Czech Technical University in Prague
Faculty of Electrical Engineering

Department of Electrotechnology

DIPLOMA THESIS ASSIGNMENT

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Title of Diploma Thesis: **Simulation of passenger lift in Witness software**

Guidelines:

1. Overview of basic principles of lift control
2. Overview of calculation methods for lift throughput calculation
3. Design of lift (lift group) models with selected control strategies and with selected passenger behavior
4. Models validity check
5. Comparison of simulation results with throughput calculation

Bibliography/Sources:

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CZECH TECHNICAL UNIVERSITY IN PRAGUE

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SIMULATION OF PASSENGER LIFT IN WITNESS SOFTWARE

Master Thesis

Study Programme: Electrical Engineering, Power Engineering and Management

Branch of study: Technological Systems

Supervisor: Karel Künzel M.Sc., Ph.D.

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Abstract

The paper is focused on development of models for single and multiple elevators. It is observed the most used and well known elevator control strategies such as Traction control, Zone strategy, Fuzzy control and others.

There were used Zone strategy, Traction point strategy and Auto parking Traction strategy to test the created models for multiple elevators. Simple and collective control – for single elevators. The modelling results are presented and analysed. Part of the test results are not presented in the paper but the features of the models can be used for the real projects. The characteristics of loads and waiting time give a good presentation of advantages and disadvantages of the models and their functionality. The models can be changed or used like base for researching the other algorithms.

Keywords

Elevator, single elevator, multiple elevators, strategy, elevator control, Witness Lanner, simulation, elevator model, passenger flow.

Declaration

I declare that my thesis is the result of my own independent work and all sources have been quoted and acknowledged according to Guidelines for ethical principles of writing theses and dissertations.

Place and date: Signature:

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T	—	Time of elevator trip
H	—	The height of building
h	—	Distance acceleration and braking of the elevator
N	—	Number of stops
V	—	Speed
k	—	Coefficient of delays
t_a	—	Delay of acceleration and breaking of the elevator
t_d	—	Time is needed to close the doors
n	—	Maximum number of passengers

1 Introduction

Level of human life rises very quickly and elevators become an integral part of life. That is why number of reasons to have optimal strategy grows with each floor of skyscraper. This approach increases the level of reliability, comfort and optimize the energy consuming of elevators. Different strategies are used for different purposes. The strategy selection can be based on many factors, for example, on the waiting time or energy consumption. The result of using a good control strategy, can be high service quality and economically profitable investment.

In high buildings with high passenger flows, especially in offices, the strategy for elevator system has a great importance. The main task is minimizing the passengers waiting time and the time of delivery to the floor, thereby improving of people comfort or productivity of employees.

Of course, there are many different elevators in many variations, which are used for not only carrying people or goods. There are those, which can only be called and controlled by operator, or elevators should be moved also horizontally or in multiple directions. The strategy should optimize the important and sometimes unique parameters that are determined for each project. That is why the number of strategies is too high and increases as number of technologies.

1.1 Motivation

The main goal of the work is to design simulation models for different strategies in Witness Lanner program to research all logical aspects of elevator control in different conditions. The models should be flexible to make changes of elevator control system and passenger flows. These parameters have a great influence on the results and conclusions. Such approach will provide better understanding of processes.

The creating of models for single and multiple elevators control systems will allow developing more specific and difficult strategies to solve real tasks in the future.

2 Analysis

Elevator control system depends on the lift type, drive systems, construction, and other factors. It should be used different control systems and strategies to solve the task for the certain situations.

There are some main distinguishes for the control systems[8]:

- the drive type;
- the controller type;
- the number of elevators;
- the strategy.

There are internal and external control systems. For the internal systems, command units are based in a cab. In the case of external controlling, all command units are placed outside the cabin. It can be used lever or push-button to set a task for elevator . The lever is installed in the cockpit and can start and stop the cab even on the intermediate floors. Using systems with push-button the cabin starts and stops at a predetermined floor automatically.

Lever controls systems can be installed only inside the cabin. Button control systems can be external and internal. For passenger elevators, the system is always internal. For small freight and shop elevators the system is external.

The drive for shaft doors are distinguished by manual and automatic drive. Manual drive for doors was used in old elevator. Nowadays, it can be installed in small trucks, for example, in hospital elevators. Commonly, it is used automatic doors. It opens after the arrival of the cabin to a predetermined floor and automatically closes after some time. The time for opening and closing doors is controlled by the main controller. In some cases, this time can be extended or reduced by special buttons inside the cabin or by operator through HMI. Such kind of drive increases the safety, comfort of people and the reliability of the elevator.

There are some call principles, which are connected with the strategies: without free calls, with the free calls down and with the free calls, both up and down. The elevators without free calls are provided with a control system, in which empty cabin can move to the requested floor only after the end of the previous task, when the cabin is free.

Elevators with the free down calls are set to carry passengers in high buildings and the elevators are characterized by a large bandwidth. This kind of system store all calls from any floor and carry people on the way down. If the car is free and it is registered more than one call, the first call is performed to the highest floor and then the cab goes down. During the upward movement, the passing cabin calls are ignored.

The elevators with the implementation of up and down free calls are stopped automatically on every floor, where the call is, accounting the direction of movement of the cabin.

If the cabin is going up, it will stop on the floor, where calls for moving up were recorded. When the car is lowered, it performs a sequence of orders and calls for downward movement.

These systems are provided in public and administrative buildings, and use dual-buttons to determine the direction of movement. These logics of elevator control are referred to the collective strategies.

According to the number of elevators, there are single systems and group systems. In the case of single system, an elevator is not connected with the work of other elevators and each elevator has its' own buttons. The multiple elevators have the opposite situation. There is only one calling device for the group of elevators on each floor and all elevator are connected together through the network. The elevators with group control system are installed in public or commercial buildings. The system provides a joint policy work of three, four and more elevators. The group control system is configured to maximize performance and decrease a waiting time of passenger.

The example is written below shortly describe the principle.

Controller stores the movement directions and positions of each cabin in the memory. When somebody calls the elevator, the system determines the nearest cabin according to the logic and sends it to the requested floor. If the cabin is loaded on 90% it is ignored and cannot be send to the requested floor.

2.1 Types of control system of elevators.

2.1.1 Manually controlled elevator

First elevators did not have automatic control systems. Elevators should be operated by elevator operators. The motor controller on this type of elevator did not have many relays. Some of elevators were controlled by switches. For safety were used the inner and outer doors that should be closed before the elevator would move.

Otis was first company who developed manually controlled elevators with automatic leveling. The operator still was in the cabin and controlled the speed. It was one step to the full automatic control systems [7][8].

2.1.2 Automatic-controlled elevator

2.1.2.1 Relay control

Automatic elevators have started to be used in the 1920s. These systems were electromechanical and used relay logic to control the speed, position and other operations of an elevator. Elevators with relay logic controllers have selector to determine the cabin’s position. The selector uses magnetic tapes and placed on the top of the cabin. First automatic systems could change the speed. Relay-controlled elevator systems were commonly used up the 1980s, and they were changed with microprocessor control systems [7][8].

The electromagnetic relay technology can be used in the next cases:

- Single lifts.
- Limitation of speed 1 m/s.
- Low traffic (residential buildings, small hotel).

2.1.2.2 Microprocessor control

Otis also was the first company who used microprocessors to control Elevators in 1979. Microprocessor was used to control every operation of the elevator.

Elevator sensors provide data about cabin positions, weight inside the cabin, door status, calls, alarms and etc. Nowadays, different kinds of microprocessors are used to control a single car, multiple cars or monitor the situation of strategy changes. These systems allow create smart and fast analysing control systems for different situations because off its advantages:[7][8]

- Small size;
- Digital I/O;
- Speed of reading, treatment and transmission of data;
- Parallel processing;
- Performing of complex operations.

2.2 Elevator control strategies

2.2.1 Simple Control

Basically, the strategy was used at the beginning of automatic control elevators systems and it means there is no any strategy. The elevator has only one call button and goes directly to the floor where the button was pushed first. It is not possible to call the elevator while it is busy. Nowadays it can be used only in houses because of many disadvantages. Some of them are high average of waiting time and high energy consumption.

2.2.2 Collective strategy control

This strategy is the most used nowadays. There should be two call buttons signalizing the trip direction. In this case, the elevator collects people from the floors with the same request. There are three basic types of collective strategy:

- Collecting going up

Free calls up. The elevator moves to the lowest floor with up request and starts to move up. The cabin collects people only from the floors with up request. If the elevator moves down it ignores down requests.

— Collecting going down

The elevator collects people only when it moves down. The cabin reaches the highest floor with down request and moves down collecting all down requests. If the elevator moves up it ignores similar up requests.

— Collecting going up and down

Free calls up and down. The strategy combines two previous cases.

It is also possible to use this strategies with extra rules. For example, some floors have higher priority than others do.

The disadvantage of collective control can appear in multiple elevator systems: if there is, a lot of traffic in a short period there can arrive more than one elevator to the same floor. In this case should be used some rules to avoid this situation [4] .

2.2.3 Zone strategy control

Strakosch described the Zone strategy in1983. Area control also was described by Sakai & Kurosawa in 1984 and it is related to zone control [5].

Zone control is alternative to collective one and it is preferred in the buildings have multiple elevators. In the case of using Zone strategy the building should be separeted into zones of sizes depending on the traffic of each zone. Each elevator has its parking place and only picks up passengers from the floors inside the zone. It also can be done from the final destination floors. In the case of Zone strategy elevator ignores all requests out of its zone even while travelling. Some elevators can have the same floors in there zones and it depends on passenger flows and used to improve the basic strategy [4].

2.2.4 Traction Point Strategy control

Traction Point Strategy also is one of the commonly used strategies for multiple elevators. The logic of this strategy is quite simple. The system determines the nearest elevator to the requested floor and sends to it the task for service. Each elevator does not have any parking place like in zone strategy. That is why would be taking into account the situation when elevators are located at the same destination from the requested floor. In other case more than one elevator can arrive to the requested floor. The certain strategy is alternative variant to Collective one.

2.2.5 Search-Based control

Search-Based strategy used the possible assignments to optimize the elevator work. It uses some criterions as waiting time or floors with highest priorities and etc. There are greedy and non-greedy search strategies. The difference between these strategies are properly described in[]

"*Greedy* search strategies perform immediate call assignment, that is, they assign hall calls to cars when they are first registered and never reconsider those assignments. Greedy algorithms give up some measure of performance due to their lack of flexibility but also require less computation time.

Non-greedy algorithms postpone their assignments or reconsider them in light of updated information they may receive about additional hall calls or passenger destinations."[]

Tobita (1991) described the next principle. The system choose the cabin that minimizes a wait time, travel time, and number of passengers. A system picks the coefficients and estimating functions. Simulations are used to verify their effectiveness.

After every event, the controller search for the best assignment of hall calls. The weaknesses of this approach is its computational demands [5][4].

2.2.6 Rule-Based control

In 1998 Ujihara & Tsuji described the Ruled–Based strategy. The control system uses expert-system and fuzzy-logic technology and based on rule IF-THEN. All rules are developed by group of experts.

It is used the experience and knowledges necessary to decries waiting times under various traffic conditions. The experts create rules based on comparing the decisions made by a conventional algorithm. The results are analyzed by the experts, which knowledge was used to create fuzzy control rules.

Ujihara & Amano described the changes in the system. Before, it was used a formula with calculations based on the current car positions and calls. A new version algorithm considers future car positions and probable future hall calls. The immediate call allocation algorithm has common features for greedy search-based algorithms [5][4].

2.2.7 Fuzzy Logic Group Controller

The strategy which includes the human behaviour factor is called Fuzzy Logic. The strategy includes the information about people moving around the buildings and possible delays caused by their actions.

Passenger flows and waiting time depends on the accuracy of predicted pattern of people decisions. That is why different solutions of fuzzy logic depend on the current traffic situation and the calculations are based on several conditions. The performance of the strategy is improved by letting the algorithm self-tune while executing [5][4].

2.3 The basic parameters of elevator movement

Loads of elevator changes through the day. The intensity of load characteristic depends on some events, location and the purpose of the building is used for: administrative, educational or houses. It is used term Passenger flow to calculate the number of elevators that is needed for comfort carriage of passengers without breaking the waiting time limitations. These limitations are described in ISO 4190.

Passenger flow is determined by the number of passengers per 5 minutes. The following numbers shows the intensity of passenger flow per 5 minutes for different kind of buildings.[6]

Table 2.1 – Peak flows for different buildings

Type of building	**Peak flow**
Houses	4-6%
Hotels	7-10%
Administrative buildings	12-20%
Education institutions	20-30%

The main parameters for researching of the performance of elevators are speed and time. It is important to keep in mind that time has greater influence than time. Analysing parameters should be said about acceleration and breaking time of elevator. If elevator makes many stops, it cannot reach the constant speed – the trip and the waiting times increases. That is why strategies are used. The strategies allow optimization of working mode of elevator decreasing trip level and also the travelled distance, that save money of energy consumption.

The nominal speed of the elevator can be taken from the standard ISO 4190 according to type of elevator and its capacity. The samples of possible capacities and speed are written bellow.

Capacity(kg): 450, 630, 800, 1000, 1275, 1350, 1600, 1800, 2000, 2500.

Speed(m/s): 0.4, 0.63, 0.75, 1.00, 1.50, 1.60, 1.75, 2.00, 2.50, 3.00, 3.50, 4.00, 5.00, 6.00.

There are many methods to calculate the theoretical trip time of the cabin. One of them is presented on the figure 2.1.

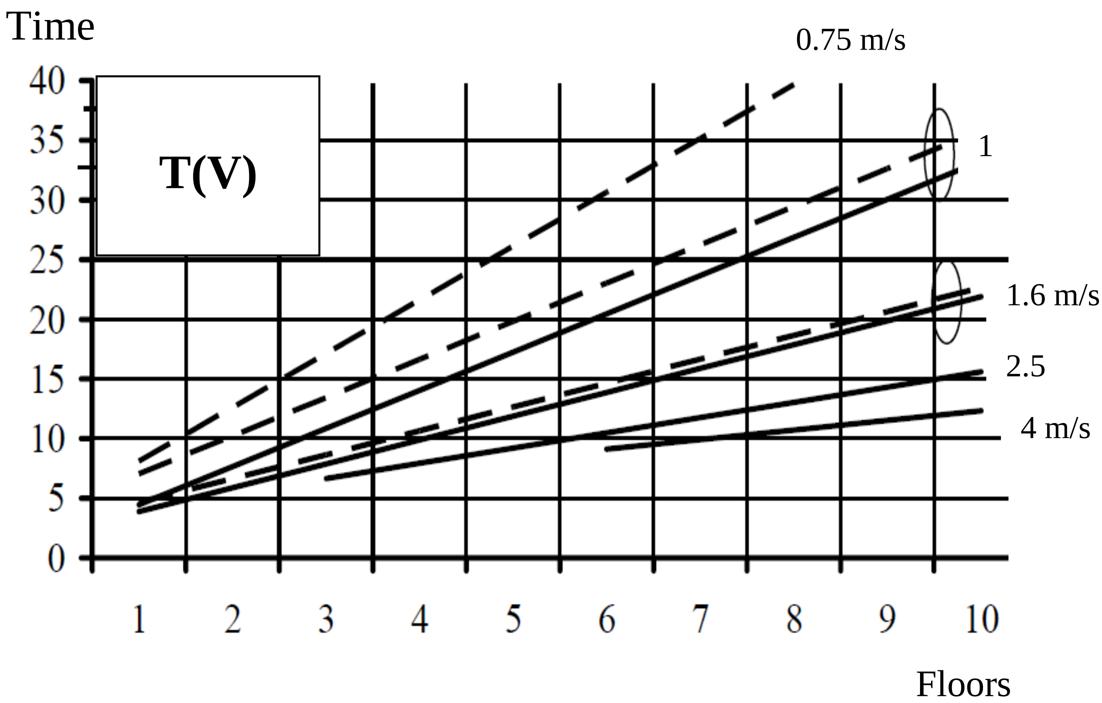


Fig 2.1 – Dependency of trip time of the elevator on the elevator speed T(V)[6]

Another method uses calculation to determine the time of the trip.[6]

$$T = \frac{2H + h(N_1 + N_2 + 1)}{V} + k(t_a(N_1 + N_2 + 1) + t_d) \quad (2.1)$$

The equation 2.1 allow calculations of trip time of elevators between different number of floors and stops. The certain view of the formula is used to calculate the round trip of elevator.

$$N = N_1 - (N_1 - 1)(\frac{N_1 - 1}{N_1})^{0.8} \quad (2.2)$$

The formula 2.2 gives the average number of stops.[6]

$$P = \frac{3600 * n}{\frac{2H}{V} + t_a + t_d} \quad (2.3)$$

The equation 2.3 is used to calculate the possible number of passengers theoretically delivered to the destination floor.[6]

It should be noticed that used calculation methods are basic and does not include advantages of any strategies.

3 Design of simulation model

The simulation models of single or group elevators are implemented in sowtware Witness Lanner. This decision was made because Witness Lanner is one of the best tools for simulating processes. Its facilities give possibilities to create optimal models with necessary parameters, which have, non linear dependency or even chaotic character.

There are two possible situations that should be modelled: single elevator and multiple elevators. In both cases would be used the same elements with similar configurations but their quantity is different.

3.2 Configuration of elements

3.2.1 Parts

The element has two the most important parameters: arrival time and lot size.

Arrival time determines the intervals when people come. This time can be set by variable which depends on the day time and allow the controlling of passenger flow.

K_Arriving determine the arrival intervals by using distribution function and it changes according to the daytime. For example, between 6 and 7 o'clock people arrive every 0-15 minutes with the average interval 7 minutes. Part of the implemented code is written below.

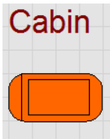
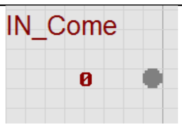
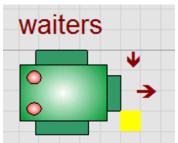
```
IF TTIME >= 6 AND TTIME < 7
K_Arriving = Binomial (0.6,15 * 60)
```

Lot size set the number of people coming at the moment. It is used distribution function to set the value. That is why number of people coming at the moment is different.

Uniform (1,6) says that 1-5 people can come at the moment and call the elevator o different floors.

There is the second element parts called TickTack in the model. The important thing is that information in the Witness Lanner model updates when some events occur. Some information, as waiting time or arrival intervals, should be updated more often than common events occur. And this element allows updating the information each second.

Table 3.1 – Description of the elements

Name	Image	Description	Quantity	
			Single	Multiple
Parts(People)		The element is used to simulate passenger flow. It is connected with a time. People arrive to the hall and call an elevator according to the time intervals.	2	2
Track(Elevator)		The element is used for simulation floors and moving the cabin between them. Their quantity determines the number of floors. Parameters of the element determine the loading and unloading conditions.	1(5)	3(5)
Vehicle(Cabin)		The element is used to for simulation of cabin. The element has two important parameters: capacity and speed.	1	3
Buffer(In_come, Out_come)		The element simulates queue of people on the floor and the number of people that arrived. The grey point indicate the call request. Green – up and Blue – down.	2(5)	2(5)
Machine		This element simulates the situation when people does not use the elevator. It only send people from input buffer to output buffer.	1	1
Timeseries		The element draw the dependency between the variables to visualise the results.		
Variables(local, global)		Variables are used for presenting an important information about		

		occurring processes in the model.		

3.2.1 Track

Track is the most complicated element in the model.

Parameters for loading or unloading events are the same and described below. The difference is in values. Conditions which are set to determine the situation when people can be loaded and unloaded shown below.

Track (Cabin) = Elevator(N) ! loading condition.

Track (Cabin) = Elevator(floor_num(1))! unloading condition

This equations specify that people can be unloaded only on destinations floors and loaded from the stages it stays on.

Quantity of loading or unloading is used to control people leaving the cabin or coming in. It is necessity for the correct working of the model. The equations are shown below.

Round (PeopleInCabin / enum_people,0) ! number of unloaded people

NParts (IN_Come(el_position)) ! number of unloaded people

For the first case: variable PeopleInCabin shows the number of people in the cabin and Enum_people – the number of unloads. Function Round is used to round the result if it is fractional.

The loading and unloading time are set by distribution function Uniform (6,10). It means that certain time is changed in the range of 6-10 seconds. It makes the model more realistic.

3.2.2 Vehicle

The Track element has a few necessary parameters to configure the realistic model of elevator.

Capacity – value that determine the number of people inside the cabin.

Start and stop Delay allow the controlling of the acceleration and breaking of the cabin. The value is set in time units. It is set 1 second.

Unloaded and loaded speed determine the time for travelling of cabin between floors. That is why it should be calculated by equations.

0.66 / (Abs (floor_call(1) - el_position) + 0.1) ! unloaded speed

0.33 / (Abs (floor_num(1) - el_position)+0.1) ! loaded speed

The formulas are based on information that the distance between floors is 3 meters and the nominal speed is 2m/s if it is unloaded and 1m/s if it is loaded.

3.2.3 Machine

Element monitor the waiting time of people on each floor and in the case it is higher than a limit the machine moves some people from IN_come buffer to the OUT_come buffer. It allows to simulate using of stairs. The certain element was tested but it is not presented in the results.

3.2.4 Buffer

There are two buffers to show the number of people calling elevator and people that has gone to the destination floor.

IN_come buffer also indicates the information about call requests: no call, call up and call down. In the case of Simple strategy control all similar requests are ignored.

3.3 Concept of the models

All models have the common principle.

The element parts create parts and sends them with predetermined interval to the buffer In_come where people call the elevator and wait for it. Standing parts in the buffer is registered position data to Floor_call array and average waiting time to waiting_time array. According to the strategy cabin moves to the destination floor.

After loading, system imitates the pushing buttons that indicates floors. The task is writing into floor_num array and the number of imitates is equal to the number of people in the cabin. When the cabin is loaded, it moves between floors according to the strategy. At the destination floor people leave the cabin to Out_come buffer. The system updates the information and the elevator continue its moving to the next floor or waits for next calling. The functional scheme of the model is presented on figure 3.1. It shows the main elements and data exchanging between them.

The connections between the elements for single and multiple elevator are presented on figures 3.2 and 3.3. The presented figures visually describe the possible movement of elements in the model.

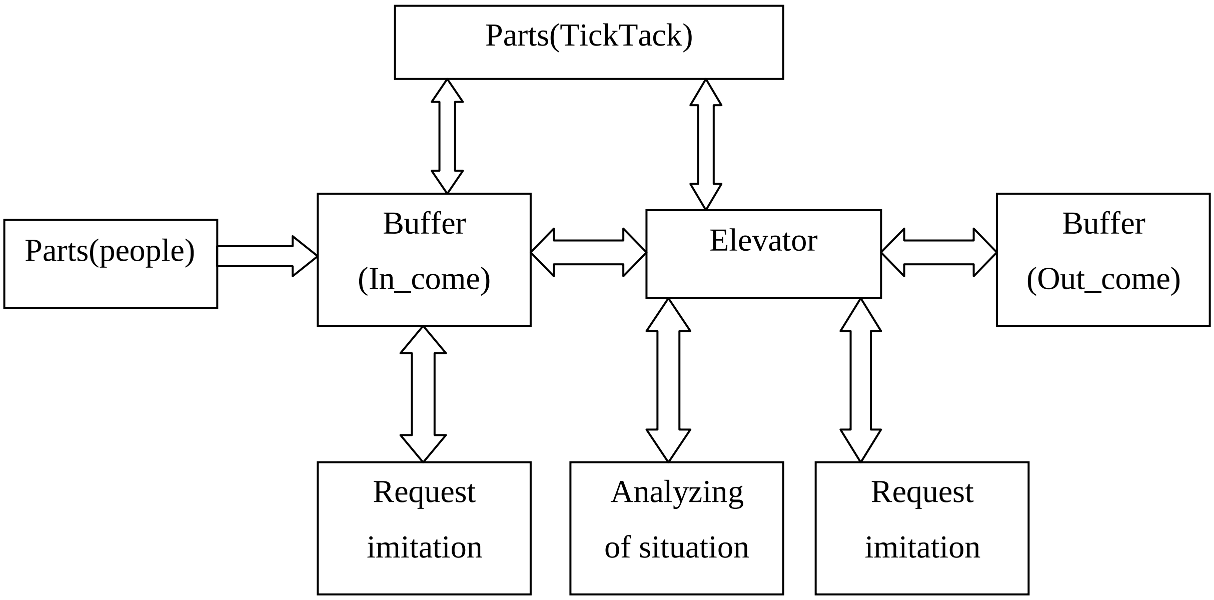


Fig. 3.1 – Functional scheme of the model

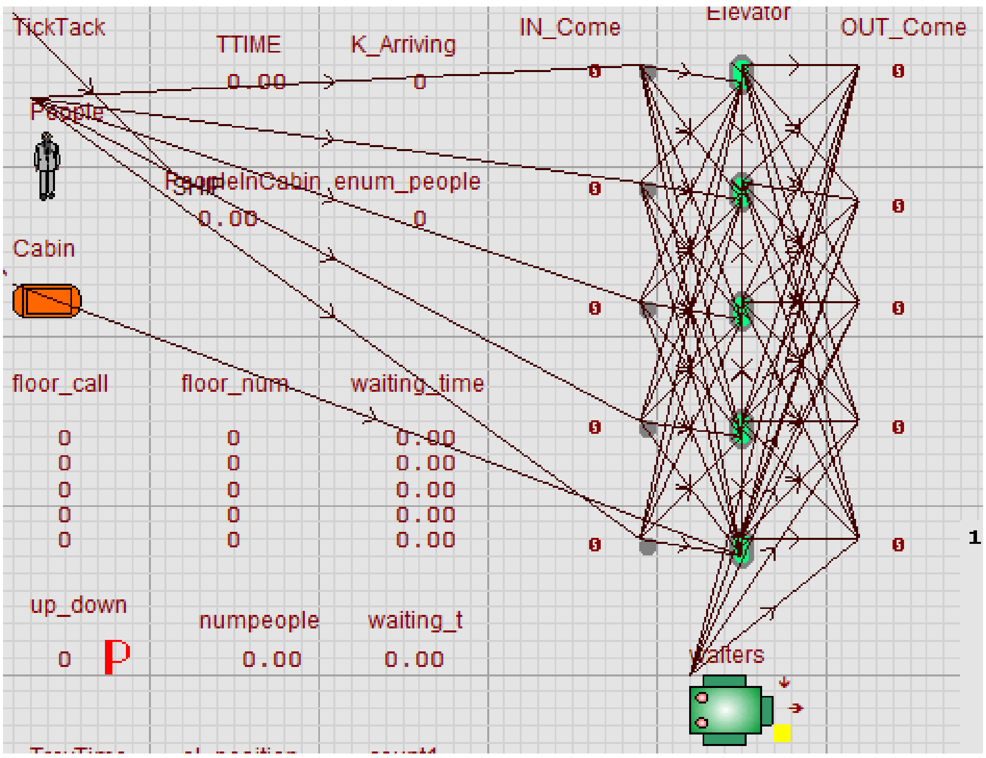


Fig. 3.2 – Elements connections in single elevator model

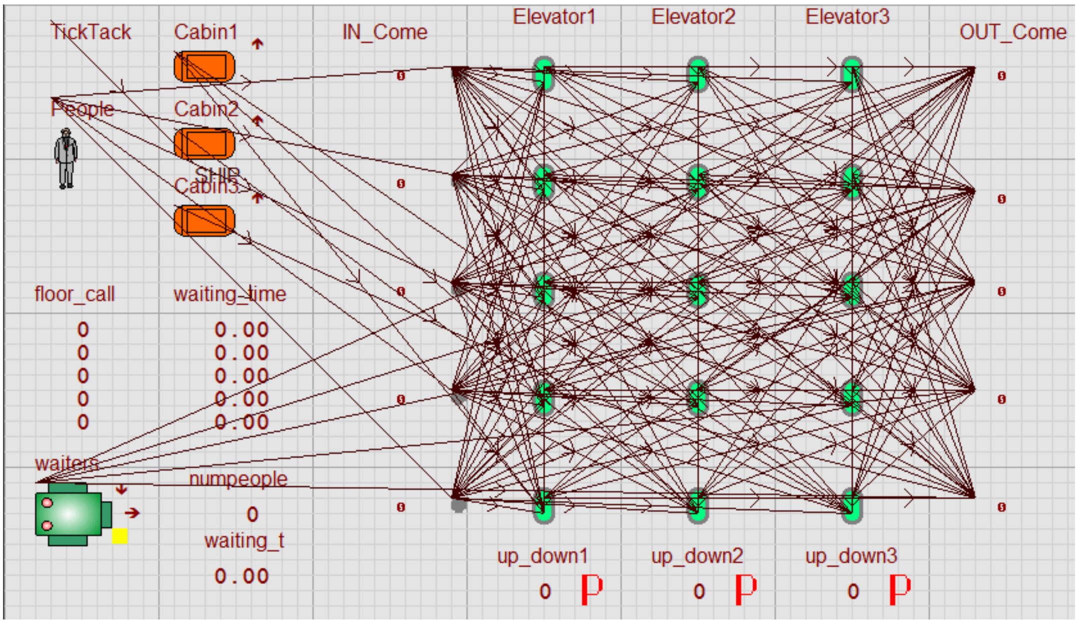


Fig. 3.3 Elements connections in multiple elevators model

3.4 Description of Single Elevator

The final model for single elevator is shown on the figure 3.4. The visual part of the model is the same for any control strategy. The difference is in configuration part.

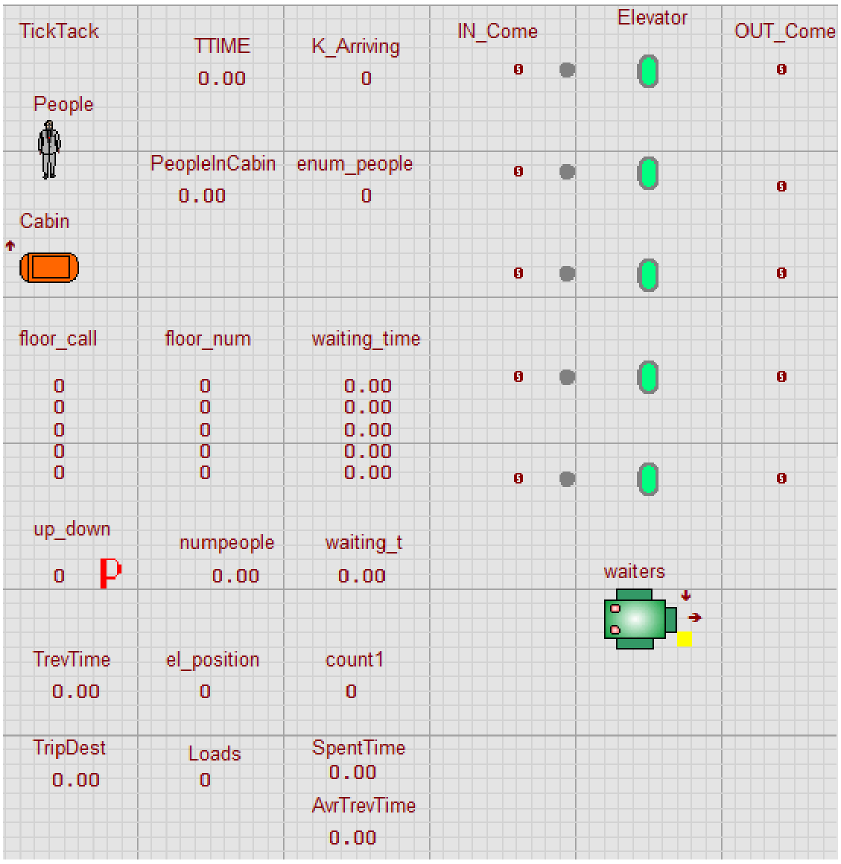


Fig. 3.4 – Single elevator model

3.4.1 Simple Strategy model

The logic of Simple Control Strategy is described in the analysis chapter.

When parts arrive to the in_come buffer the system checks all floors for presence of the people and activates the requests where it is necessary by green or blue colours. All Call requests are written in floor_call array and elevater moves to the first requested one. The request is determined by distribution function.

The next step is analysing of the elevator state. If the elevator is not busy it is sent to the requested floor and the loading begin.

When the loading is occur the system imitates the destination floor tasks (pushing of buttons) equal to the number of people in the cabin. Code written below gives better understanding of the event.

```
WHILE count1 + 1 <= NParts (Cabin)
 count1 = count1 + 1
 floor_num(count1) = Uniform (el_position + 1,6)
ENDWHILE
```

The similar tasks are checked and neglected. In the case elevator goes up the tasks are permutated into increasing sequence, if down – into decreasing one. It is written a part of code of permutation for the first situation.

```
floor_num(in_c2 + 1) = floor_num(in_c2 + 1) + floor_num(in_c2)
floor_num(in_c2) = floor_num(in_c2 + 1) - floor_num(in_c2)
floor_num(in_c2 + 1) = floor_num(in_c2 + 1) - floor_num(in_c2)
```

At the time of loading, the system updates the certain floor request and the direction of movement.

After loading, the cabin moves to the destination floor. The movement of the cabin is determined by output rule of the Track (elevator) and written below.

```
IF floor_num(1) > 0
PUSH to Elevator(floor_num(1))
ELSEIF floor_num(1) = 0 AND floor_call(1) > 0 AND Track (Cabin) <> Elevator(floor_call(1))
PUSH to Elevator(floor_call(1))
ELSEIF floor_num(1) = 0 AND Track (Cabin) = Elevator(floor_call(1)) AND floor_call(1) > 0 AND PeopleInCabin = 0 AND NParts (IN_Come(floor_call(1))) > 0
PUSH to Elevator(floor_call(1))
ELSE
Wait
ENDIF
```

The certain code only repeat the logic of the Simple control strategy.

At the destination floor, the system unloads people to the certain out_come buffer and updates the task information and number of people in the cabin. It is also updated the direction of the movement of the cabin.

3.4.2 Collective strategy model

The sequence of events for the model is similar to the simple control strategy.

There are the same calculations in the buffer or at loading and unloading events like in the previous case. However, according to logic of the strategy it should be accounted all floors with the same requests. It is implemented by using next code.

```
FOR dir = 1 TO 5
IF GetIcon (IN_Come(dir),1) = FC1 AND (FC1 = 25 OR FC1 = 26) AND PeopleInCabin = 0
 FOR dir2 = 1 TO 5
  IF path(dir2) = 0
   path(dir2) = dir
   dir2 = 5
  ENDIF
 NEXT
ENDIF
NEXT
```

This code also is used at loading and unloading events, but the number of people in the cabin has influence only in the case of buffer. It is done to increase the priority to make decisions with updating the cabin state. The sequence of numbers in the path array is changed according to the direction of movement.

The important aspect of this model is that the cabin can stop not only on destination floors. That is why it was written the code which always update the speed of cabin at loading and unloading events according to the next destination floor. The certain decision is caused by the Witness Lanner features.

```
IF PeopleInCabin > 0 AND path(1) < floor_num(1) AND FC1 = 25
CabSpeed = 0.33 / (Abs (path(1) - el_position) + 0.1)
ELSEIF PeopleInCabin > 0 AND path(1) > floor_num(1) AND FC1 = 25
CabSpeed = 0.33 / (Abs (floor_num(1) - el_position) + 0.1)
ELSEIF PeopleInCabin > 0 AND path(1) < floor_num(1) AND FC1 = 26
CabSpeed = 0.33 / (Abs (floor_num(1) - el_position) + 0.1)
ELSEIF PeopleInCabin > 0 AND path(1) < floor_num(1) AND FC1 = 26
CabSpeed = 0.33 / (Abs (path(1) - el_position) + 0.1)
ENDIF
```

The output rule for moving cabin includes all possible situation and looks great. But the code can be easily smplified by changing logic of storage data of similar call requests and destination floors. It is stored in two separeted arrays, that is why the system should always compare theese arrays. If the arrays will be united the code will be reduced.

3.5 Multiple elevators

All events are happened in the model are similar to the single elevator model. There are some important features for each strategy for multiple elevators systems. The coding is not presented in this chapter. But the modes can be found on the CD.

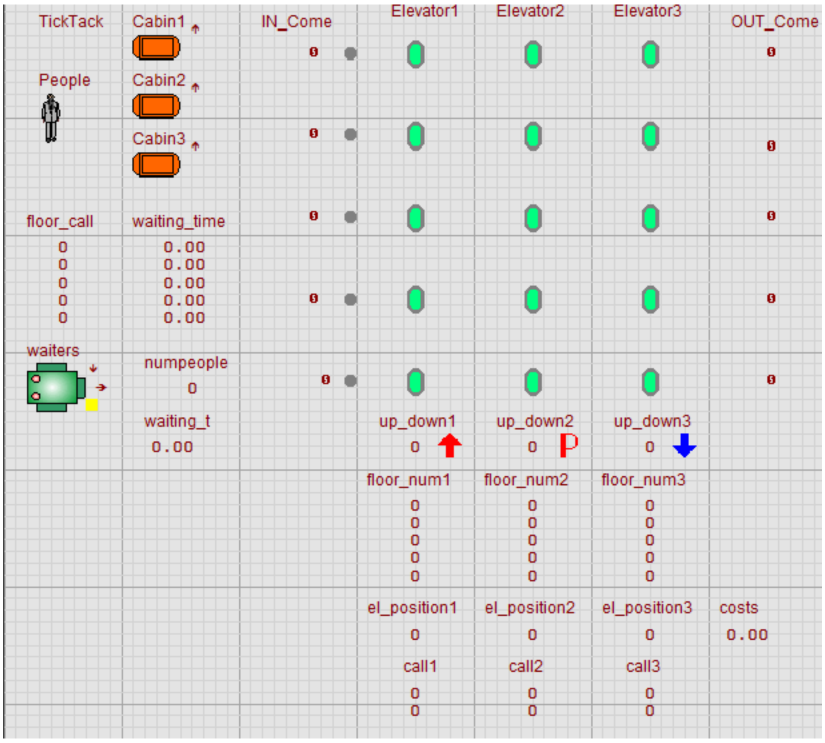


Fig. 3.5 – Multiple elevators model

3.5.1 Zone strategy

According to the strategy the cabins are parked on 1st, 3rd and 5th floors. These condition firstly occur at initialization of the model. Then thee system checks the state of each cabin and in the case it finished its task the cabin is sent to the parking place.

Each cabin ignores the requests out of its zone. It is implemented by conditions IF THEN.

The elevator can service the floors out of its zone if it stays on the certain floor at the moment.

The model can be easily upgraded by collective strategy for each cabin inside its zone.

3.5.2 Traction Point Strategy

Comparing to the previous strategy, the cabins can stay on the other floor after service. The system determines the nearest cabin to the requested floor and pushes it for service. If some elevator placed at the same distance from the requested floor, system pushes the elevator with the lowest index. Such approach solves the main disadvantage of the Traction Point strategy.

3.5.3 Auto parking Traction point Strategy

The strategy is based on traction point one. The algorithm search floors with the highest passenger flows and the system parks the cabins on these floors. The algorithm is presented below.

```
FOR f_c = 1 TO 5
IF temp1 < Totalarr(f_c)
 IF temp1 > 0
  temp2 = temp1
  Positions(2) = Positions(1)
 ENDIF
 temp1 = Totalarr(f_c)
 Positions(1) = f_c
ENDIF
IF temp2 < Totalarr(f_c) AND Positions(1) <> f_c AND Positions(3) <> f_c
 IF temp2 > 0
  temp3 = temp2
  Positions(3) = Positions(2)
 ENDIF
 temp2 = Totalarr(f_c)
 Positions(2) = f_c
ENDIF
IF temp3 < Totalarr(f_c) AND Positions(1) <> f_c AND Positions(2) <> f_c
 temp3 = Totalarr(f_c)
 Positions(3) = f_c
ENDIF
NEXT
```

The array Totalarr store the number of people called the elevator from the corresponding floors. That is why the algorithm looks for the indexes of the maximum numbers in the array. Indexes determine the number of floors.

The certain strategy can be used only for specific purposes and conditions. The possible problem can occur when passengers arrive to the certain floor and after some time call the elevator from another floor. The described problem can be solved by calculating the gradient of passengers arrives. Such control strategy is more flexible and fast adapted.

3.6 Variables

Single and multiple elevators models use basically the same variables. The description of some main variables can be found in the table 3.2.

Table 3.2 – Description of the main variables of the models

Floor_call	—	Array of the call requests.
Floor_num	—	Array of the destination floors.
Waiting_time	—	Array of average waiting time.
El_position	—	Position of the cabin.
Up_down	—	Indicator of direction.
PeopleinCabin	—	Number of people in the cabin.
Enum_people	—	Number of unloads.
TTime	—	Time of simulation.
K_arriving	—	Coefficient of the arrival interval.

4 Results

According to the formulas described in the 2nd chapter, the theoretical data about travel time and number of passengers can be serviced per one hour is written in below.

According to formula (2.3) the number of passenger can be serviced by one elevator per hour is 327.

The round trip of the cabin is about 64 seconds. Trip for one floor is taken about 37 seconds. These numbers are received by using equation (2.1).

Theoretical data will be compared with simulation results to make the conclusion about functionality of the models.

4.1 Single elevators

On the figures 4.1, 4.2 are presented characteristic of passenger loads and waiting time per hour for collective strategy control. The model was simulated for 8 hours with different arrival intervals – 40 seconds for the case a) and 30 seconds for b).

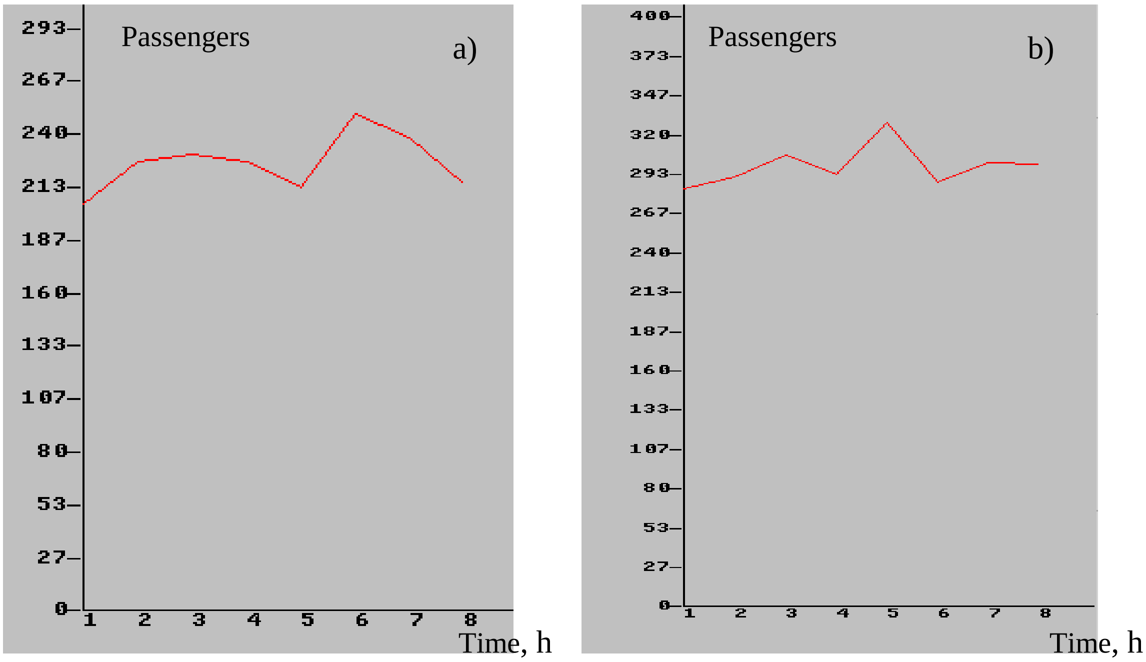


Fig 4.1 – Passenger load characteristic for collective control with passenger arrival interval a) – 40 sec; b) – 30 sec.

Characteristichs have polyline form. It is specified by the using of distribution function to describe the process of loading and unloading.

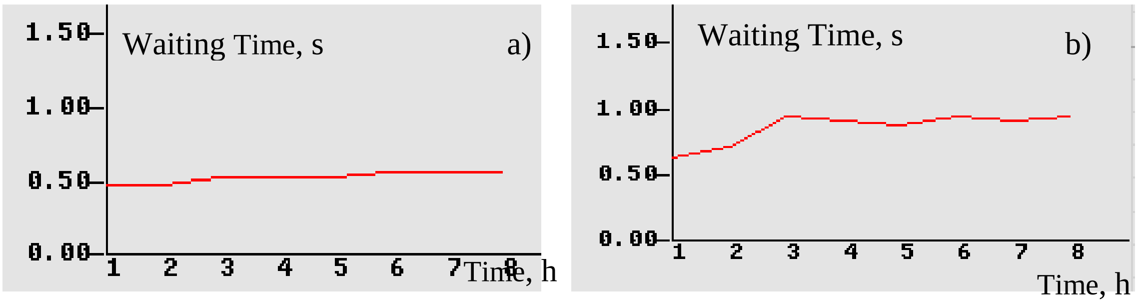


Fig 4.2 – Waiting time characteristic for collective control with passenger arrival interval a) – 40 sec, b) – 30 sec.

On the figures 4.3, 4.4 are presented characteristic of passenger loads and waiting time per hour for simple strategy control. The model was also simulated for 8 hours with different arrival intervals – 35 seconds for the case a) and 30 seconds for b).

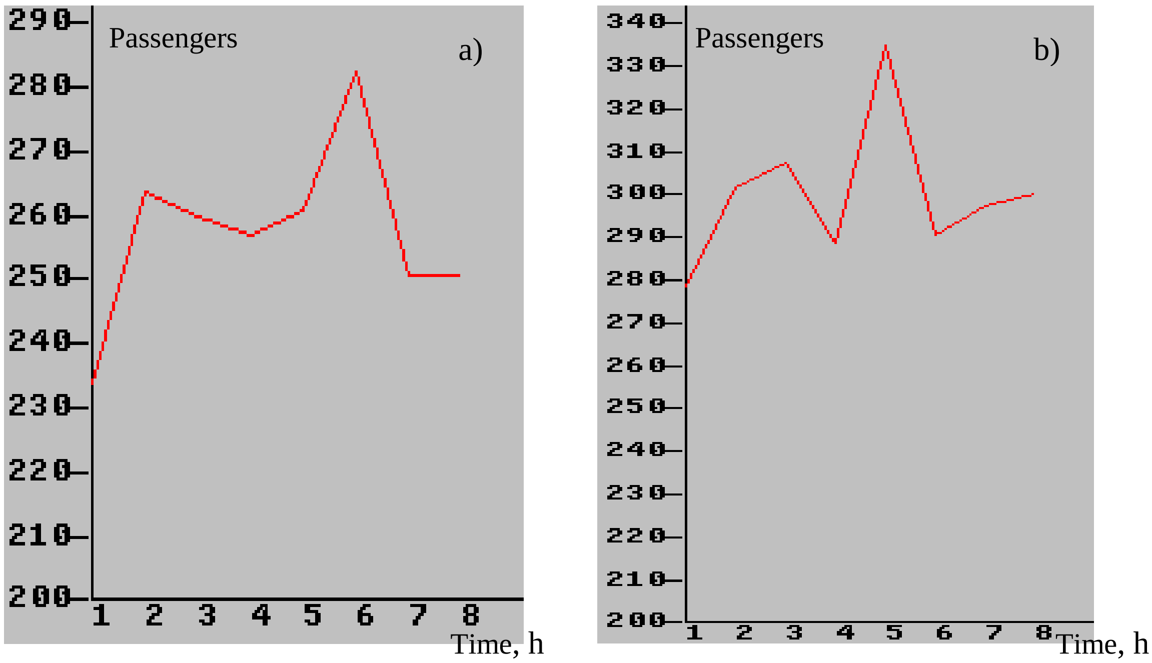


Fig 4.3 – Passenger load characteristic for simple control with passenger arrival interval a) – 40 sec; b) – 30 sec.

The reason of the occuring of polylines is the same like in the privious case.

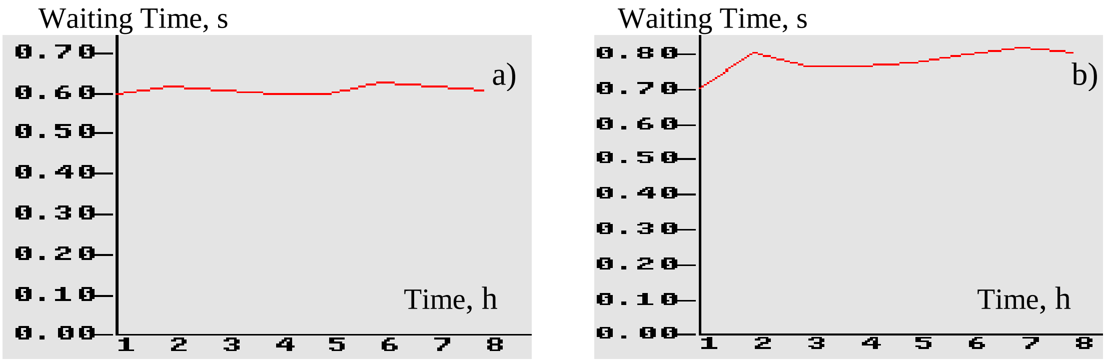


Fig 4.4 – Waiting time characteristic for simple control with passenger arrival interval a) – 40 sec; b) – 30 sec.

Comparing figures of Collective and Simple strategies can be seen that the results are quite similar. The probability that it happens because off events described by distribution functions is very low. That is why the logic of realized collective strategy should be analysed and optimized.

4.2 Multiple elevators

On the figures 4.5, 4.6 are presented characteristic of passenger loads and waiting time per hour for Traction point strategy control. The model was simulated for 6 hours with arrival interval – 10 seconds.

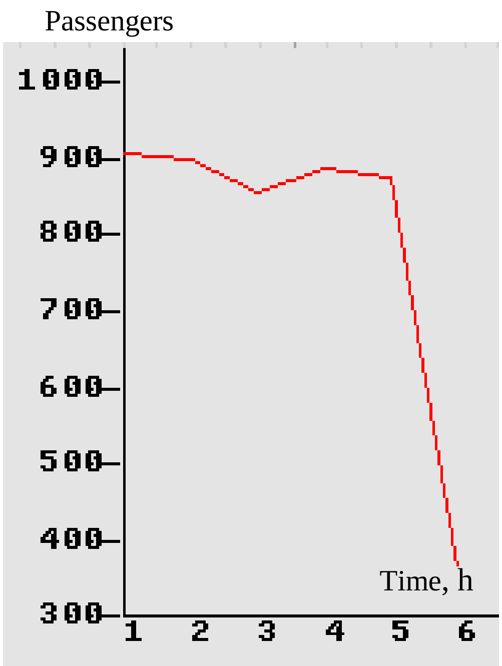


Fig 4.5 – Passenger load characteristic for traction point control

Waiting Time, s

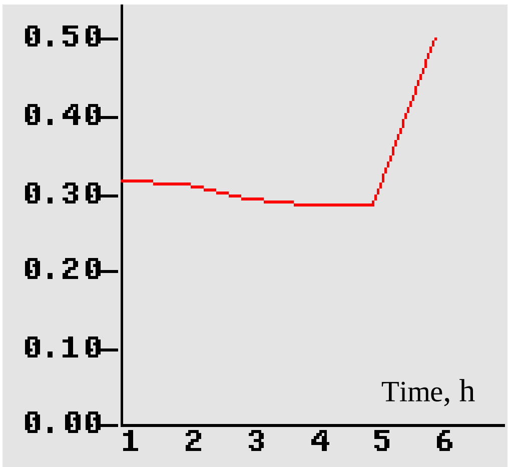


Fig 4.6 – Waiting time characteristic for traction point control

Looking the figures 4.5 and 4.6 can be seen that after 5 o'clock of simulation the number of delivered passengers decreased and the waiting time rising up. The situation happened because of limited size of buffer. At some moment the buffer was full and passenger could not be unloaded.

On the figures 4.6, 4.7 are presented characteristic of passenger loads and waiting time per hour for Zone control strategy. The model was simulated for 4 hours with arrival interval – 30 seconds.

Passengers

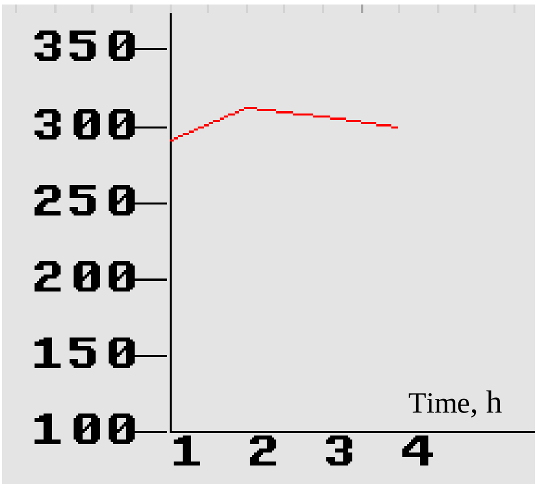


Fig 4.7 – Passenger load characteristic for traction point control

Waiting Time, s

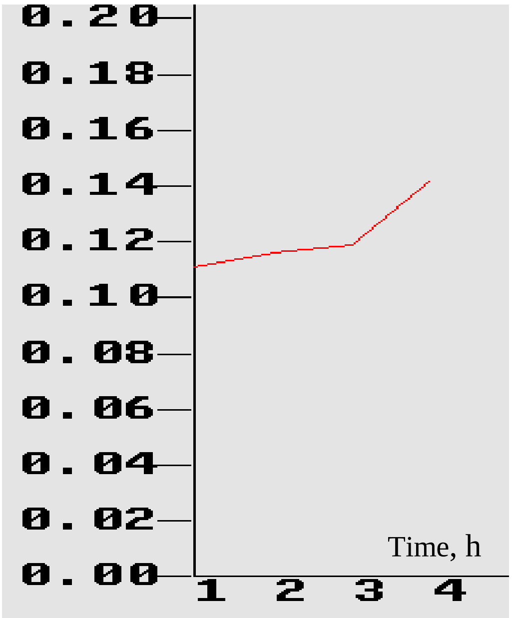


Fig 4.8 – Waiting time characteristic for traction point control

It should be noticed according to the certain results the strategy must have similar results to Traction point. But, at some moment of peak flows the 3rd elevator is loaded by the element which is not in buffer and not in cabin. Finally the system cannot control the cabin3.

On the figures 4.9, 4.10 are presented characteristic of passenger loads and waiting time per hour for Auto parking Traction point control strategy. The model was simulated for 4 hours with arrival interval – 30 seconds.

Passengers

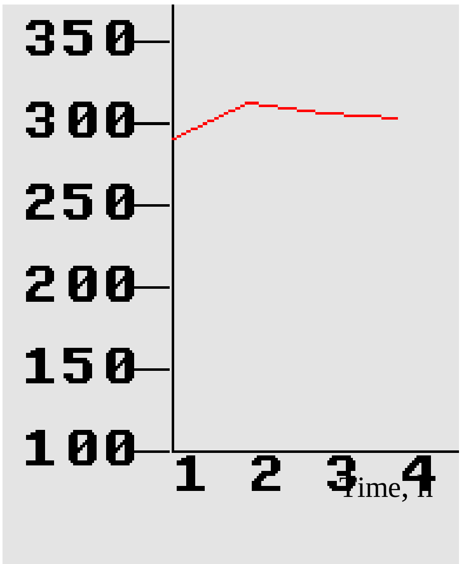


Fig 4.9 – Passenger load characteristic for traction point control

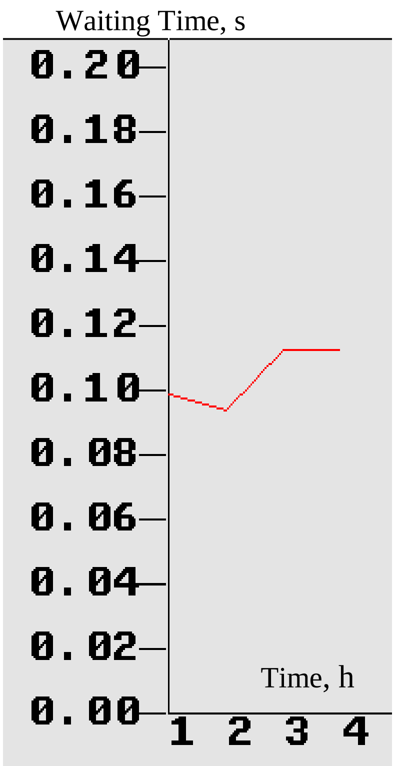


Fig 4.10 – Waiting time characteristic for traction point control

Results of simulation for certain strategy are quite good and similar to the previous cases of multiple elevators. But the bug which makes cabin3 uncontrolled also occurs. The reason can be some mistake in any conditions. Such problem occur only on peak of passing flows.

5 Conclusion

Analysing the work was done it should be said that models working well although some of them does not work perfect.

Comparing strategies for single elevator it is clear the results are very similar to theoretical that prove the good functionality of both models. And at the same time, changes in the Collective control strategy should be done to increase the efficiency.

The result of multiple elevators systems are also good. Each of strategy can service about 900 people per hour. The problem that was found in Zone and Auto parking Traction strategies is not solved at the moment and should be found out.

Summarizing up the results should be noted advantages and disadvantages of the models.

Advantages:

- simple for visual understanding;
- flexible to make any changes;
- allow to simulate processes with parameters equal to real;
- gives the result with high accuracy;
- does not need any calculation.

Disadvantages:

- complicated synchronization of the events;
- lack of literature for using Witness Lanner software.

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