



Tecnológico
de Monterrey

Programming Languages

Final Project

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IDEA OF THE PROJECT

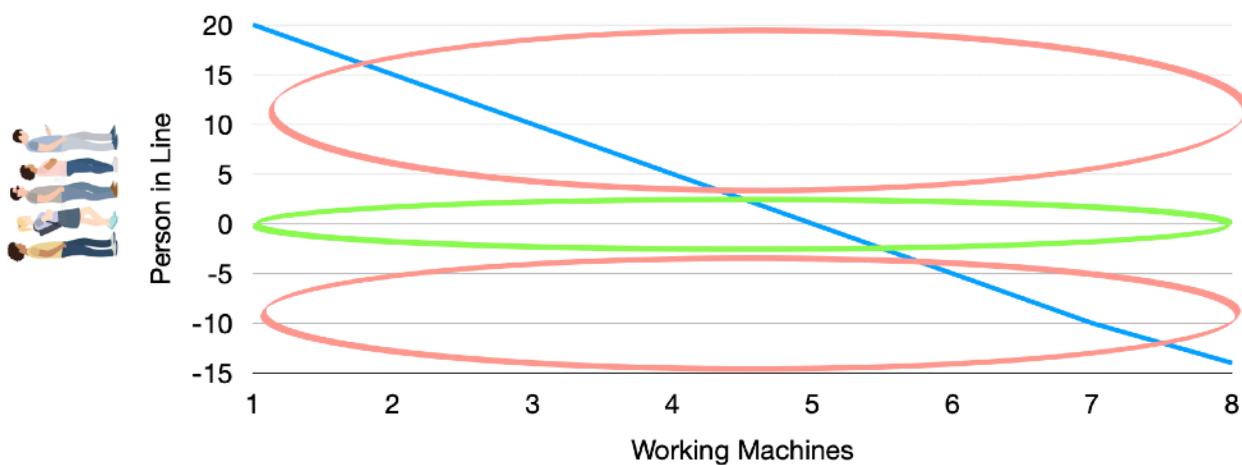
The purpose of this project is to implement the programming paradigm of concurrency to simulate the use of machines or cash counters. The idea is to provide companies with a tool that helps calculate, at a specific day and hour, the ideal amount of machines or cash counters that need to be working in order to maintain short lines, but also keeping the operating costs low.

I decided to develop this project to help companies, mainly because of two reasons:

1. When lines are too big, the persons decide to leave and go to other establishment or company, therefore the establishment loses clients or commissions for lost transactions.
2. When establishments have more machines or cash counters working than needed, the machines or cash counters generate unnecessary expenses for the companies.

So basically, the idea is to maintain the lowest number of machines or cash counters working, but always keeping a small line of persons waiting.

The idea can be observed in the graph below, the green circle is what ideally the companies want, (to maintain persons in line between 0 and less than 5).



DATA FOR THE SIMULATION

The data given to run the simulation plays an important role because the information is different depending the hour and the day, that is why the statistical departments of the companies need to provide the simulator with specific information to run the program.

The parameters with which the program works are:

1. Specific hour of the day.
2. Number of working machines or cash counters, in a specific hour of the day.
3. Number of persons that use the machines or cash counters, in a specific hour of the day.
4. Average time of transaction.

TIME FOR THE SIMULATION

The idea of the simulation is to run the processes of persons waiting in line and using the machines in an hour, therefore the simulation will last approximately 1 minute because is in scale.

Note: In order to run the simulation at a more accessible time, the simulation runs in the following scale.

1 hour - 1 minute
1 minute - 1 second

The transaction time will be generated randomly according to the input of the user of the average time of a transaction, (the input is used to set the limits of the generation of the random transaction time).

The arriving time of the persons that will use the machines will be generated randomly, but within 1 hour, (1 minute in scale).

The waiting time in line to use a machine will vary according to the parameters of number of persons and machines.

FUNCTIONING OF THE PROJECT

The project was developed in Java with the implementation of the programming paradigm of concurrency.

Concurrency

The programming paradigm of concurrency was used in the project, because it allows and supports more than two actions in progress at the same time.

Being able to support more than two actions in progress at the same time is essential to run the simulations because there are different actions in progress that need to be taken into account.

Actions that need to be taken into account:

1. The persons on their way to use a machine or cash counter.
2. The persons entering the waiting line to use the machine or cash counter.
3. The persons waiting in the line to use the machine or cash counter.
4. The persons exiting the waiting line to use the machine or cash counter.
5. The persons using the machine or cash counter.
6. The persons fishing using the machine or cash counter.

Threads

In order to implement the concurrence in the project and to control the different actions being processed, the project makes use of threads.

The program uses threads, because they allow to control and manage the different processes in action, since threads are paths of execution within processes.

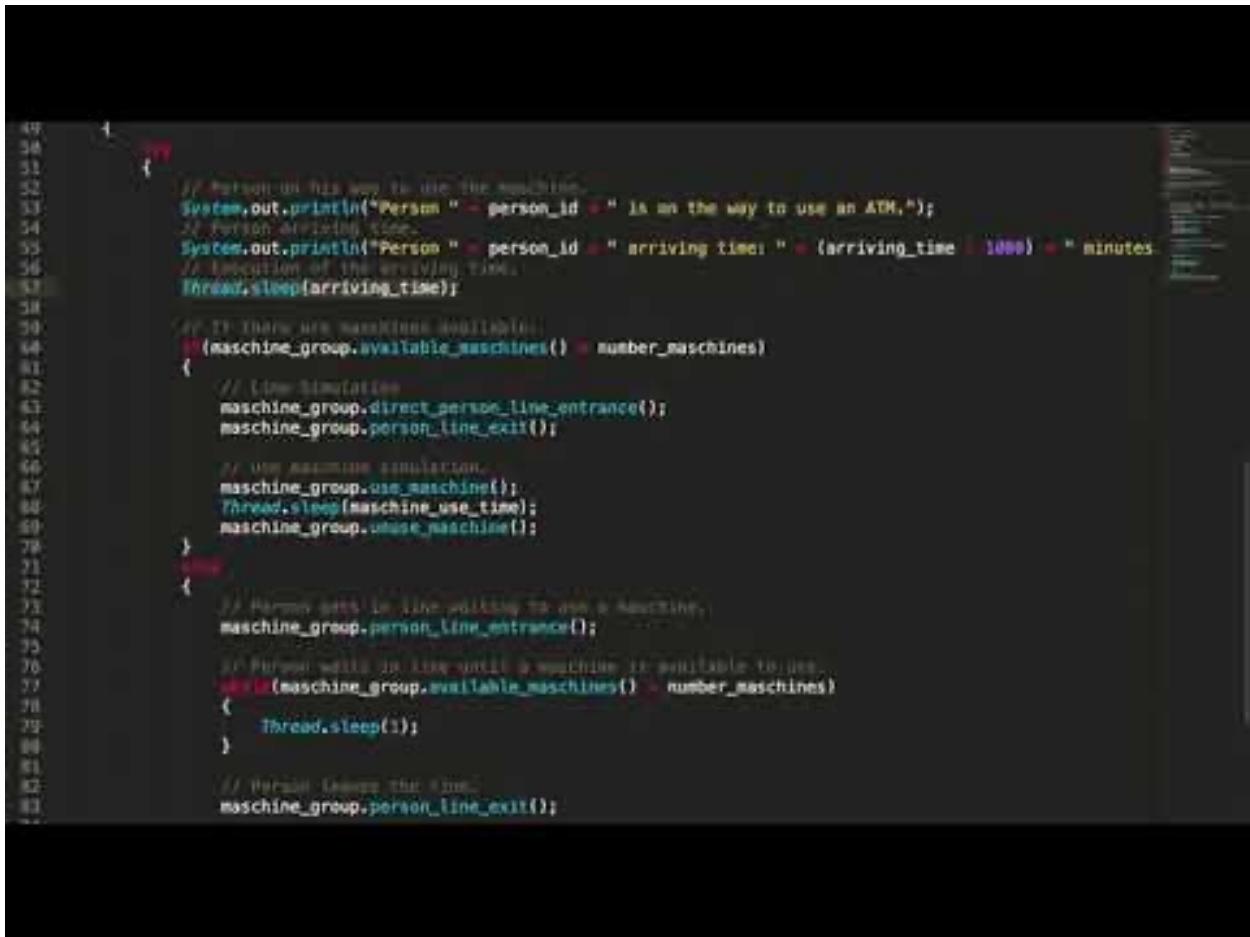
Classes

The project is divided in three classes:

1. Machine Group
2. Person
3. Main (Allows to run the program or the simulations).

Code

Explanation of the code, video link:



```
49
50
51
52
53     // Person arrives to use the machine
54     System.out.println("Person " + person_id + " is on the way to use an ATM.");
55     // Person arrives
56     System.out.println("Person " + person_id + " arriving time: " + (arriving_time / 1000) + " minutes");
57     // Execution of the arriving time
58     Thread.sleep(arriving_time);
59
60     // If there are machines available
61     if (maschine_group.available_maschines() > number_maschines)
62     {
63         // Line simulation
64         maschine_group.direct_person_line_entrance();
65         maschine_group.person_line_exit();
66
67         // Use machine simulation
68         maschine_group.use_maschine();
69         Thread.sleep(maschine_use_time);
70         maschine_group.use_maschine();
71     }
72
73     else
74     {
75         // Person gets in line waiting to use a machine
76         maschine_group.person_line_entrance();
77
78         // Person waits to use until a machine is available to use
79         while (maschine_group.available_maschines() < number_maschines)
80         {
81             Thread.sleep(1);
82         }
83
84         // Person leaves the line
85         maschine_group.person_line_exit();
86     }
87
88 }
```

Code explained with comments:

```
>Main.java
```

```
1 // Library to scan inputs from the user.
2 import java.util.Scanner;
3
4 // Class Main
5 public class Main
6 {
7     // Main to run the program.
8     public static void main(String[] args)
9     {
10         // Creates object from the class machine group.
11         Machine_Group machine_group = new Machine_Group();
12
13         // Prints header of the program.
14         System.out.println("\n _____");
15         System.out.print(" |");
16         System.out.print(" | Machines Use Simulation");
17         System.out.print(" | Machines - ATMs");
18         System.out.print(" | _____");
19
20         // Creates scanner object to get the inputs from the user.
21         Scanner input = new Scanner(System.in);
22
23         // Variables to store the number of visitors, number of machines and average operation time.
24         int number_visitors;
25         int number_machines;
26         int average_operation_time;
27
28         // Number of visitors in a specific hour provided by the user with an input.
29         System.out.print("\nNumber of ATM users for the hour: ");
30         number_visitors = input.nextInt();
31
32         // Number of machines working in a specific hour provided by the user with an input.
33         System.out.print("\nNumber of ATMs working for the hour: ");
34         number_machines = input.nextInt();
35
36         // Average operation time provided by the user with an input.
37         System.out.print("\nAverage operation time in minutes: ");
38         average_operation_time = input.nextInt();
39         System.out.print("\n");
40
41         // Close inputs by the user.
42         input.close();
43
44         // Creates an array of the type person from the class Person, according to the number of visitors.
45         Person persons[] = new Person[number_visitors];
46
47         // Creates an array of threads from the class Thread, according to the number of visitors.
48         Thread threads[] = new Thread[number_visitors];
49
50         // The for loop:
51         // 1. Creates person objects from the class Person and stores them in the persons array.
52         // 2. Creates threads objects from the class Thread and stores them in the threads array.
53         // 3. Starts the threads.
54         for(int i = 0; i < number_visitors; i++)
55         {
56             persons[i] = new Person(i, machine_group, number_machines, average_operation_time);
57             threads[i] = new Thread(persons[i]);
58             threads[i].start();
59         }
60     }
61 }
```



Machine_Group.java

```
1 // Class Machine Group
2 public class Machine_Group
3 {
4     /* Variables that help simulate and control
5      the waiting in line of persons to use the machines. */
6     private int persons_line;
7     private int machines_in_use;
8
9     // Constructor, with the attributes persons in line and machines in use.
10    public Machine_Group()
11    {
12        // Persons in line counter.
13        persons_line = 0;
14
15        // Machines in use counter.
16        machines_in_use = 0;
17    }
18
19    // Method to simulate the waiting in line of a person.
20    public synchronized void person_line_entrance()
21    {
22        persons_line++; // Adds to the counter of the persons waiting in the line.
23        System.out.println("Persons in line waiting to use an ATM: " + number_persons_in_line());
24    }
25
26    // Method to simulate passing the line without waiting, because its empty.
27    public synchronized void direct_person_line_entrance()
28    {
29        persons_line++; // Adds to the counter of the persons waiting in the line.
30    }
31
32    // Method to simulate the exit of the line of a person.
33    public synchronized void person_line_exit()
34    {
35        persons_line--; // Subtracts to the counter of the persons waiting in the line.
36        System.out.println("Persons in line waiting to use an ATM: " + number_persons_in_line());
37    }
38
39    // Method that returns the number of persons waiting in line to use a machine.
40    public synchronized int number_persons_in_line()
41    {
42        return persons_line;
43    }
44
45    // Method to simulate the use of a machine.
46    public synchronized void use_machine()
47    {
48        machines_in_use++; // Adds to the counter of machines in use.
49    }
50
51    // Method to simulate the unuse of a machine.
52    public synchronized void unuse_machine()
53    {
54        machines_in_use--; // Subtracts to the counter of machines in use.
55    }
56
57    // Method to obtain the machines in use.
58    public synchronized int available_machines()
59    {
60        return machines_in_use;
61    }
62 }
```

```
Person.java x
1 // Library to generate random numbers.
2 import java.util.Random;
3
4 // Person class.
5 public class Person implements Runnable
6 {
7     /* Variable from the class machine group to use
8     the methods in that class. */
9     private Machine_Group machine_group;
10
11    // Variables to control the time.
12    private int arriving_time;
13    private int machine_use_time;
14
15    // Variable to identify the persons.
16    private int person_id;
17
18    // Variables to control the operation process.
19    private int number_machines;
20    private int average_operation_time;
21
22    /* Constructor of the person, with the attributes person id, machine group,
23    number machines, average operation time.*/
24    public Person (int person_id, Machine_Group machine_group, int number_machines, int average_operation_time)
25    {
26        // Atributes
27        this.person_id = person_id;
28        this.machine_group = machine_group;
29        this.number_machines = number_machines;
30        this.average_operation_time = average_operation_time;
31
32        // Creates an object of the Random class to generate random numbers.
33        Random random = new Random();
34
35        // Generates random number for the operation time within the indicated time.
36        machine_use_time = random.nextInt(average_operation_time * 1000);
37        // Generates random number for the arriving time within 60 minutes.
38        arriving_time = random.nextInt(60000);
39    }
40}
```

```
Person.java
```

```
41     // Method run, specific to specify the actions that the threads perform.
42     @Override
43     public void run()
44     {
45         try
46         {
47             // Person on his way to use the machine.
48             System.out.println("Person " + person_id + " is on the way to use an ATM.");
49             // Person arriving time.
50             System.out.println("Person " + person_id + " arriving time: " + (arriving_time / 1000) + " minutes.");
51             // Execution of the arriving time.
52             Thread.sleep(arriving_time);
53
54             // If there are machines available.
55             if(machine_group.available_machines() < number_machines)
56             {
57                 // Line Simulation
58                 machine_group.direct_person_line_entrance();
59                 machine_group.person_line_exit();
60
61                 // Use machine simulation.
62                 machine_group.use_machine();
63                 Thread.sleep(machine_use_time);
64                 machine_group.unuse_machine();
65             }
66             else
67             {
68                 // Person gets in line waiting to use a machine.
69                 machine_group.person_line_entrance();
70
71                 // Person waits in line until a machine is available to use.
72                 while(machine_group.available_machines() > number_machines)
73                 {
74                     Thread.sleep(1);
75                 }
76
77                 // Person leaves the line.
78                 machine_group.person_line_exit();
79
80                 // Use machine simulation.
81                 machine_group.use_machine();
82                 Thread.sleep(machine_use_time);
83                 machine_group.unuse_machine();
84             }
85         }
86         catch (Exception e)
87         {
88             // In case something goes wrong in the program.
89             System.out.println("\n");
90             System.out.println("The program has presented a problem!");
91             System.out.println("Please, contact the IT department.");
92         }
93     }
94 }
```

Link to GitHub Repository: <https://github.com/A01705317/Programming-Languages>

RUNNING THE SIMULATION

The program can be used to run simulations for different types of paying or transaction machines, such as: machines to pay the electric power, machines to buy movie theatre tickets, machines to pay parking, ATMs, etc.

Examples:



Note: For the purpose of a better analysis of the results of the simulation, the project will be focused in running simulations for ATMs.

Note: The simulations takes multiple lines depending on the parameters given by the user, therefore this documentation only shows 5 lines of each section.

Note: In order to get the number of recommended machines we round the maximum number of persons waiting in line to the next multiple of 5, (with the exception of numbers less than 5), and then divide that number by 5.

Remember: The idea is to maintain the persons waiting in line between 0 and 5.

SIMULATION 1

Table of Results

Number of Persons	50
Number of Machines	1
Transaction Average Time	10
Running Time	1 min 34 sec
Max. Number Persons Line	19
Recommended Machines	4 more

```
Machines Use Simulation  
Maschines - ATMs

Number of ATM users for the hour: 50
Number of ATMs working for the hour: 1
Average operation time in minutes: 10

Person 11 is on the way to use an ATM.
Person 48 is on the way to use an ATM.
Person 49 is on the way to use an ATM.
Person 4 is on the way to use an ATM.
Person 5 is on the way to use an ATM.
Person 47 arriving time: 6 minutes.
Person 12 arriving time: 48 minutes.
Person 6 arriving time: 51 minutes.
Person 36 arriving time: 36 minutes.
Person 46 arriving time: 36 minutes.

Persons in line waiting to use an ATM: 19
Persons in line waiting to use an ATM: 18
Persons in line waiting to use an ATM: 17
Persons in line waiting to use an ATM: 18
Persons in line waiting to use an ATM: 19
```

SIMULATION 2

Table of Results

Number of Persons	50
Number of Machines	2
Transaction Average Time	10
Running Time	1 min 14 sec
Max. Number Persons Line	15
Recommended Machines	3 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 50

Number of ATMs working for the hour: 2

Average operation time in minutes: 10

Person 34 is on the way to use an ATM.
Person 44 is on the way to use an ATM.
Person 27 is on the way to use an ATM.
Person 32 is on the way to use an ATM.
Person 4 is on the way to use an ATM.
Person 35 arriving time: 26 minutes.
Person 48 arriving time: 46 minutes.
Person 7 arriving time: 30 minutes.
Person 49 arriving time: 17 minutes.
Person 42 arriving time: 29 minutes.
Persons in line waiting to use an ATM: 13
Persons in line waiting to use an ATM: 14
Persons in line waiting to use an ATM: 15
Persons in line waiting to use an ATM: 14
Persons in line waiting to use an ATM: 13

SIMULATION 3

Table of Results

Number of Persons	50
Number of Machines	3
Transaction Average Time	10
Running Time	1 min 8 sec
Max. Number Persons Line	9
Recommended Machines	2 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 50

Number of ATMs working for the hour: 3

Average operation time in minutes: 10

Person 49 is on the way to use an ATM.

Person 36 is on the way to use an ATM.

Person 4 is on the way to use an ATM.

Person 24 is on the way to use an ATM.

Person 28 is on the way to use an ATM.

Person 49 arriving time: 4 minutes.

Person 25 arriving time: 57 minutes.

Person 18 is on the way to use an ATM.

Person 18 arriving time: 4 minutes.

Person 22 is on the way to use an ATM.

Persons in line waiting to use an ATM: 7

Persons in line waiting to use an ATM: 8

Persons in line waiting to use an ATM: 9

Persons in line waiting to use an ATM: 8

Persons in line waiting to use an ATM: 9

SIMULATION 4

Table of Results

Number of Persons	50
Number of Machines	4
Transaction Average Time	10
Running Time	1 min 2 sec
Max. Number Persons Line	5
Recommended Machines	1 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 50

Number of ATMs working for the hour: 4

Average operation time in minutes: 10

Person 21 is on the way to use an ATM.

Person 9 is on the way to use an ATM.

Person 16 is on the way to use an ATM.

Person 8 is on the way to use an ATM.

Person 26 is on the way to use an ATM.

Person 3 arriving time: 38 minutes.

Person 27 arriving time: 4 minutes.

Person 45 arriving time: 23 minutes.

Person 12 arriving time: 41 minutes.

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 4

Persons in line waiting to use an ATM: 3

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 2

SIMULATION 5

Table of Results

Number of Persons	50
Number of Machines	5
Transaction Average Time	10
Running Time	1 min
Max. Number Persons Line	2
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 50

Number of ATMs working for the hour: 5

Average operation time in minutes: 10

Person 16 is on the way to use an ATM.
Person 1 is on the way to use an ATM.
Person 33 is on the way to use an ATM.
Person 20 is on the way to use an ATM.
Person 35 is on the way to use an ATM.
Person 18 arriving time: 41 minutes.
Person 11 arriving time: 10 minutes.
Person 1 arriving time: 7 minutes.
Person 28 arriving time: 40 minutes.
Person 20 arriving time: 27 minutes.
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 2
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 0

SIMULATION 6

Table of Results

Number of Persons	70
Number of Machines	1
Transaction Average Time	8
Running Time	1 min 57 sec
Max. Number Persons Line	34
Recommended Machines	7 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 1

Average operation time in minutes: 8

Person 38 is on the way to use an ATM.
Person 44 is on the way to use an ATM.
Person 43 is on the way to use an ATM.
Person 45 is on the way to use an ATM.
Person 46 is on the way to use an ATM.
Person 14 arriving time: 17 minutes.
Person 49 arriving time: 15 minutes.
Person 32 arriving time: 39 minutes.
Person 41 arriving time: 39 minutes.
Person 35 arriving time: 21 minutes.
Persons in line waiting to use an ATM: 33
Persons in line waiting to use an ATM: 34
Persons in line waiting to use an ATM: 33
Persons in line waiting to use an ATM: 32
Persons in line waiting to use an ATM: 31

SIMULATION 7

Table of Results

Number of Persons	70
Number of Machines	2
Transaction Average Time	8
Running Time	1 min 39 sec
Max. Number Persons Line	15
Recommended Machines	3 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 2

Average operation time in minutes: 8

Person 40 is on the way to use an ATM.
Person 61 is on the way to use an ATM.
Person 62 is on the way to use an ATM.
Person 63 is on the way to use an ATM.
Person 60 is on the way to use an ATM.
Person 40 arriving time: 7 minutes.
Person 17 arriving time: 1 minutes.
Person 50 arriving time: 17 minutes.
Person 62 arriving time: 31 minutes.
Person 51 arriving time: 33 minutes.
Persons in line waiting to use an ATM: 14
Persons in line waiting to use an ATM: 15
Persons in line waiting to use an ATM: 14
Persons in line waiting to use an ATM: 13
Persons in line waiting to use an ATM: 12

SIMULATION 8

Table of Results

Number of Persons	70
Number of Machines	3
Transaction Average Time	8
Running Time	1 min 23 sec
Max. Number Persons Line	8
Recommended Machines	2 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 3

Average operation time in minutes: 8

Person 21 is on the way to use an ATM.

Person 20 is on the way to use an ATM.

Person 39 is on the way to use an ATM.

Person 25 is on the way to use an ATM.

Person 27 is on the way to use an ATM.

Person 33 arriving time: 17 minutes.

Person 61 arriving time: 20 minutes.

Person 35 arriving time: 21 minutes.

Person 52 arriving time: 17 minutes.

Persons in line waiting to use an ATM: 7

Persons in line waiting to use an ATM: 8

Persons in line waiting to use an ATM: 7

Persons in line waiting to use an ATM: 8

Persons in line waiting to use an ATM: 7

SIMULATION 9

Table of Results

Number of Persons	70
Number of Machines	4
Transaction Average Time	8
Running Time	1 min 12 sec
Max. Number Persons Line	3
Recommended Machines	3 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 4

Average operation time in minutes: 8

Person 19 is on the way to use an ATM.

Person 7 is on the way to use an ATM.

Person 51 is on the way to use an ATM.

Person 34 is on the way to use an ATM.

Person 27 is on the way to use an ATM.

Person 59 arriving time: 53 minutes.

Person 19 arriving time: 50 minutes.

Person 52 arriving time: 25 minutes.

Person 33 arriving time: 13 minutes.

Person 53 arriving time: 26 minutes.

Persons in line waiting to use an ATM: 11

Persons in line waiting to use an ATM: 12

Persons in line waiting to use an ATM: 13

Persons in line waiting to use an ATM: 12

Persons in line waiting to use an ATM: 11

SIMULATION 10

Table of Results

Number of Persons	70
Number of Machines	5
Transaction Average Time	8
Running Time	1 min 8 sec
Max. Number Persons Line	6
Recommended Machines	1 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 5

Average operation time in minutes: 8

Person 36 is on the way to use an ATM.

Person 64 is on the way to use an ATM.

Person 57 is on the way to use an ATM.

Person 56 is on the way to use an ATM.

Person 16 is on the way to use an ATM.

Person 30 arriving time: 13 minutes.

Person 64 arriving time: 28 minutes.

Person 59 arriving time: 52 minutes.

Person 16 arriving time: 27 minutes.

Persons in line waiting to use an ATM: 4

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 6

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 4

SIMULATION 11

Table of Results

Number of Persons	70
Number of Machines	6
Transaction Average Time	8
Running Time	1 min
Max. Number Persons Line	3
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 6

Average operation time in minutes: 8

Person 23 is on the way to use an ATM.

Person 58 is on the way to use an ATM.

Person 68 is on the way to use an ATM.

Person 32 is on the way to use an ATM.

Person 59 is on the way to use an ATM.

Person 11 arriving time: 54 minutes.

Person 42 arriving time: 28 minutes.

Person 39 arriving time: 39 minutes.

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 3

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 1

SIMULATION 12

Table of Results

Number of Persons	70
Number of Machines	7
Transaction Average Time	8
Running Time	1 min
Max. Number Persons Line	1
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 70

Number of ATMs working for the hour: 7

Average operation time in minutes: 8

Person 58 is on the way to use an ATM.

Person 52 is on the way to use an ATM.

Person 35 is on the way to use an ATM.

Person 62 is on the way to use an ATM.

Person 53 is on the way to use an ATM.

Person 43 arriving time: 43 minutes.

Person 32 arriving time: 42 minutes.

Person 16 arriving time: 19 minutes.

Person 12 arriving time: 13 minutes.

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 0

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 0

Persons in line waiting to use an ATM: 0

SIMULATION 13

Table of Results

Number of Persons	100
Number of Machines	1
Transaction Average Time	5
Running Time	2 min 14 sec
Max. Number Persons Line	30
Recommended Machines	6 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 1

Average operation time in minutes: 5

Person 69 is on the way to use an ATM.

Person 80 is on the way to use an ATM.

Person 68 is on the way to use an ATM.

Person 79 is on the way to use an ATM.

Person 81 is on the way to use an ATM.

Person 43 arriving time: 11 minutes.

Person 71 arriving time: 12 minutes.

Person 27 arriving time: 56 minutes.

Person 51 arriving time: 53 minutes.

Person 48 arriving time: 54 minutes.

Persons in line waiting to use an ATM: 30

Persons in line waiting to use an ATM: 31

Persons in line waiting to use an ATM: 30

Persons in line waiting to use an ATM: 29

Persons in line waiting to use an ATM: 30

SIMULATION 14

Table of Results

Number of Persons	100
Number of Machines	2
Transaction Average Time	5
Running Time	1 min 49 sec
Max. Number Persons Line	25
Recommended Machines	5 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 2

Average operation time in minutes: 5

Person 50 is on the way to use an ATM.

Person 60 is on the way to use an ATM.

Person 48 is on the way to use an ATM.

Person 61 is on the way to use an ATM.

Person 49 is on the way to use an ATM.

Person 93 arriving time: 34 minutes.

Person 94 arriving time: 56 minutes.

Person 16 arriving time: 18 minutes.

Person 29 arriving time: 32 minutes.

Person 98 arriving time: 13 minutes.

Persons in line waiting to use an ATM: 24

Persons in line waiting to use an ATM: 25

Persons in line waiting to use an ATM: 24

Persons in line waiting to use an ATM: 23

Persons in line waiting to use an ATM: 22

SIMULATION 15

Table of Results

Number of Persons	100
Number of Machines	3
Transaction Average Time	5
Running Time	1 min 26 sec
Max. Number Persons Line	16
Recommended Machines	4 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 3

Average operation time in minutes: 5

Person 26 is on the way to use an ATM.

Person 13 is on the way to use an ATM.

Person 56 is on the way to use an ATM.

Person 58 is on the way to use an ATM.

Person 61 is on the way to use an ATM.

Person 70 arriving time: 53 minutes.

Person 97 arriving time: 10 minutes.

Person 99 arriving time: 16 minutes.

Person 98 arriving time: 7 minutes.

Person 55 arriving time: 45 minutes.

Persons in line waiting to use an ATM: 15

Persons in line waiting to use an ATM: 16

Persons in line waiting to use an ATM: 15

Persons in line waiting to use an ATM: 16

Persons in line waiting to use an ATM: 15

SIMULATION 16

Table of Results

Number of Persons	100
Number of Machines	4
Transaction Average Time	5
Running Time	1 min 11 sec
Max. Number Persons Line	6
Recommended Machines	2 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 4

Average operation time in minutes: 5

Person 60 is on the way to use an ATM.

Person 35 is on the way to use an ATM.

Person 21 is on the way to use an ATM.

Person 26 is on the way to use an ATM.

Person 99 arriving time: 10 minutes.

Person 11 arriving time: 35 minutes.

Person 22 arriving time: 14 minutes.

Person 65 arriving time: 15 minutes.

Person 67 arriving time: 42 minutes.

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 6

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 4

Persons in line waiting to use an ATM: 3

SIMULATION 17

Table of Results

Number of Persons	100
Number of Machines	5
Transaction Average Time	5
Running Time	1 min 7 sec
Max. Number Persons Line	30
Recommended Machines	more

Machines Use Simulation
Maschines - ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 5

Average operation time in minutes: 5

Person 34 is on the way to use an ATM.

Person 4 is on the way to use an ATM.

Person 9 is on the way to use an ATM.

Person 3 is on the way to use an ATM.

Person 22 is on the way to use an ATM.

Person 12 arriving time: 6 minutes.

Person 83 arriving time: 5 minutes.

Person 82 arriving time: 0 minutes.

Person 37 arriving time: 57 minutes.

Person 4 arriving time: 19 minutes.

Persons in line waiting to use an ATM: 4

Persons in line waiting to use an ATM: 3

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 3

Persons in line waiting to use an ATM: 2

SIMULATION 18

Table of Results

Number of Persons	100
Number of Machines	6
Transaction Average Time	5
Running Time	1 min
Max. Number Persons Line	2
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 100

Number of ATMs working for the hour: 6

Average operation time in minutes: 5

Person 38 is on the way to use an ATM.

Person 9 is on the way to use an ATM.

Person 51 is on the way to use an ATM.

Person 13 is on the way to use an ATM.

Person 33 is on the way to use an ATM.

Person 6 arriving time: 21 minutes.

Person 33 arriving time: 39 minutes.

Person 95 arriving time: 13 minutes.

Person 14 arriving time: 44 minutes.

Person 96 arriving time: 14 minutes.

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 0

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 0

SIMULATION 19

Table of Results

Number of Persons	20
Number of Machines	1
Transaction Average Time	15
Running Time	1 min
Max. Number Persons Line	5
Recommended Machines	1 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 20

Number of ATMs working for the hour: 1

Average operation time in minutes: 15

Person 3 is on the way to use an ATM.
Person 9 is on the way to use an ATM.
Person 16 is on the way to use an ATM.
Person 10 is on the way to use an ATM.
Person 12 is on the way to use an ATM.
Person 15 arriving time: 3 minutes.
Person 19 arriving time: 30 minutes.
Person 18 arriving time: 57 minutes.
Person 4 arriving time: 26 minutes.
Person 12 arriving time: 41 minutes.
Persons in line waiting to use an ATM: 4
Persons in line waiting to use an ATM: 5
Persons in line waiting to use an ATM: 4
Persons in line waiting to use an ATM: 3
Persons in line waiting to use an ATM: 2

SIMULATION 20

Table of Results

Number of Persons	20
Number of Machines	2
Transaction Average Time	15
Running Time	1 min
Max. Number Persons Line	3
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 20

Number of ATMs working for the hour: 2

Average operation time in minutes: 15

Person 18 is on the way to use an ATM.
Person 12 is on the way to use an ATM.
Person 16 is on the way to use an ATM.
Person 4 is on the way to use an ATM.
Person 0 is on the way to use an ATM.
Person 9 arriving time: 25 minutes.
Person 7 arriving time: 55 minutes.
Person 0 arriving time: 45 minutes.
Person 11 arriving time: 16 minutes.
Person 15 arriving time: 26 minutes.
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 2
Persons in line waiting to use an ATM: 3
Persons in line waiting to use an ATM: 2
Persons in line waiting to use an ATM: 1

SIMULATION 21

Table of Results

Number of Persons	30
Number of Machines	1
Transaction Average Time	10
Running Time	1 min 5 sec
Max. Number Persons Line	8
Recommended Machines	2 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 30

Number of ATMs working for the hour: 1

Average operation time in minutes: 10

Person 16 is on the way to use an ATM.
Person 10 is on the way to use an ATM.
Person 22 is on the way to use an ATM.
Person 27 is on the way to use an ATM.
Person 0 is on the way to use an ATM.
Person 18 arriving time: 11 minutes.
Person 4 arriving time: 59 minutes.
Person 20 arriving time: 12 minutes.
Person 11 arriving time: 0 minutes.
Person 19 arriving time: 31 minutes.
Persons in line waiting to use an ATM: 7
Persons in line waiting to use an ATM: 8
Persons in line waiting to use an ATM: 7
Persons in line waiting to use an ATM: 6
Persons in line waiting to use an ATM: 5

SIMULATION 22

Table of Results

Number of Persons	30
Number of Machines	2
Transaction Average Time	10
Running Time	1 min 1 sec
Max. Number Persons Line	5
Recommended Machines	1 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 30

Number of ATMs working for the hour: 2

Average operation time in minutes: 10

Person 16 is on the way to use an ATM.

Person 19 is on the way to use an ATM.

Person 22 is on the way to use an ATM.

Person 1 is on the way to use an ATM.

Person 3 is on the way to use an ATM.

Person 19 arriving time: 21 minutes.

Person 18 arriving time: 15 minutes.

Person 11 arriving time: 32 minutes.

Person 25 arriving time: 47 minutes.

Persons in line waiting to use an ATM: 5

Persons in line waiting to use an ATM: 4

Persons in line waiting to use an ATM: 3

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 1

SIMULATION 23

Table of Results

Number of Persons	30
Number of Machines	3
Transaction Average Time	10
Running Time	1 min
Max. Number Persons Line	2
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 30

Number of ATMs working for the hour: 3

Average operation time in minutes: 10

Person 27 is on the way to use an ATM.

Person 25 is on the way to use an ATM.

Person 0 is on the way to use an ATM.

Person 3 is on the way to use an ATM.

Person 8 is on the way to use an ATM.

Person 3 arriving time: 36 minutes.

Person 15 arriving time: 29 minutes.

Person 17 arriving time: 57 minutes.

Person 12 arriving time: 25 minutes.

Person 28 arriving time: 49 minutes.

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 2

Persons in line waiting to use an ATM: 1

Persons in line waiting to use an ATM: 0

Persons in line waiting to use an ATM: 0

SIMULATION 24

Table of Results

Number of Persons	40
Number of Machines	1
Transaction Average Time	7
Running Time	1 min 17 sec
Max. Number Persons Line	9
Recommended Machines	2 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 40

Number of ATMs working for the hour: 1

Average operation time in minutes: 7

Person 13 is on the way to use an ATM.
Person 8 is on the way to use an ATM.
Person 39 is on the way to use an ATM.
Person 32 is on the way to use an ATM.
Person 19 is on the way to use an ATM.
Person 14 arriving time: 17 minutes.
Person 15 arriving time: 30 minutes.
Person 25 arriving time: 11 minutes.
Person 38 arriving time: 47 minutes.
Persons in line waiting to use an ATM: 8
Persons in line waiting to use an ATM: 9
Persons in line waiting to use an ATM: 8
Persons in line waiting to use an ATM: 9
Persons in line waiting to use an ATM: 8

SIMULATION 25

Table of Results

Number of Persons	40
Number of Machines	2
Transaction Average Time	7
Running Time	1 min 3 sec
Max. Number Persons Line	4
Recommended Machines	1 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 40

Number of ATMs working for the hour: 2

Average operation time in minutes: 7

Person 5 is on the way to use an ATM.
Person 10 is on the way to use an ATM.
Person 35 is on the way to use an ATM.
Person 33 is on the way to use an ATM.
Person 2 is on the way to use an ATM.
Person 3 arriving time: 40 minutes.
Person 32 arriving time: 17 minutes.
Person 19 arriving time: 33 minutes.
Person 18 arriving time: 16 minutes.
Person 27 arriving time: 14 minutes.
Persons in line waiting to use an ATM: 4
Persons in line waiting to use an ATM: 3
Persons in line waiting to use an ATM: 2
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 2

SIMULATION 26

Table of Results

Number of Persons	40
Number of Machines	3
Transaction Average Time	7
Running Time	1 min
Max. Number Persons Line	1
Recommended Machines	0 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 40

Number of ATMs working for the hour: 3

Average operation time in minutes: 7

Person 25 is on the way to use an ATM.
Person 37 is on the way to use an ATM.
Person 28 is on the way to use an ATM.
Person 21 is on the way to use an ATM.
Person 35 is on the way to use an ATM.
Person 12 arriving time: 11 minutes.
Person 27 arriving time: 36 minutes.
Person 29 arriving time: 33 minutes.
Person 26 arriving time: 12 minutes.
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 0

SIMULATION 27

Table of Results

Number of Persons	80
Number of Machines	3
Transaction Average Time	5
Running Time	1 min 13 sec
Max. Number Persons Line	4
Recommended Machines	0 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 80

Number of ATMs working for the hour: 3

Average operation time in minutes: 5

Person 57 is on the way to use an ATM.
Person 25 is on the way to use an ATM.
Person 55 is on the way to use an ATM.
Person 19 is on the way to use an ATM.
Person 64 is on the way to use an ATM.
Person 4 arriving time: 25 minutes.
Person 53 arriving time: 22 minutes.
Person 52 arriving time: 21 minutes.
Person 66 arriving time: 7 minutes.
Person 49 arriving time: 49 minutes.
Persons in line waiting to use an ATM: 4
Persons in line waiting to use an ATM: 3
Persons in line waiting to use an ATM: 4
Persons in line waiting to use an ATM: 3
Persons in line waiting to use an ATM: 2

SIMULATION 28

Table of Results

Number of Persons	150
Number of Machines	7
Transaction Average Time	8
Running Time	1 min 59 sec
Max. Number Persons Line	26
Recommended Machines	6 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 150

Number of ATMs working for the hour: 7

Average operation time in minutes: 8

Person 25 is on the way to use an ATM.
Person 16 is on the way to use an ATM.
Person 51 is on the way to use an ATM.
Person 28 is on the way to use an ATM.
Person 63 is on the way to use an ATM.
Person 4 arriving time: 39 minutes.
Person 111 arriving time: 24 minutes.
Person 78 arriving time: 7 minutes.
Person 15 arriving time: 19 minutes.
~~Person 1 arriving time: 6 minutes.~~

Persons in line waiting to use an ATM: 26
Persons in line waiting to use an ATM: 25
Persons in line waiting to use an ATM: 24
Persons in line waiting to use an ATM: 25
Persons in line waiting to use an ATM: 24
Persons in line waiting to use an ATM: 23

SIMULATION 29

Table of Results

Number of Persons	10
Number of Machines	1
Transaction Average Time	10
Running Time	1 min
Max. Number Persons Line	2
Recommended Machines	0 more

Machines Use Simulation
Maschines - ATMs

Number of ATM users for the hour: 10

Number of ATMs working for the hour: 1

Average operation time in minutes: 10

Person 7 is on the way to use an ATM.
Person 8 is on the way to use an ATM.
Person 5 is on the way to use an ATM.
Person 3 is on the way to use an ATM.
Person 1 is on the way to use an ATM.
Person 8 arriving time: 42 minutes.
Person 3 arriving time: 7 minutes.
Person 6 arriving time: 1 minutes.
Person 1 arriving time: 51 minutes.
Person 9 arriving time: 22 minutes.
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 2

SIMULATION 30

Table of Results

Number of Persons	300
Number of Machines	10
Transaction Average Time	5
Running Time	1 min 51 sec
Max. Number Persons Line	20
Recommended Machines	4 more

Machines Use Simulation
Maschines – ATMs

Number of ATM users for the hour: 300

Number of ATMs working for the hour: 10

Average operation time in minutes: 5

Person 117 is on the way to use an ATM.

Person 118 is on the way to use an ATM.

Person 119 is on the way to use an ATM.

Person 120 is on the way to use an ATM.

Person 121 is on the way to use an ATM.

Person 122 arriving time: 37 minutes.

Person 109 arriving time: 5 minutes.

Person 77 arriving time: 23 minutes.

Person 23 arriving time: 16 minutes.

Person 78 arriving time: 7 minutes.

Persons in line waiting to use an ATM: 19

Persons in line waiting to use an ATM: 20

Persons in line waiting to use an ATM: 19

Persons in line waiting to use an ATM: 18

Persons in line waiting to use an ATM: 19

SIMULATION 31

Table of Results

Number of Persons	47
Number of Machines	6
Transaction Average Time	7
Running Time	1 min
Max. Number Persons Line	1
Recommended Machines	0 more

Machines Use Simulation Maschines – ATMs

Number of ATM users for the hour: 47

Number of ATMs working for the hour: 6

Average operation time in minutes: 7

Person 23 is on the way to use an ATM.
Person 45 is on the way to use an ATM.
Person 35 is on the way to use an ATM.
Person 13 is on the way to use an ATM.
Person 32 is on the way to use an ATM.
Person 2 arriving time: 59 minutes.
Person 12 arriving time: 56 minutes.
Person 45 arriving time: 59 minutes.
Person 19 arriving time: 44 minutes.
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 1
Persons in line waiting to use an ATM: 0
Persons in line waiting to use an ATM: 0

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