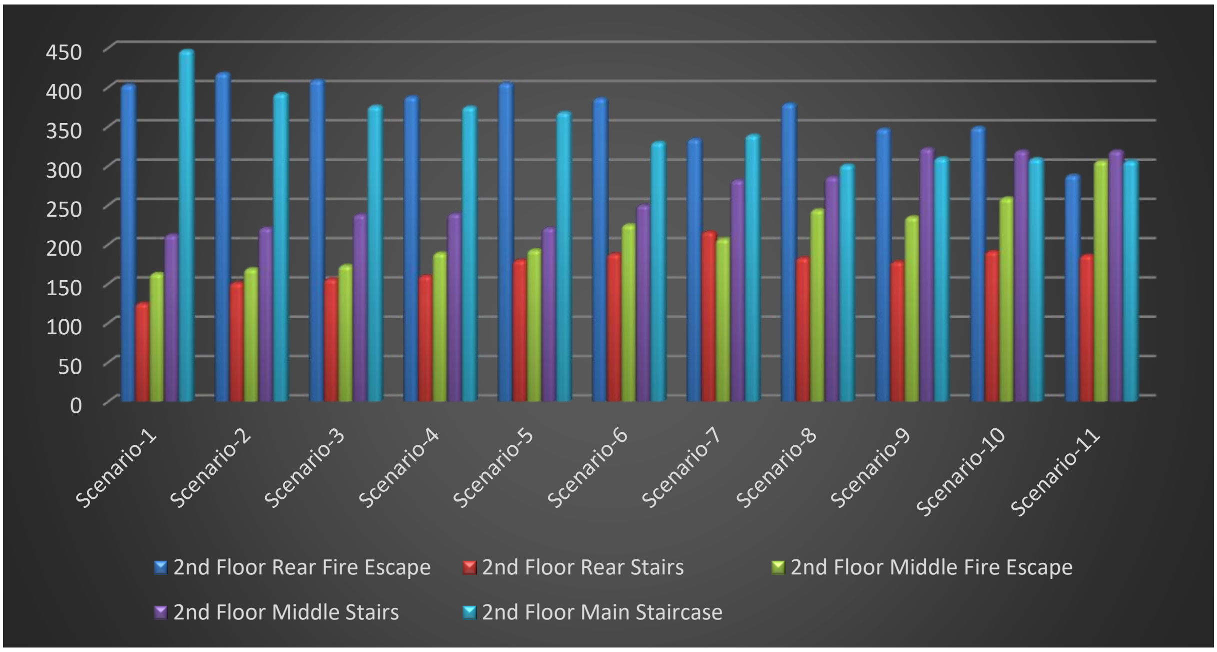


Figure10: Graph of People Using the 2nd Floor Stairs

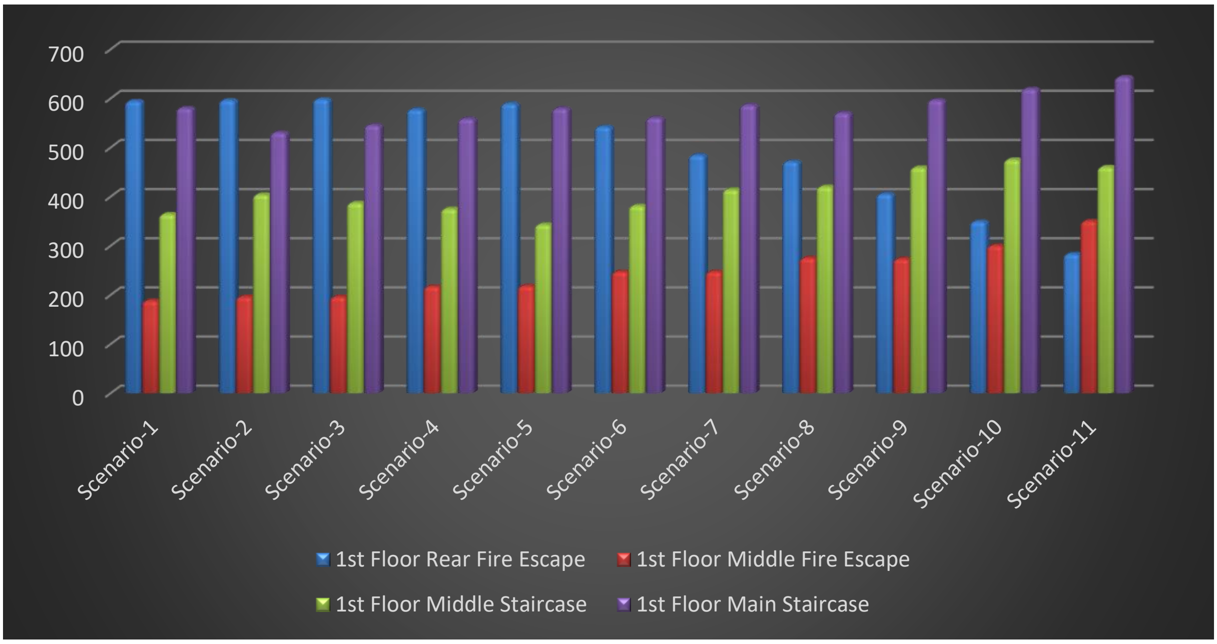


Figure11: Graph of People Using the 1st Floor Stairs

The analysis of stairs used was examined in detail in 4 scenarios. Scenario-8, scenario-10, scenario-1, and scenario-11 mentioned in the emergency exit doors examination and specified in Table 3 are emphasized.

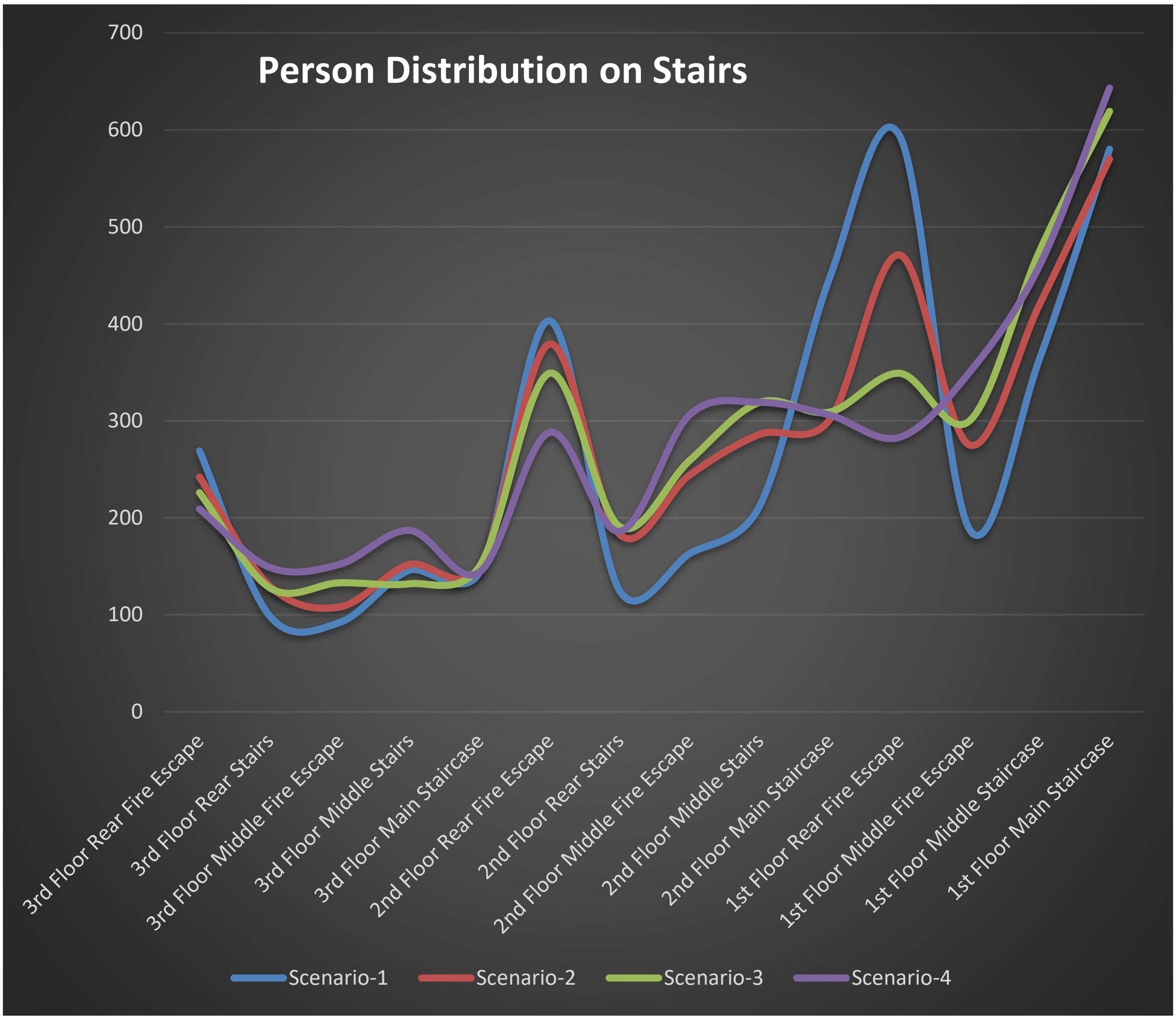
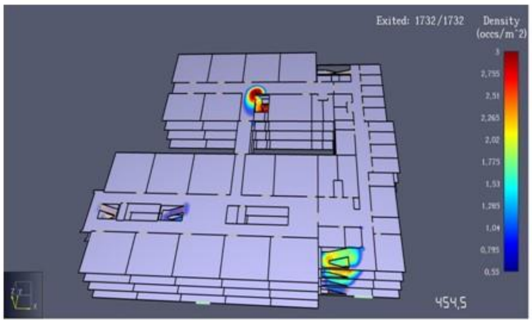


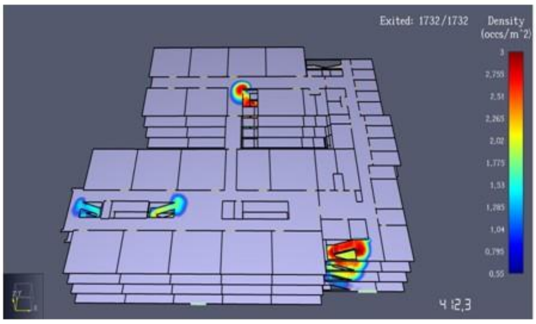
Figure12.Distribution of Persons on the Stairs (4 Scenarios)

The graph shows the ladder person distribution of the 4 scenarios. The differences in the use of stairs between these scenarios, the explanations of which are given in Table 3, are seen. No significant difference was observed on the 3rd floor. On the 2nd floor, the use of back stairs, middle fire escape and middle stairs affected the evacuation times. On the 1st floor, it is seen that the use of the backfire escape significantly affects the change in evacuation time.

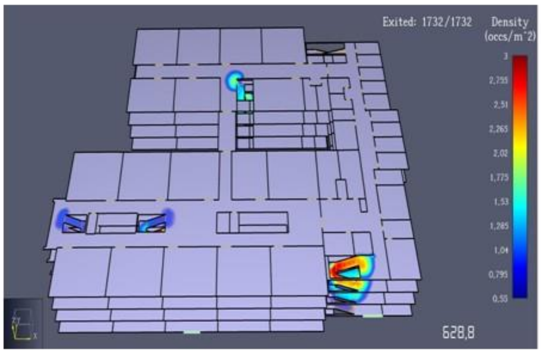
Densities can also be monitored visually with the simulation program. By examining the visual results, the densities of the stairs used can be compared. In the intensity comparison, scenario-1, scenario-8, scenario-10 and scenario-11 were examined. The shortest evacuation, the longest evacuation, the evacuation where people randomly leave the exits, and the evacuation densities where all the people know the exits were observed.



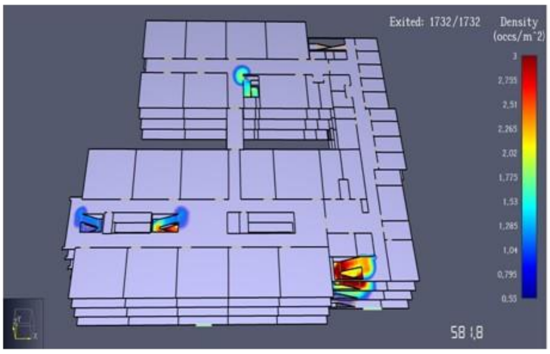
Scenario-1



Scenario-8



Scenario-10



Scenario-11

Figure13: Scenarios Density Condition

When the stair densities seen above are examined, it is seen that the rear fire escape ladder is used more intensively in the scenario where everyone leaves randomly. It is seen that the middle ladder is used a little more in the scenario with the shortest evacuation time. In the scenario with the longest evacuation time, too much condensation was seen on the 2nd floor of the middle staircase. In the scenario where everyone knows the exit and does not use other alternatives, it is seen that the middle stairs and main stairs are used very intensely.

With the simulation made, the distance travelled by 1732 people during the emergency evacuation can be measured. In 4 different scenarios, which we examined in detail, the population of people was analysed in terms of distance meters. The scenario-8, scenario-10, scenario-1 and scenario-11 data given in Table 3 are discussed. Persons are indicated by numbers. The graphs of the analysed data are below.

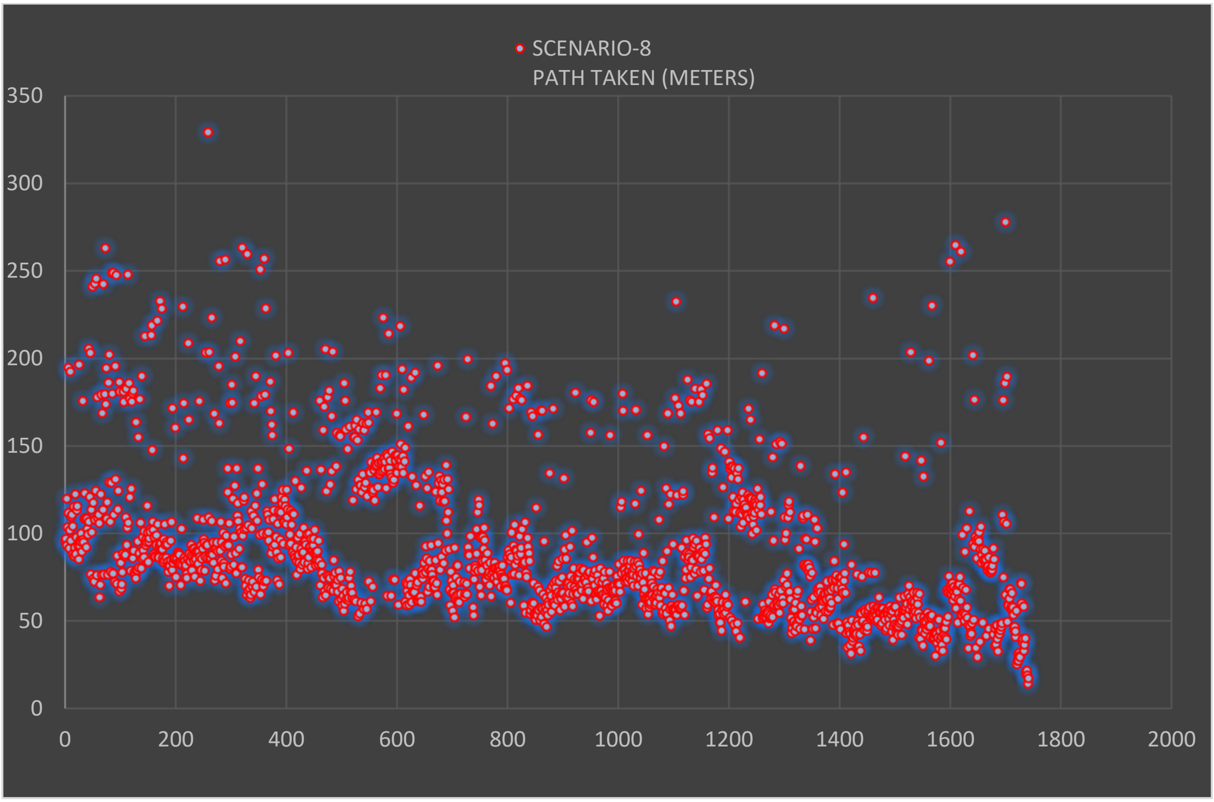


Figure 14: The Path People Take During Evacuation Scenario-8

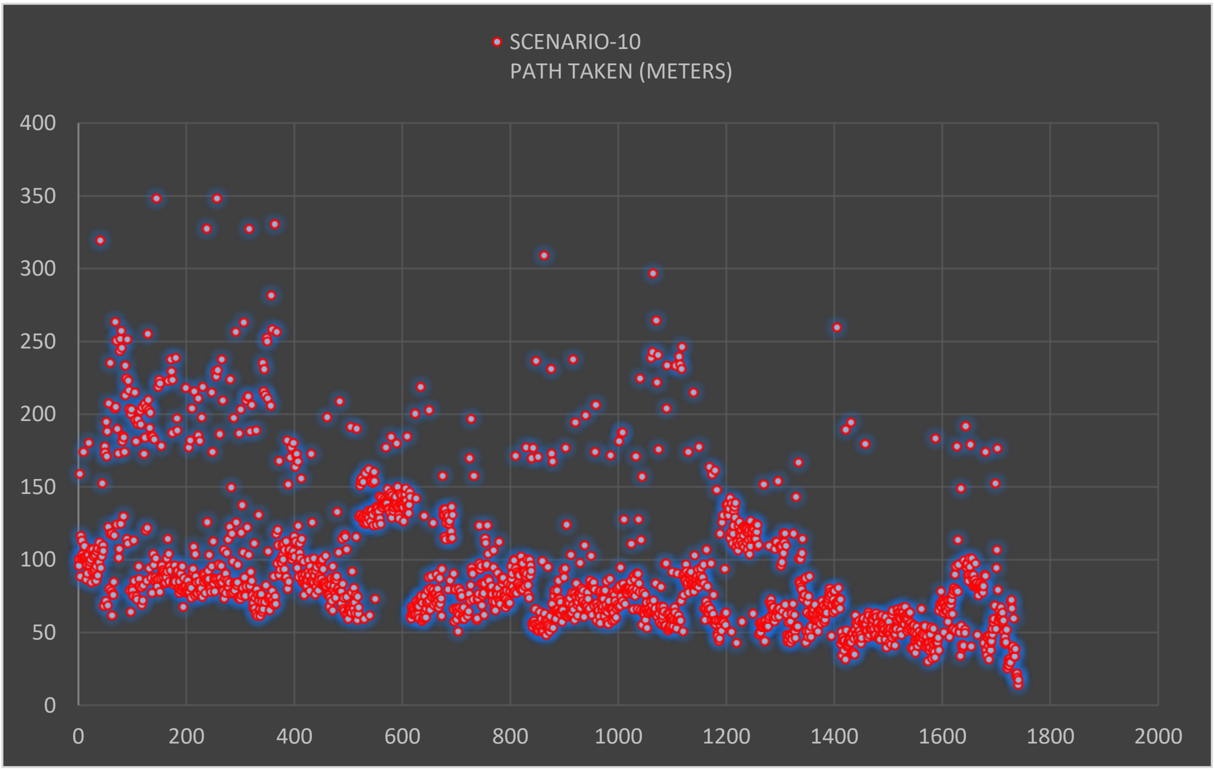


Figure 15: The Path People Take During Evacuation Scenario-10

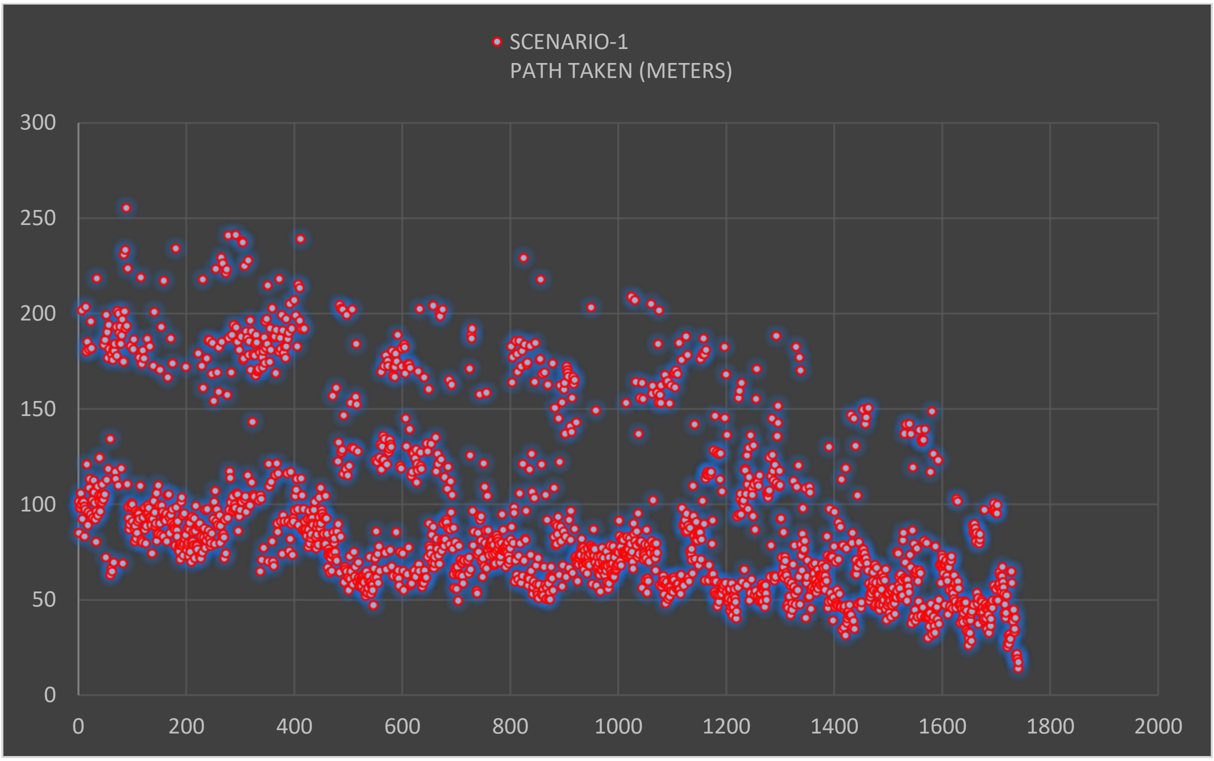


Figure 16: The Path People Take During Evacuation Scenario-1

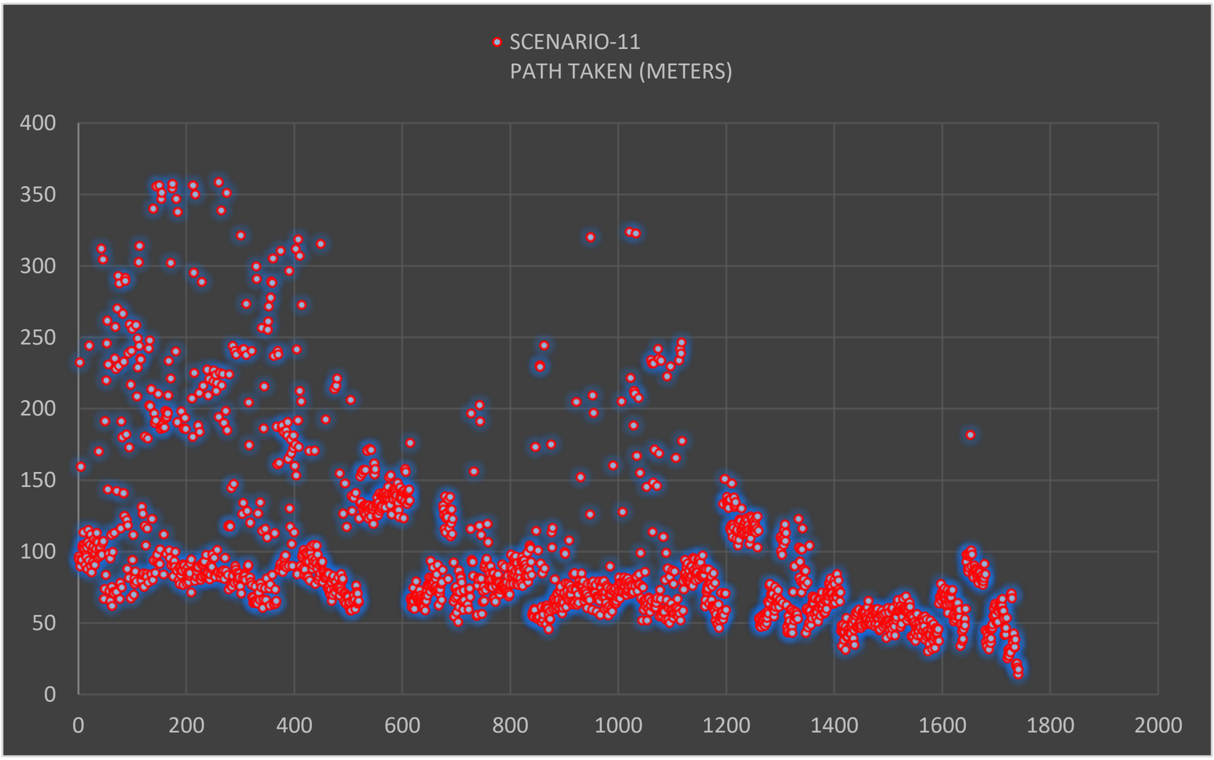


Figure 17: The Path People Take During Evacuation Scenario-11

Scenario-8 is the plan with the shortest evacuation time. When examined, a balanced escape distance is seen. It has been observed that people between 1300 and 1500 travel less. Scenario-10 is the plan with the longest evacuation period. When examined, it was seen that people between 420 and 600 and people between 1450 and 1600 travelled less. Scenario-1 is the plan where everyone randomly disperses to the doors. It has been observed that the total distance taken is higher due to the random distribution of the people. Scenario-11 is the plan where everyone knows the route they will take and they do not take the initiative. When examined, it was seen that the first 400 people went much further.

As the paths taken and the exit times are known in the Pathfinder simulation program data, individual exit speeds can be found. The exit velocity of agents can be found by applying the formula *Egress Rate = Path Taken / Exit Time*. It is the emergency evacuation speed, expressed as the exit rate. Thus, the programmed speed and the actual speed can be compared and the waiting times can be analysed. The analyses were made with 4 different scenarios. Scenarios with the best evacuation time, the worst evacuation time, everyone randomly heading for the exit and everyone knowing the door to the exit were examined and the differences were analysed. These data are given in Table 3. Analyses are shown in the chart below.

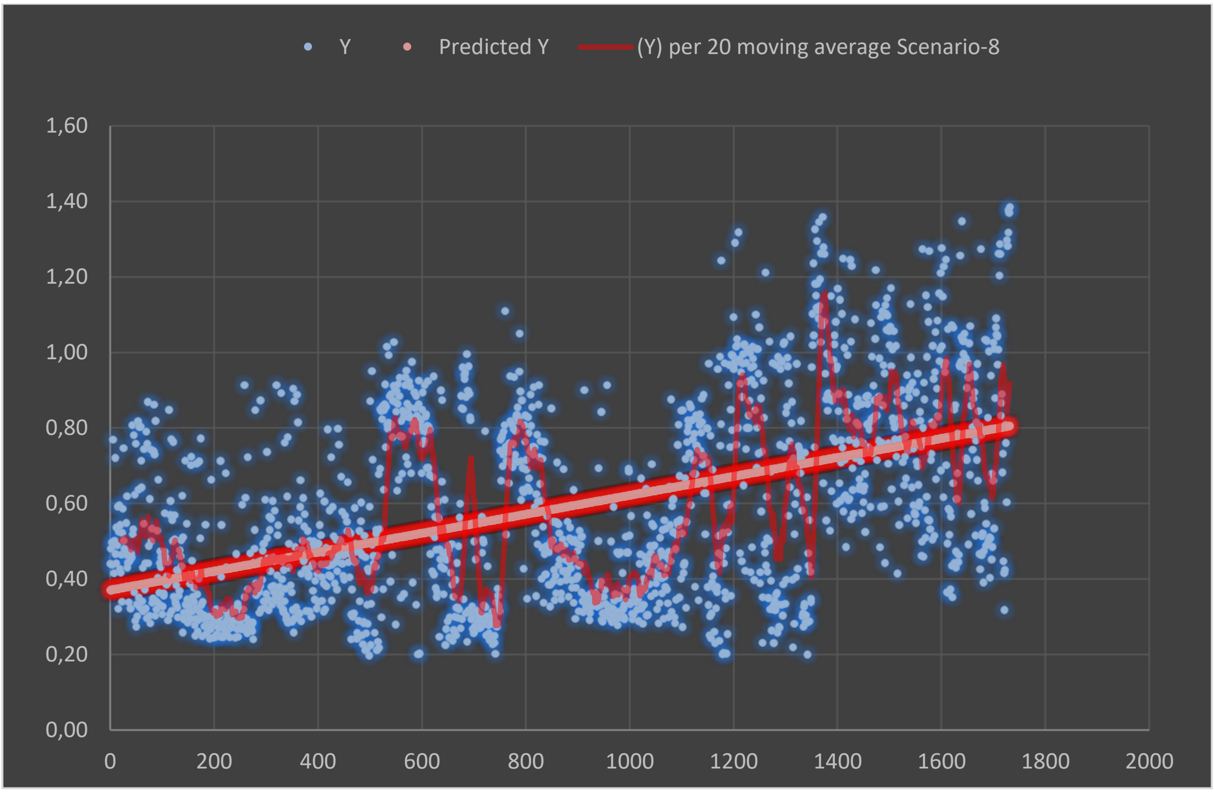


Figure 18: Actual Exit Rates of People Scenario-8

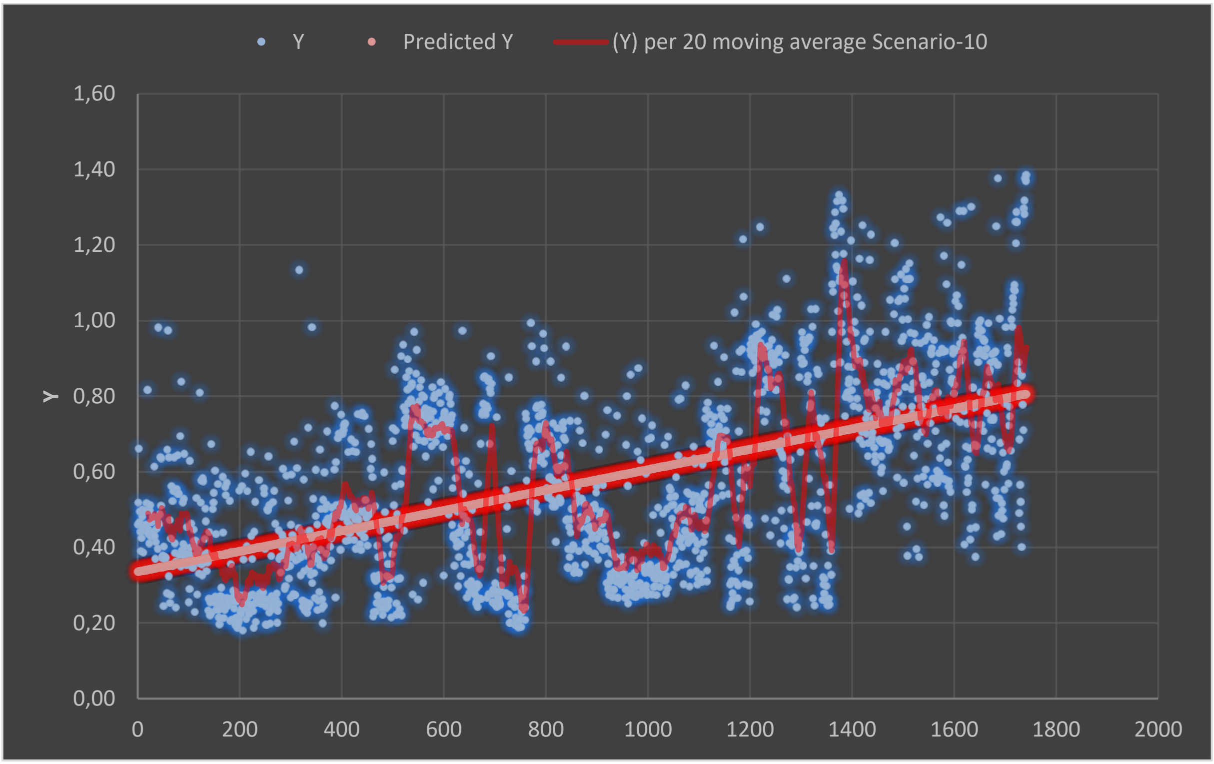


Figure 19: Actual Exit Rates of People Scenario-10

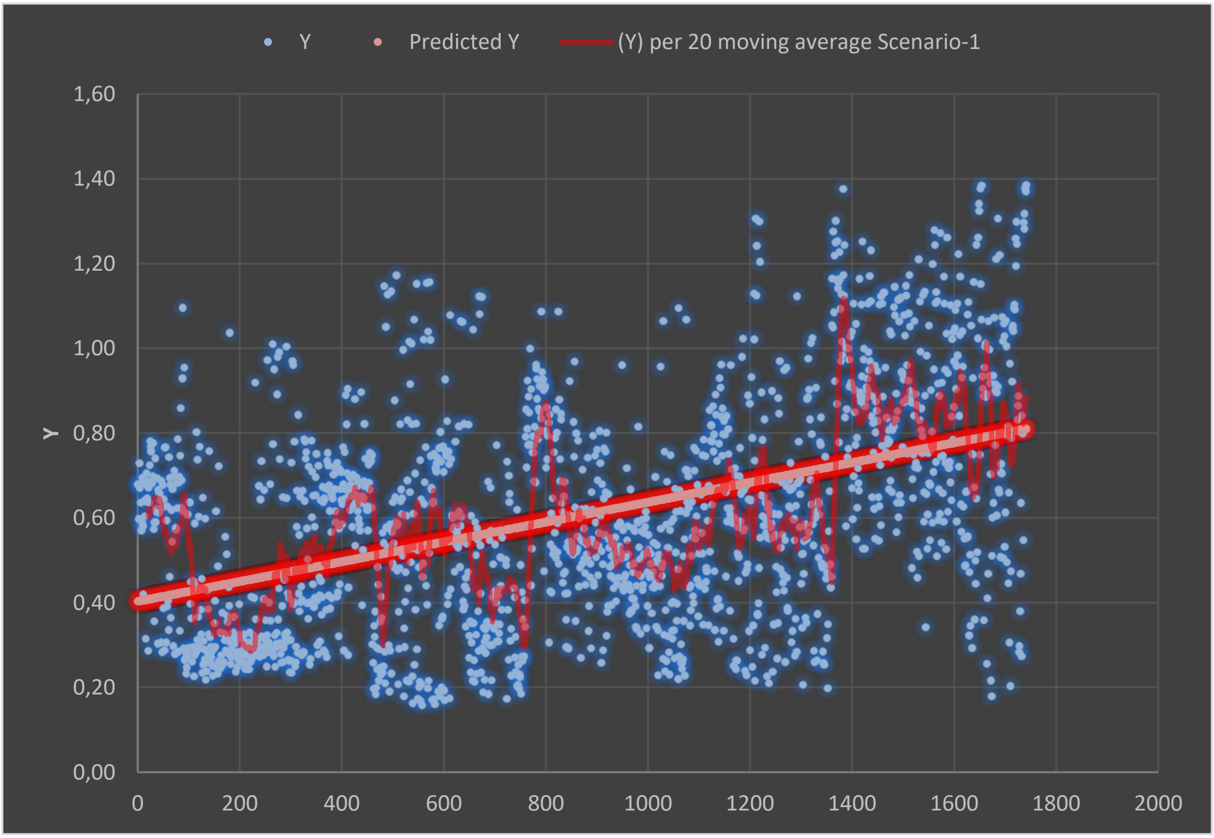


Figure 20: Actual Exit Rates of People Scenario-1

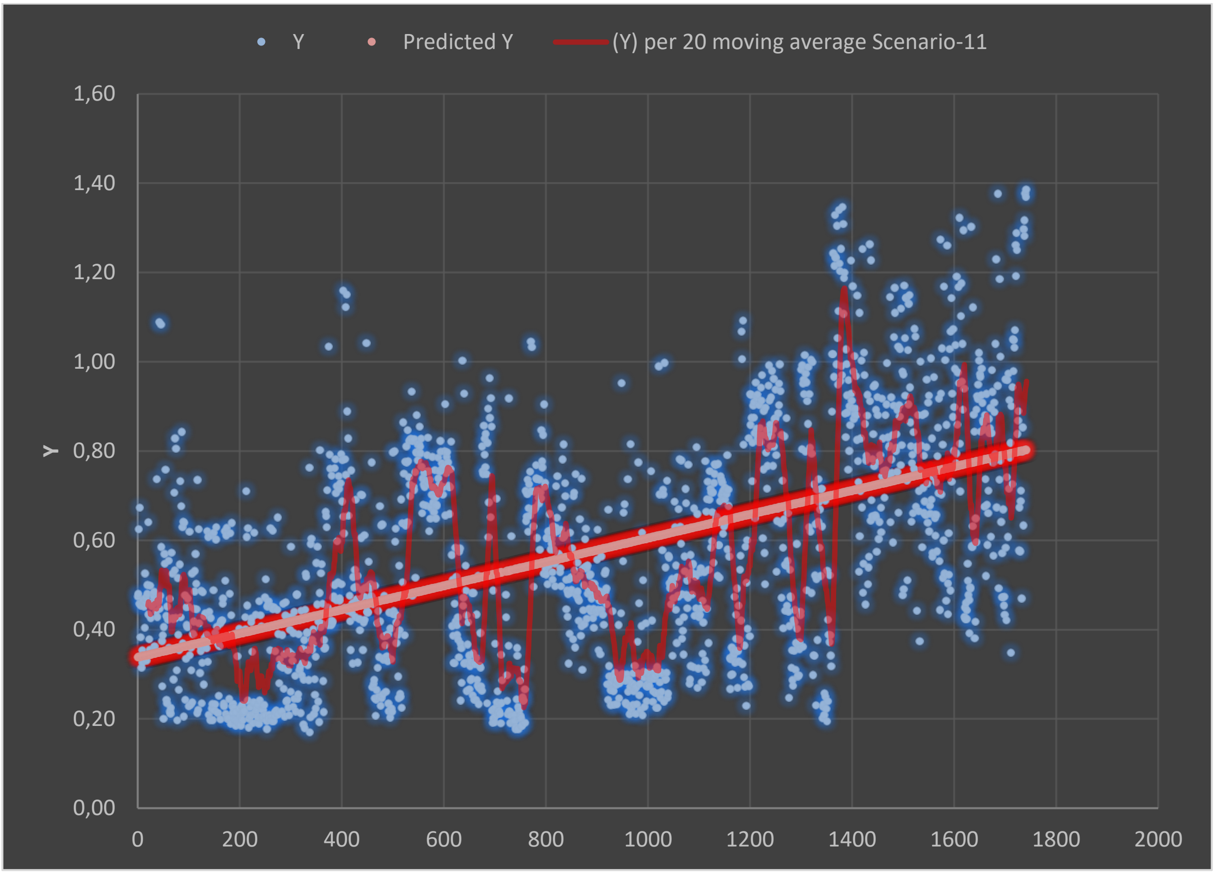


Figure 21: Actual Exit Rates of People Scenario-11

In Scenario-8, it is seen that the speed of the first 1200 people is quite low. Discharge speeds vary between 0.20 m/s and 1.00 m/s. It is seen that evacuation speeds increase after the 1200^{th} person and reach up to 1.40 m/s. In Scenario-10, it was observed that the evacuation rates for the first 1200 people were similarly low, but fluctuations occurred. It was observed that the speeds increased similarly after the 1200^{th} person. In Scenario-1, it was observed that the speed of people between 480 and 660 could reach up to 1.20 m/s. After the first 1200 people, it was observed that the speeds increased and reached 1.40 m/s. In scenario-11, it was observed that the speeds increased after the 1300th person and reached 1.40 m/s. It has been observed that the speeds of people between 120 and 300 are quite low at 0.60 m/s.

According to the programmed person parameters in Table 2, the average speed of 1732 people was set as 1.46 m/s. According to the simulation results, the average evacuation speed of people in 4 different scenarios was found to be 0.58 m/s. Due to the delays during the evacuation, an average of 0.88 m/s slowdown was detected per person.

The evacuation speed of the people was examined by creating a graph of the distance and exit times taken. These data are shown in the graphs below.

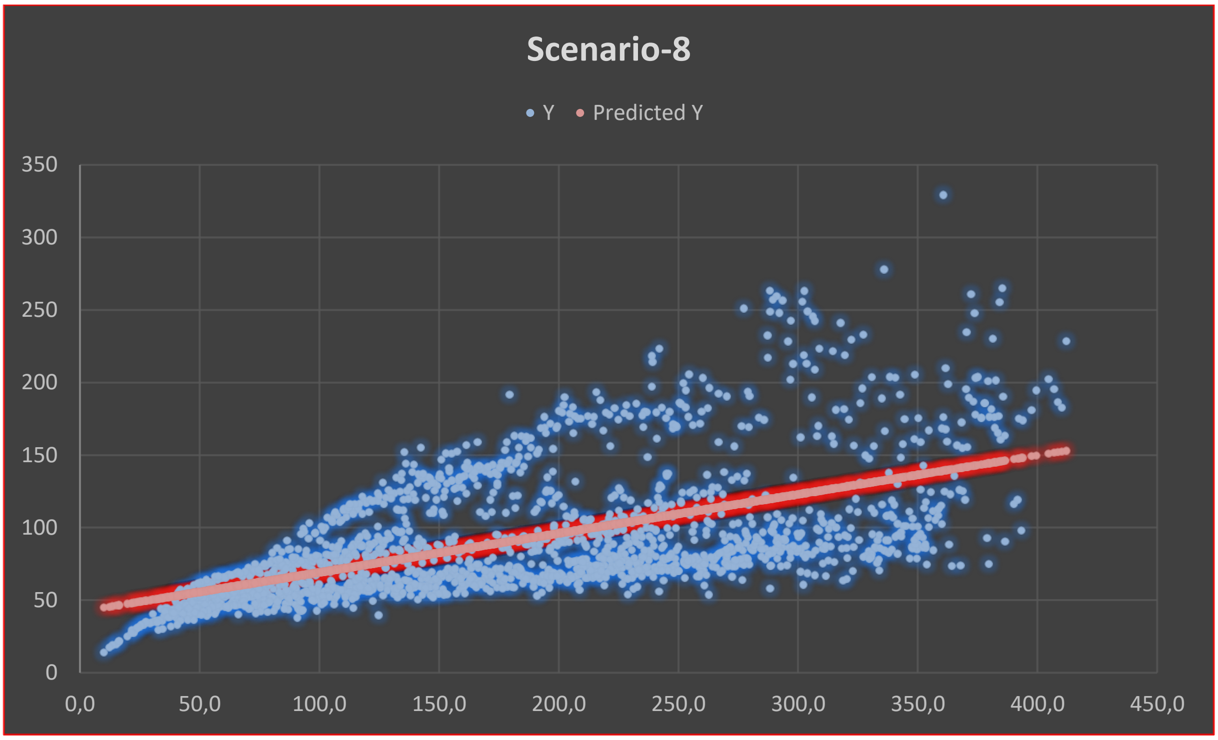


Figure 22: Path taken and exit times graph scenario-8

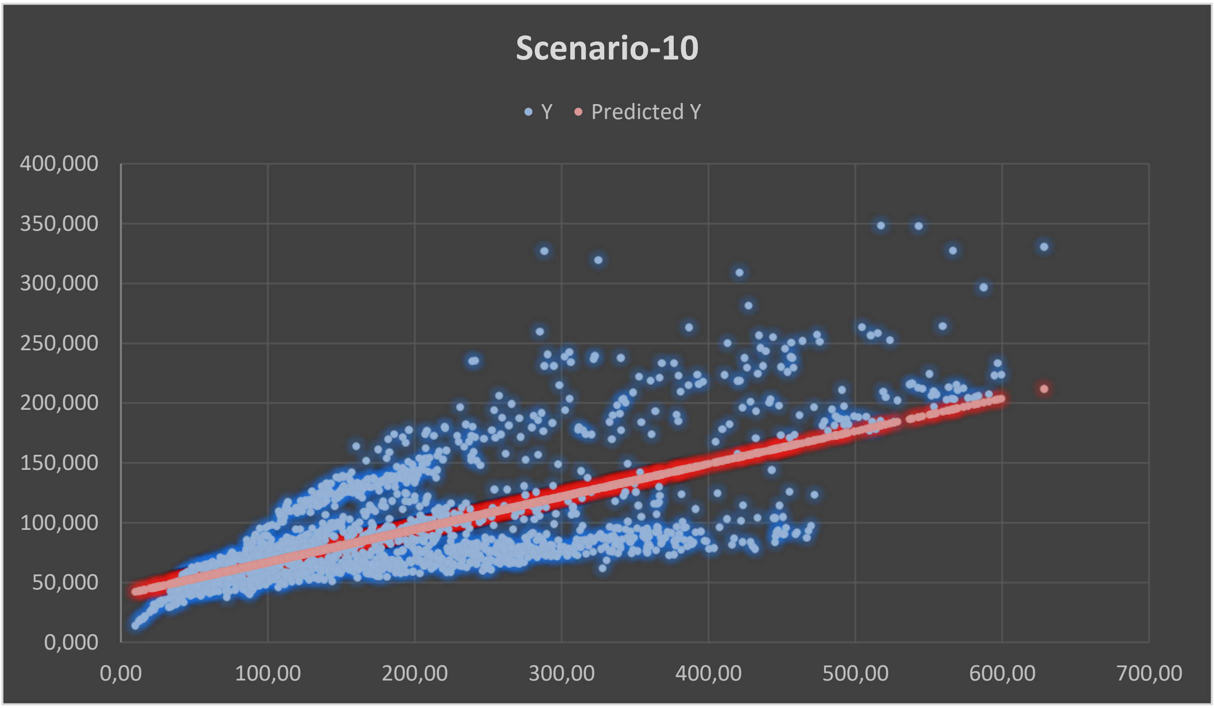


Figure 23: Path taken and exit times graph scenario-10

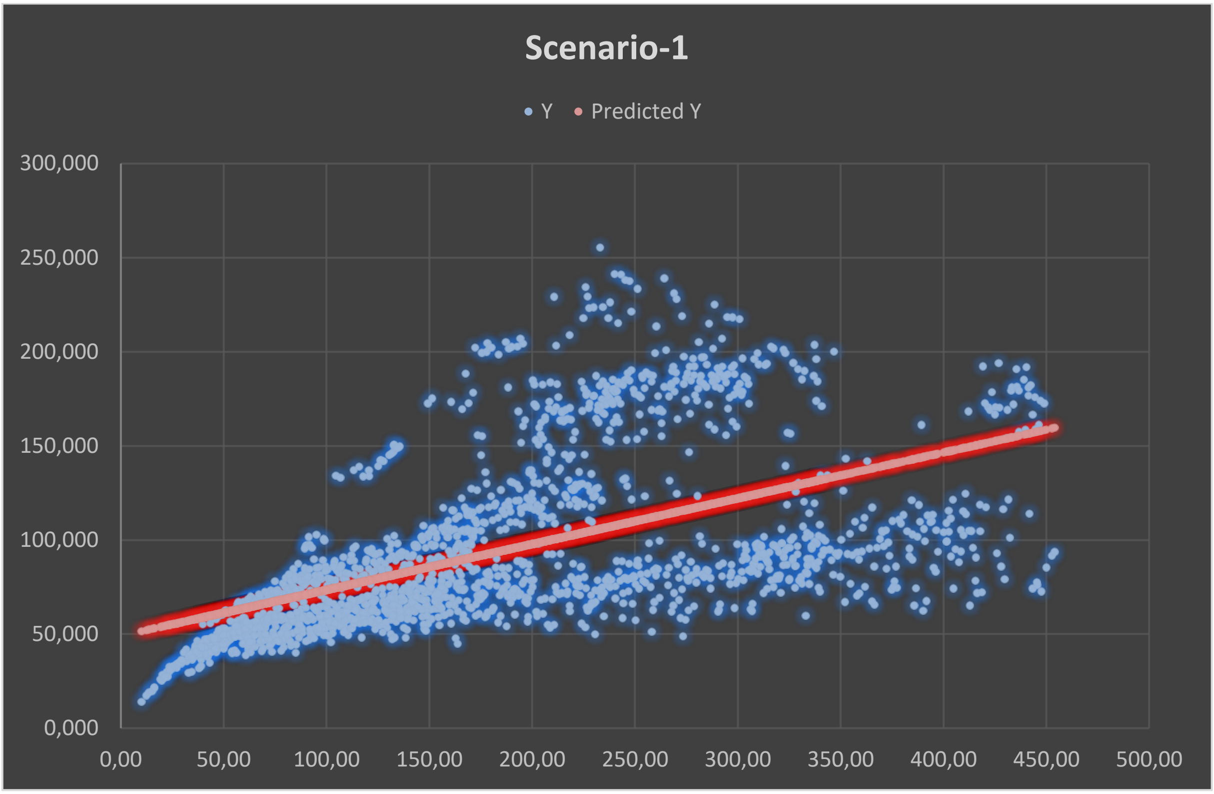


Figure 24: Path taken and exit times graph scenario-1

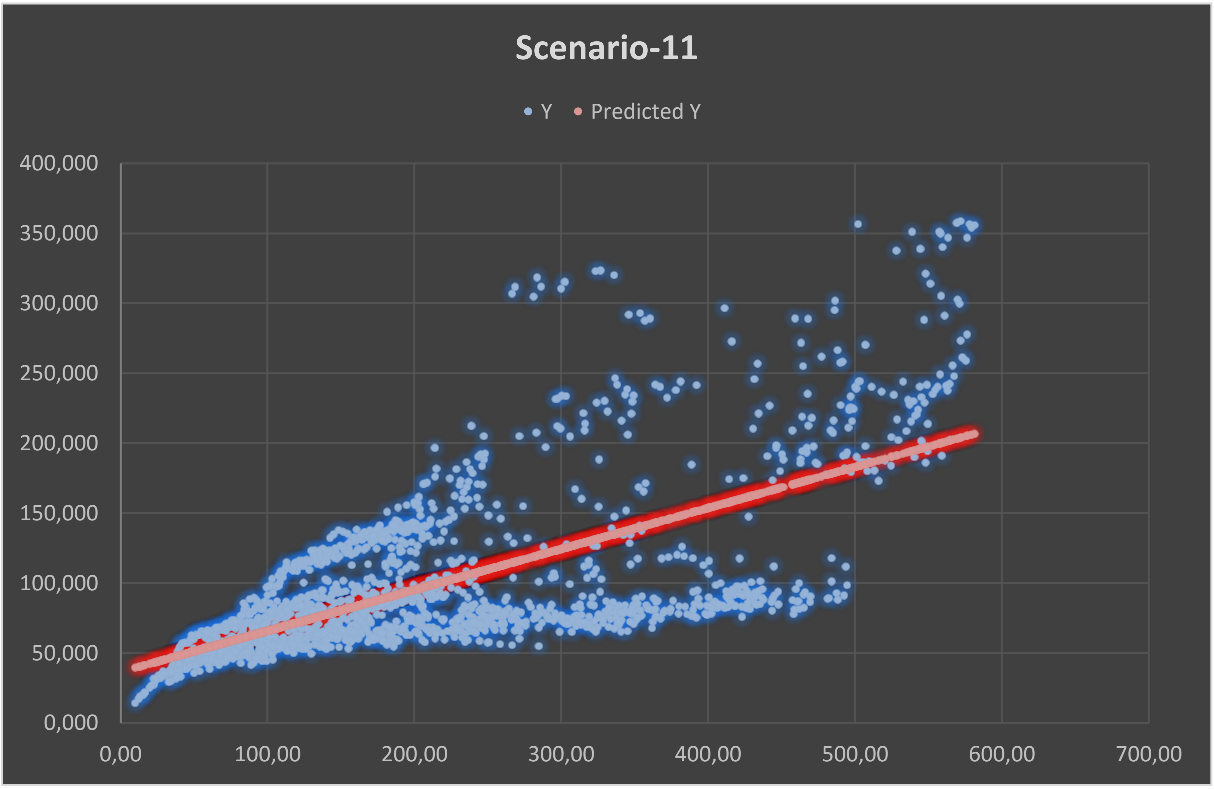


Figure 25: Path taken and exit times graph scenario-11

When Figures 22,23,24 and 25 are examined, it is seen that values close to the average speed in scenario-8. It was observed that a small number of people walked too much and lost time. In Scenario-10, it was observed that more people were walking too much and wasting time. In Scenario-1, the average speed has slightly deviated. The number of people who waste too much time walking is high. In Scenario-11, the exit time was adversely affected due to the excess of roads taken.

3.2 Second Part Findings

The following results were obtained in the scenario applications made according to Table 4.

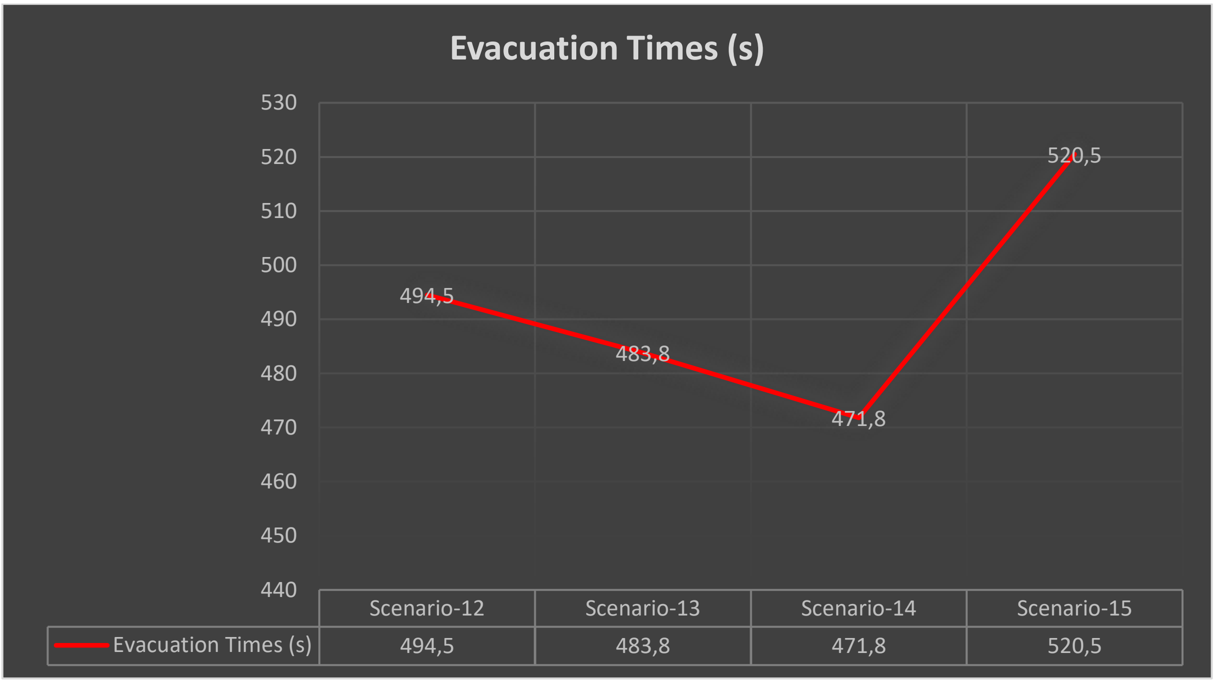


Figure26: Second Part Evacuation Times Chart

It is seen that the longest evacuation period is in scenario-12. This scenario is when one of the open exit doors is locked. It scored 108.2 s worse than the best evacuation time. It caused a delay of nearly 2 minutes in the emergency evacuation time.

In Scenario-16, on the other hand, it is programmed with which exit door to head to before the agents are presented with an alternative. The agents were not diverted due to the closed emergency exit. After 494.5 s, 96 people were trapped in the rear fire escape. The simulation is automatically stopped due to jamming.

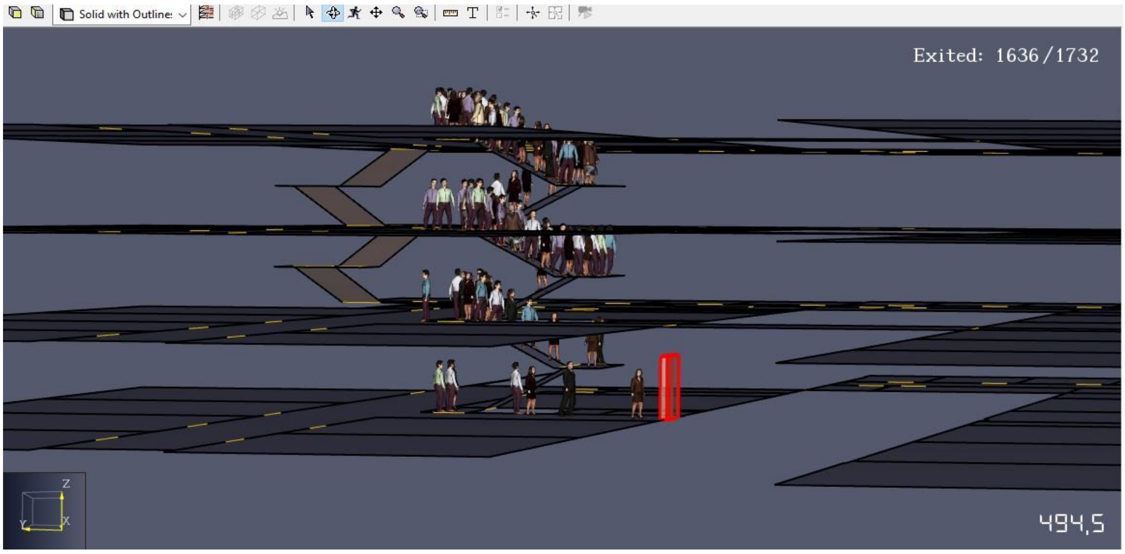


Figure 27: Agents Stuck on Stairs in Scenario-16

The results with the best evacuation time were analysed with other scenarios without jamming. The number of people using the three separate exits on the ground floor is given below. Scenario-16 was excluded from the analysis, as the number of people using the back-exit door could not be determined due to jamming.

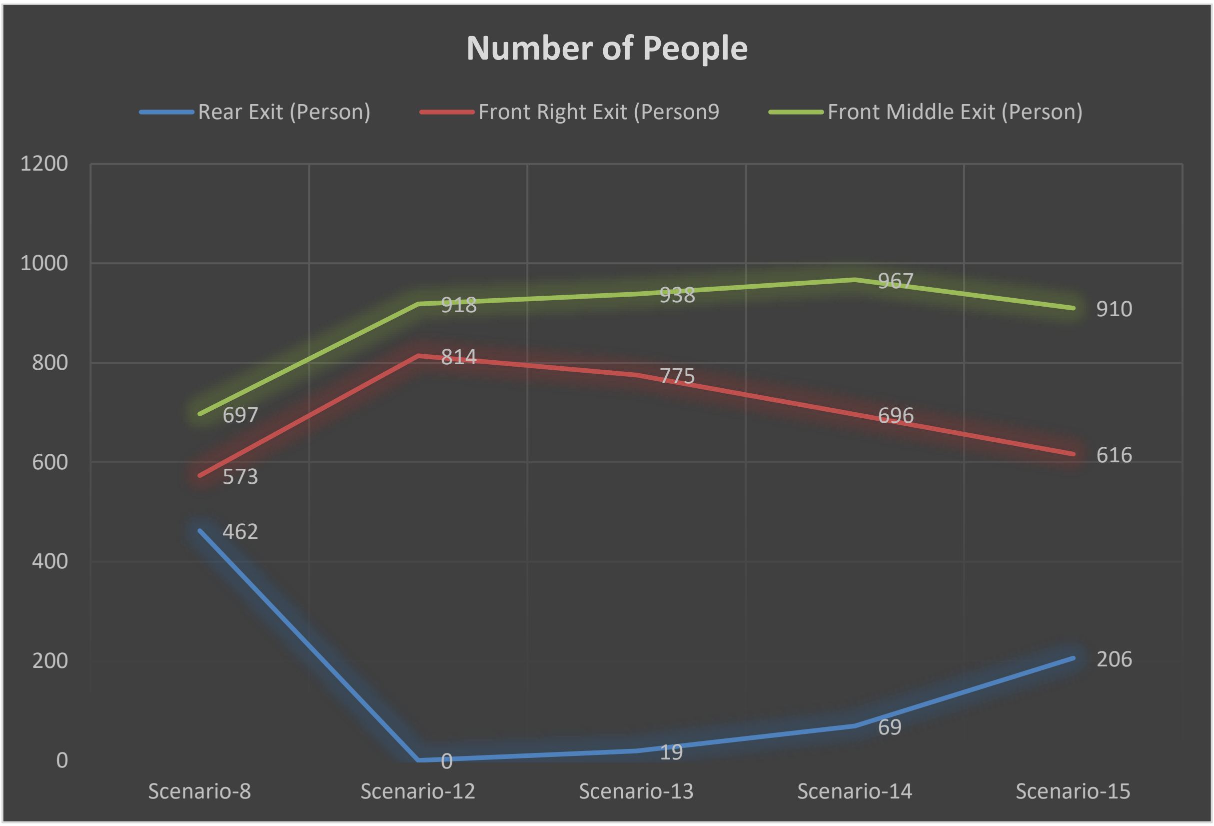


Figure28: Graph of Use of Exit Gates in the Second Part Scenarios

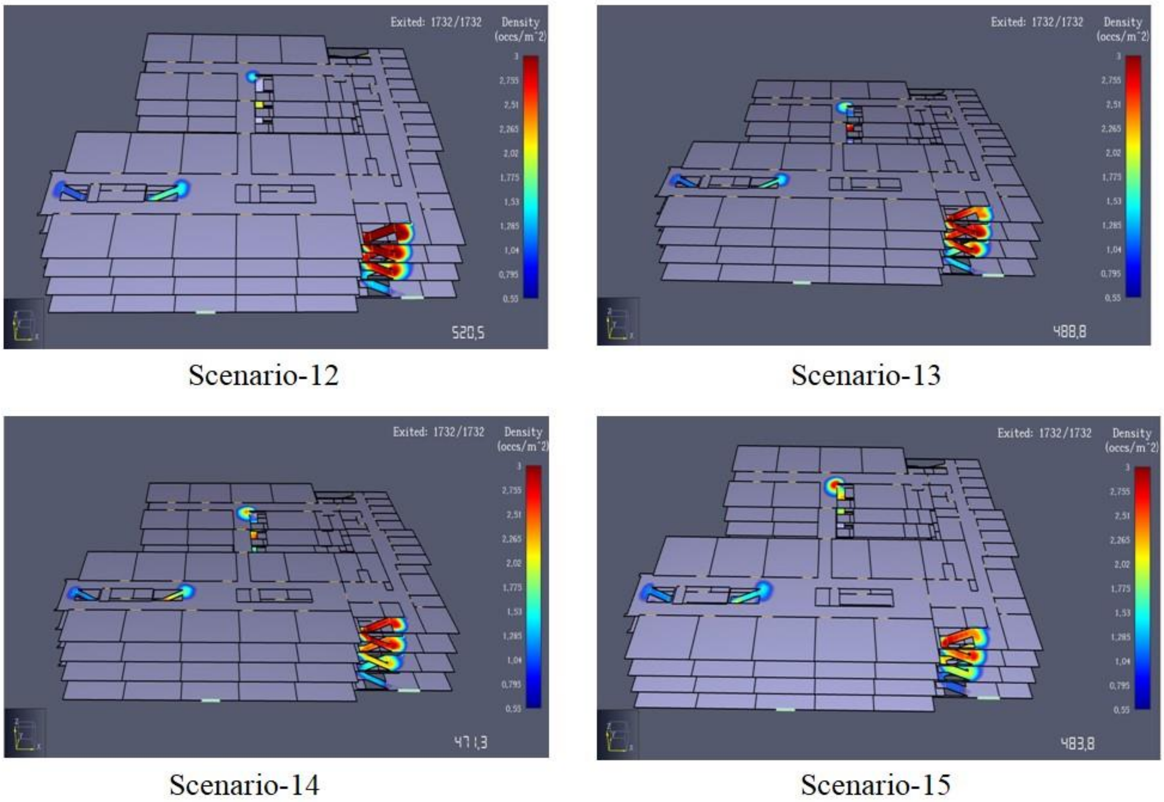


Figure29: Second Part Scenarios Stair Densities

The unusable stair densities of the doors built on the best evacuation time scenario were examined in various periods. In scenario12, where the rear exit door is locked, it was observed that the main stairs were extremely busy. In scenario13, where the rear exit door is closed at the 50th second, the density of the rear stairs on the 1st floor has increased significantly. The main stairs seem to be busy as well. In scenario14, where the rear exit door is closed at the 100th second, the middle stair 2nd floor, the back stair 1st floor and the 3rd floor of the main stairs were used intensively. Scenario-15, where the rear exit door is closed at the 200th second, it is seen that there is a density on the main staircase and the back stairs on the 3rd floor. Thanks to the scenarios of the second part, the errors of the plan with the best evacuation time can be determined. How long these disruptions will delay the evacuation process can be found.

4.DISCUSSION AND CONCLUSION

According to Table 3, in the scenario results where everyone turns to random exits, people know the exit doors and head for the doors they see as empty. It is not a situation where the people inside the building know nothing. Therefore, people were informed about the locations of the emergency exits and were told that they should be randomly distributed at the exit doors. As a result, people in the building need to know the building and know the location of the emergency exits.

According to Table 3, the scenario where everyone knows the doors to exit and leaves the door they are told, even if it is busy, has a score of 581.8 s, which is 169.5 s worse than the best score of 412.3 s. In this case, a delay of about 3 minutes occurred. In this scenario, when the exit direction is crowded, there was a density due to people who took the initiative and did not turn to another exit. Due to the density, the evacuation time was prolonged. When people are busy, they should be trained on alternative routes.

According to Table 3, the scenario with the best score is the scenario where 70% of the people in the building know the exit doors they will go to, and 30% of them head for the exit randomly. The best evacuation time was obtained as a result of people who noticed the density at the exit stairs and doors being directed to another exit that was close to them and less dense. The balance of 70% - 30% should be given with good emergency training and planning should be done.

Thanks to the simulation program, not only the evacuation time but also the results of other parameters can be observed. Stair densities, escape routes, the number of people passing through exit doors, and frequency of use can be analysed. This is difficult to achieve in a real evacuation exercise.

Thanks to the pathfinder simulation program used in this study, the path followed by the so-called agents during the evacuation, in other words, the length of the escape route, can be determined. Representatives can be called realistic. How many meters they travel during an evacuation can be monitored. With countless scenarios, it is possible to monitor which person travelled how many meters. This is very difficult to implement in real practice.

Person parameters can be adjusted realistically in the Pathfinder simulation program. The speed settings specified in Table 2 were made. According to the results of the program, the actual speed of the people can be calculated since the exit time and the distance they travel is known. By comparing the programmed speeds with the actual speeds, it can be determined how much delay the person experienced during the evacuation. Densities, delay times, and faults can be detected. In a realistic application, it is very difficult to calculate the delay times of 1732 people individually.

According to Table 4, the failures of the plan with the best evacuation time were analysed in the scenarios of the second part. Delays are calculated with the scenarios where the doors are blocked and the doors are locked. Thanks to simulation programs, the number of people stuck in disaster scenarios and who stays in that area can be determined.

This study has been prepared considering that there are 1732 people in the university building. In today's pandemic conditions, it is not possible to gather so many people together. It is possible to find the closest results to reality by using simulation programs.

The success of emergency evacuation plans should be tested by applying evacuation drills. These trials can be done a limited number of times. By producing numerous scenarios with simulation, the best evacuation plan can be prepared.

These simulations can be used in disasters, fires, and explosions. With the use of artificial intelligence, instant guidance can be made in an emergency. For example, an open exit door may become unusable after a certain period due to fire. In this case, the routing needs to be changed or people may die in that area. By integrating the use of artificial intelligence into the simulation, the exit route can be changed instantly. This change can be displayed on the electronic boards with the emergency evacuation plan. The changed emergency evacuation plan can be notified to people with light and sound warnings.

In Pathfinder simulation, people can be defined realistically by name. Electronic routing can be done instantaneously, individually, with messages sent to mobile phones. People will be able to be evacuated as soon as possible by forwarding messages on their mobile phones.

The innovations that this study will reveal can be applied to all workplaces and living centres. These countless trials, implemented with simulation programs, save time, reduce labour loss, provide life safety and increase productivity. Thanks to these programs, countless negative scenarios can be applied. Scenarios where the doors are closed or even people are trapped can be designed. There may also be people who were injured or lost their lives during the exercises. With simulations, results can be obtained without any loss of life. Material losses are eliminated.

After the emergency plan is prepared, the applicability of the plan can be tested with simulation programs in the legislation of the countries. If there is such a requirement in the Legislation of the countries, many workplaces will create the best plan by making many trials with the simulation of their emergency plans. The best scenario application will be tested with the real exercise to be done. Thus, time losses, production losses and labour losses will decrease. Most importantly, a realistic emergency evacuation plan will be created in that workplace.

REFERENCES

Bossel, H. (2017). Modelling and Simulation (e-book). A K Peters/CRC Press. https://doi.org/10.1201/9781315275574 https://www.taylorfrancis.com/books/mono/10.1201/9781315275574/modeling-simulation-hartmut-bossel

Haihao, C.U.I. (2021). An Evaluation Model for Fire Fighting and Emergency Evacuation Plan. In *IOP Conference Series: Earth and Environmental Science* (Vol. 760, No. 1, p. 012040). IOP Publishing.

Han, F., Liu, L.,Zhang, Y. (2021). Pathfinder-Based Simulation and Optimisation of Personnel Evacuation Modelling of a Shopping Mall. In *Journal of Physics: Conference Series* (Vol. 1757, No. 1, p. 012112). IOP Publishing.

National Fire Protection Association (2021). Date of Access October 2021. https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Structure-fires-in-schools/US-school-fires-with-ten-or-more-deaths

Qin,J., Liu,C., Huang,Q. (2020). Simulation on fire emergency evacuation in special subway station based on pathfinder. *Case Studies İn Thermal Engineering*. Cilt 21, 100677. doi.org/10.1016/j.csite.2020.100677

The Society of Fire Protection Engineers. (2020). Date of Access May 2021. https://www.sfpe.org/about-sfpe/about

Thunderhead Engineering Consultants, Inc. (2019). Date of Access May 2021. https://www.thunderheadeng.com/pathfinder/pathfinder-features/

TSHA (2021). Texas State Historical Association. Date of Access October 2021. https://www.tshaonline.org/handbook/entries/new-london-school-explosion

Tuladhar, G. Yatabe, R. Dahal, R. K., Bhandary, N. P. (2014). Knowledge of disaster risk reduction among school students in Nepal. *Geomatics, Natural Hazards and Risk, 5*(3), 190-207. https://doi.org/10.1080/19475705.2013.809556

Wang, F. (2021). Multi-Scenario Simulation of Subway Emergency Evacuation Based on Multi-Agent. *International Journal of Simulation Modelling (IJSIMM), 20*(2).

Xinhai, Z., Shoushi, Z., Sichen, Z., Kai, W. (2021). Research on Evacuation of Hotel Staff Based on Pathfinder. In *IOP Conference Series: Earth and Environmental Science* (Vol. 768, No. 1, p. 012171). IOP Publishing.

Zang, Y., Mei, Q., Liu, S. (2021). Evacuation simulation of a high-rise teaching building considering the influence of obstacles. *Simulation Modelling Practice and Theory*, 102354.

Zhang, H., Long, HC (2021). Simulation of Evacuation in Crowded Places Based on BIM and Pathfinder. In *Journal of Physics: Conference Series* (Vol. 1880, No. 1, p. 012010). IOP Publishing.

Conflict of Interest

No conflict of interest was declared by the authors.

Researchers' Participation Rates

ÜREDEN B., who is the responsible author in this study, created the main concept and idea of the study, made the design and design, performed the literature review and wrote the article. Therefore, the participation rate of ÜREDEN B. is 40%.

BİDERCİ H., the second author of the study, provided statistical analyzes and interpretation of the analyzes. Therefore, the contribution rate of BİDERCİ H. is 30%. CANBAZ B., the third author in the study, controlled the design of the study and provided the interpretation of the main concept and idea of the study. Therefore, the contribution rate of CANBAZ B. is 30%.