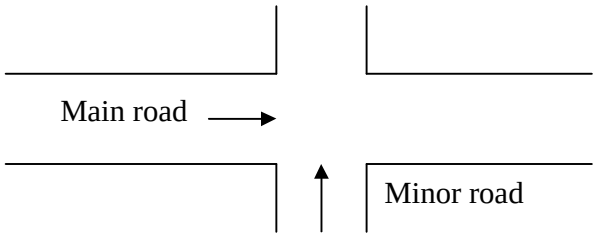
Introduction

In this assignment, we examine an unsignalized intersection (see below), in which the „Main road" has priority against the „Minor road".



Parts of the assignment

1. Based on the given parameters, calculate the average time headways and traffic volumes.
2. Determine the following parameters for all minor road vehicles: access time, waiting time, queue length. Calculate the average and deviation of waiting time and queuing.
3. Calculate the maximum number of minor road vehicles and the capacity utilization.

About the assignment – in general

One solution of the exercise – which is called *one block* – consists of the three parts described below. To complete the assignment, 3 blocks have to be solved during the class, successively. Thus all parts of the assignment have to be solved 3 times.
Very important: number of mistakes is limited in the assignment. If you exceed this limit, you have to restart the exercise from the beginning of the current block – with a new dataset. (When you start a new block, all mistakes are erased.) Limits are the followings:

1. In the first part, 9 mistakes are allowed.
2. In the second part, 15 mistakes are allowed.
3. In the third part, 5 mistakes are allowed.

In the mistake counter, you can see the total mistakes in the current block.

You can move between data fields with TAB button or by mouse.

Data input, mistakes
After typing result into a field, ENTER has to be hit for check. If the typed result is not correct, it will be deleted and the field will become orange. (Yellow colour means rounding error.) If the answer is accepted, the field will be green. (Blue fields have not been checked yet.)

Required accuracy of results
On the top right of the screen the software describes the needed accuracy of results. These are the followings:

1. In the first part *average time headways* of both roads have to be given with all decimals (without rounding), while *traffic volumes* – calculated from headways – have to be given rounded to 2 decimals.
2. In the second part, *access and waiting times* are obviously 1 decimal accurate (while *queues* are whole numbers). Thus, *average values* have maximum 2 decimals, all of these are needed.

   However, *deviations* have to be given rounded to 2 decimals!
3. In the third part, the *maximum number of minor road vehicles* is a whole number. *Capacity of minor road* has to be given rounded to 2 decimals; *capacity utilization* has to be calculated from this value and has to be given rounded to 2 decimals!

Both comma and point are accepted as decimal separator ("1,2" or "1.2").

Time limits for blocks

On the class, time for each exercise block is limited: 35 minutes are available for the first, 30 for the second and 25 for the third block.

Remaining time is displayed on the top of the screen. After time is up, timer turns to red colour (but this has no other effects – this is just a feedback for you).

Have a successful assignment!

Solution of the 1st part

$$Average\ time\ headway = \frac{Arrival\ \ time\ of\ last\ vehicle}{Number\ of\ vehicles}\ \ [s]$$

$$Traffic\ volume = \frac{3600\ s}{Average\ time\ headway}\ \ [Veh/h]$$

EXAMPLE

MAIN ROAD	
Arrival time [s]	Headway [s]
2,6	2,6
5,6	3
13,2	7,6
17,1	3,9
25,9	8,8
32	6,1
34	2
46,5	12,5
49	2,5
52,3	3,3
56,9	4,6
65,7	8,8
73,3	7,6
80,4	7,1
87,8	7,4
90,7	2,9

MINOR ROAD
Arrival time [s]
22,9
27,6
30,1
32,2
44,8

	Average time headway [s]	Traffic-volume [Veh/h]
MAIN ROAD	5.66875	635.06
MINOR ROAD	8.96	401.79

$$Average\ time\ headway\ (main\ road) = \frac{90,7}{16} = \mathbf{5.66875\ [s]}$$

$$Average\ time\ headway\ (minor\ road) = \frac{44,8}{5} = \mathbf{8.96\ [s]}$$

$$Traffic\ volume\ (main\ road) = \frac{3600}{5.66875} = 635.06064 \rightarrow \mathbf{635.06\ [Veh/h]}$$

$$Traffic\ volume\ (minor\ road) = \frac{3600}{8.96} = 401.78571 \rightarrow \mathbf{401.79\ [Veh/h]}$$

Solution of the 2nd part

The time required for passing through the intersection from the minor road depends on many objective factors (e.g. traffic control type, speeds, type of movement, visibility, geometry), and the drivers themselves. For examination and evaluation, standardised values are needed. The required time gap for a manoeuvre (at a specific intersection) can be determined as the statistical median of the accepted time gaps by different drivers. This value is usually between 4.5 and 7 seconds.

If a group of minor road vehicle can access continuously (without break), the second, third etc. vehicle will require shorter time gaps than the previous one (because they do not need to fully stop). If the first vehicle needs a *g* time gap, then the second needs only 0.82*g*, the third 0.71*g* and so on. But these shorter time gaps only occur when these vehicles access the intersection continuously in a group, without any interruption. If there is any time break (or a main road vehicle) between minor road vehicles, the later on will need the original time gap again.

Determining times and queue lengths:

- There are three conditions for a minor road vehicle (i) to access the intersection:
  - **1)** Obviously, *Access time ≥ Arrival time;*
  - **2)** *Previous* minor road vehicle *(i-1)* has already *egressed*;
  - **3)** Time *headway* in the *main road* is the same or higher than the required time gap.
    Time gap for vehicle *(i)* is shorter than the previous vehicle *(i-1)*, if *(i)* follows *(i-1)* immediately, i.e. access time of *(i)* = egress time of *(i-1)*; but only in this case – see below.

  Access time is the first moment when all conditions are met.
- After determining access time – although it is not needed by the software – it is advised to calculate *egress time*, which is the sum of access time and the (actual) required time gap. (This is useful to check condition 2 for the next vehicle.)
- *Waiting time* is the difference of access and arrival times.
- Minor road vehicles are queuing if they cannot access immediately (if they can, queue is 0). For *queue length*, arrival time has to be regarded (how many vehicles are in the queue right after the actual one has arrived).
- *Deviation* (sample standard deviation) $s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$
  (“STDEV.S” or “SZÓRÁSA” in Excel)

EXAMPLE

MAIN ROAD	
Arrival time [s]	Headway [s]
2,6	2,6
5,6	3
13,2	7,6
17,1	3,9
25,9	8,8
32	6,1
34	2
46,5	12,5
49	2,5
52,3	3,3
56,9	4,6
65,7	8,8
73,3	7,6
80,4	7,1
87,8	7,4
90,7	2,9

MINOR ROAD
Arrival time [s]
22,9
27,6
30,1
32,2
44,8

MINOR ROAD		
Access time [s]	Waiting time [s]	Queuing
25.9	3	1
34	6.4	1
38.5	8.4	2
42.2	10	3
52.3	7.5	1

Req. time gap values [s]	4,5	3,7	3,2	2,8	2,6	2,5

Average waiting time [s]	7.06	Deviation	2.62

Average queue length	1.6	Deviation	0.89

- First minor road vehicle arrives at 22.9 s.
  Required time gap is 4.5 s (it is the first one).
  As it is the first one, condition 2 is met. On the main road there is a long time interval (8.8 s) around the arrival time, but it started at 17.1 s and at the arrival time, there is only 3 s left until the next main road vehicle (25.9 s), so condition 3 is not met yet.
  In this case the next time headway has to be found which is long enough. After the main road vehicle has passed at 25.9 s, the interval is suitable (6.1 s), so the first vehicle can access.

  Access time of vehicle 1 is **25.9 s**, egress time is 30.4 s.
  Waiting time is 25.9 – 22.9 = **3 s**, queue length is **1**.

- Second minor road vehicle arrives at 27.6 s.
  The first possible time for its access would be 30.4 s (according to condition 2). If it could access immediately, its required time gap would be 3.7 s (as the 2nd member of a group), but in this case it would only egress at 34.1, which is not acceptable, as the next main road vehicle arrives at 32 s. Thus, a new time headway has to be found again between main road vehicles, and required time gap will be the normal 4.5 s (no grouping). This will occur at 34 s.

  Access time of vehicle 2 is **34 s**, egress time is 38.5 s.
  Waiting time is 34 – 27.6 = **6.4 s**, queue length is **1** (as vehicle 1 has already accessed the intersection by 27.6).

- Third minor road vehicle arrives at 30.1 s.
  The first possible time for its access is at 38.5 s (after vehicle 2). If it could access immediately, required time gap would be 3.7 s (grouping), so it would egress at 42.2 s. As no main road vehicles arrive until this time (next one only appears at 46.5 s), this case is acceptable.

  Access time of vehicle 3 is **38.5 s**, egress time is 42.2 s, waiting time is **8.4 s**. Queue length is **2**, because 30.1 s vehicle 2 is still waiting to access in the queue.

- Fourth minor road vehicle arrives at 32.2 s.
  If it could access right after vehicle 3 at 42.2 s, it would require a 3.2 s gap (3rd in the group). This would mean 45.4 s egress, which is still acceptable.

  Access time of vehicle 4 is **42.2 s**, egress time is 45.4 s, waiting time is **10 s**. Queue length is **3**, because at its arrival, vehicle 2 and 3 are still queuing.

- Fifth minor road vehicle arrives at 44.8 s.
  As the next main road vehicle is very close (46.5 s), it cannot join to the group of vehicles 2, 3 and 4, so its required time gap will be again the normal value, 4.5 s. The next suitable time gap on the main road will start at 52.3 s (and lasts 4.6 s).

  Access time of vehicle 5 is **52.3 s** (egress time is 56.8 s), waiting time is **7.5 s**, queue is **1** again (previous vehicles have already accessed when it arrives).

Average and deviation of waiting time:

$$\frac{3 + 6.4 + 8.4 + 10 + 7.5}{5} = \mathbf{7.06\ [s]}$$

$$\sqrt{\frac{(3-7.06)^2+(6.4-7.06)^2+(8.4-7.06)^2+(10-7.06)^2+(7.5-7.06)^2}{5-1}} = 2.62449995 \rightarrow \mathbf{2.62\ [s]}$$

Average and deviation of queue length:

$$\frac{1 + 1 + 2 + 3 + 1}{5} = \mathbf{1.6}$$

$$\sqrt{\frac{3\cdot(1-1.6)^2 + (2-1.6)^2 + (3-1.6)^2}{5-1}} = 0.8944272 \rightarrow \mathbf{0.89}$$

Solution of the 3rd part

Capacity of minor road has to be examined until the egress time of the last minor road vehicle.

$$Capacity\ of\ minor\ road = 3600 \cdot \frac{Possible\ no.\ of\ minor\ road\ vehicles}{Egress\ time\ of\ last\ minor\ road\ vehicle}\ \text{[Veh/h]}$$

$$Capacity\ utilization = \frac{Traffic\ volume}{Capacity}\ [\cdot 100\%]$$

(As our sample is quite low, Capacity utilization has to be regarded with reservation.)

EXAMPLE

MAIN ROAD	
Arrival time [s]	Headway [s]
2,6	2,6
5,6	3
13,2	7,6
17,1	3,9
25,9	8,8
32	6,1
34	2
46,5	12,5
49	2,5
52,3	3,3
56,9	4,6
65,7	8,8
73,3	7,6
80,4	7,1
87,8	7,4
90,7	2,9

MINOR ROAD
Arrival time [s]
22,9
27,6
30,1
32,2
44,8

MINOR ROAD	
Egress time moment of last vehicle [s]	Traffic volume [Veh/h]
55,8	401,79

Aggregate time gap [s] req. for the given no. of veh. crossing together							
1	2	3	4	5	6	7	8
4,5	8,2	11,4	14,2	16,8	19,3	21,8	24,3

Possible number of minor road vehicles [Veh]	8
Capacity of minor road [Veh/h]	507.04
Capacity utilization [%]	79.24

Possible number of minor road vehicles:

For the capacity calculation, the possible number of minor road vehicles has to be determined, i.e. regarding actual main road traffic, how many vehicles could have passed through if they arrived continuously.

Firstly, the time interval between the last minor road vehicle egress time and the previous main road vehicle should be checked. This is 56.8 – 52.3 = 4.5 s, which is enough for only one vehicle.

For next, time headways of the main road should be regarded, from this time back to 0. The values which are higher than the required time gap for a single vehicle (4.5 s); from the bottom to the top: 12.5, 6.1, 8.8, 7.6 s.
(Values under 52.3 s are not regarded, because we have already checked the last interval).

Comparing these times to the aggregated required time gaps, possible number of accessing vehicles can be determined:

12.5 → 3
6.1 → 1
8.8 → 2
7.6 → 1.

Thus, the maximum possible number of minor road vehicles (from the bottom to the top):
$1 + 3 + 1 + 2 + 1 =$ **8 [Veh]**
(First one is for the last interval, between 52.3 and 56.8 s.)

$$Capacity\ of\ minor\ road = \frac{3600 \cdot 8}{56.8} = 507.0422535 \rightarrow \mathbf{507.04\ [Veh/h]}$$

$$Capacity\ utilization = \frac{401.79}{507.04} = 0.7924227 \rightarrow \mathbf{79.24\%}$$