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TRAFFIC ENGINEERING AND MANAGEMENT

PROJECT 2 : TRAFFIC SIGNAL DESIGN

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Introduction

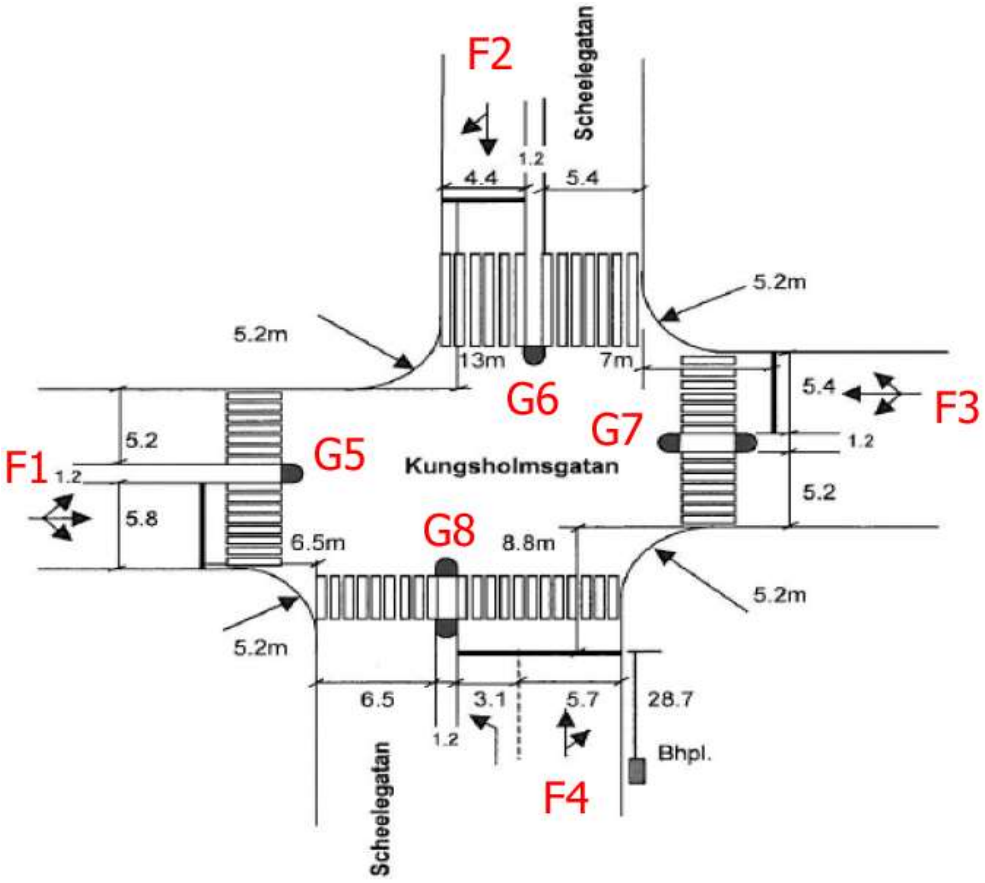
Objective and methodology

In this project, we aim to have an overall understanding of the impact of traffic signals in delays at an intersection, to evaluate different strategies to design and operate traffic signals and to understand the effects of each strategy on traffic performance.

We have done 3 kinds of method to the signal design: Manual calculation, TRANSYT and microscopic simulation using VISSIM in this project.

Study area

The study area is in Kungsholmen, located in the core of Stockholm City. Kungsholmen is an island in Lake Mälaren in Sweden, part of Stockholm City. The geometric design is as figure 1. And we use F1-4 to give notations for traffic flows and G5-8 to give notations for pedestrians.



Graph 1 : Configuration of the studied intersection

Part A : Manual Calculations

- Two green seconds per vehicle and lane
- Lost time of approximately 5 seconds per stage change in a small intersection
- Green split proportional to traffic flows
- Cycle time not exceeding 100 seconds in a city central

Q1. Is it there enough capacity with the number of lanes in the sketch above?

Assume that the cycle time is 100sec, an hour has $\frac{3600}{100} = 36\,{}^{c}/_{h}$.

There are two stages, so :

- the lost time=10 sec/c
- the total lost time=360s/h
- effective time=3600-360=3240s/h

For F2, there are 330veh/lane, which needs 660sec/h green time.

For F3 there are 444veh/lane, which needs 888sec/h green time.

For F4, there are 53veh/lane turn left, and 487veh/lane turn right and straight, which needs 974sec/h green time (the longest one).

For F1, there are 166veh/lane, which needs 332sec/h green time.

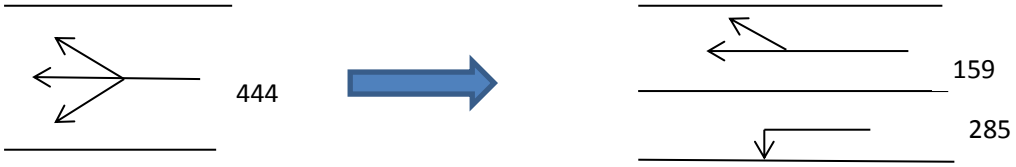
Here we choose the longer ones (F4, F3). The total green time we need is 974+888=1862sec, which is smaller than 3240sec, so the capacity is enough.

Q2. Is there enough capacity to increase the traffic to twice the observed flows?

If the traffic is increased to twice, the green time we need would be: $1860 \times 2 > 3240$, which means that the capacity would be not enough.

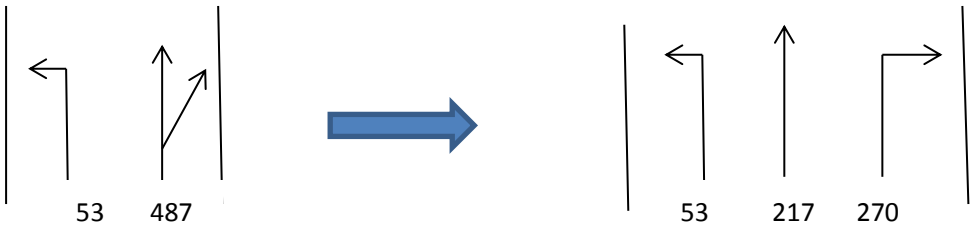
Q3. If not; where is extra lanes needed to accommodate doubled flows?

There are two ways to improve, one is to add a left turn lane for F3, in which way we can separate the left-turn flow, which is almost twice as much as the straight and right-turn.



In this way, the green time would be $487 \times 4 + 285 \times 4 = 3088\text{sec} < 3240\text{sec}$, which satisfies the requirement.

The other way is to add a right-turn lane for F4.



This way, the green time would be $330 \times 4 + 444 \times 4 = 3096\text{sec} < 3240\text{sec}$, which also satisfies the requirement.

However, considering that F4 already has 2 lanes, it would be better to separate F3, which just has one lane now.

So we choose the first solution.

Q4. Calculate the minimum green period for all pedestrian crossings in the intersection Scheelegatan – Kungsholmsgatan.

The minimum green period for pedestrians "pedestrian green" (Gg) is calculated as:

$$G_g = L/Vfg$$

Where:

L = length of the pedestrian crossing

Vfg = pedestrian walking speed = 1.2 m/s

$$G_6 = \frac{11.2}{1.2} = 9.16s, \qquad G_7 = \frac{11.8}{1.2} = 9.8s$$

$$G_8 = \frac{16.5}{1.2} = 13.75s, \qquad G_5 = \frac{12.2}{1.2} = 10.17s$$

Q5. Calculate red periods with respect to approaching and clearing pedestrians in the intersection Scheelegatan – Kungsholmsgatan. Choose the ones you think gives the longest red times, but at least one per stage.

The inter-green period is the time from the end of green signal in one signal group until a conflicting signal group is allowed to show green indication. It is due to safety reasons.
The inter-green time should be long enough to allow an existing road user to leave the conflict area before an approaching road user from a conflicting movement reaches it. In some cases, the inter-green time is also referred to as "lost time" since no approach has green during that period.

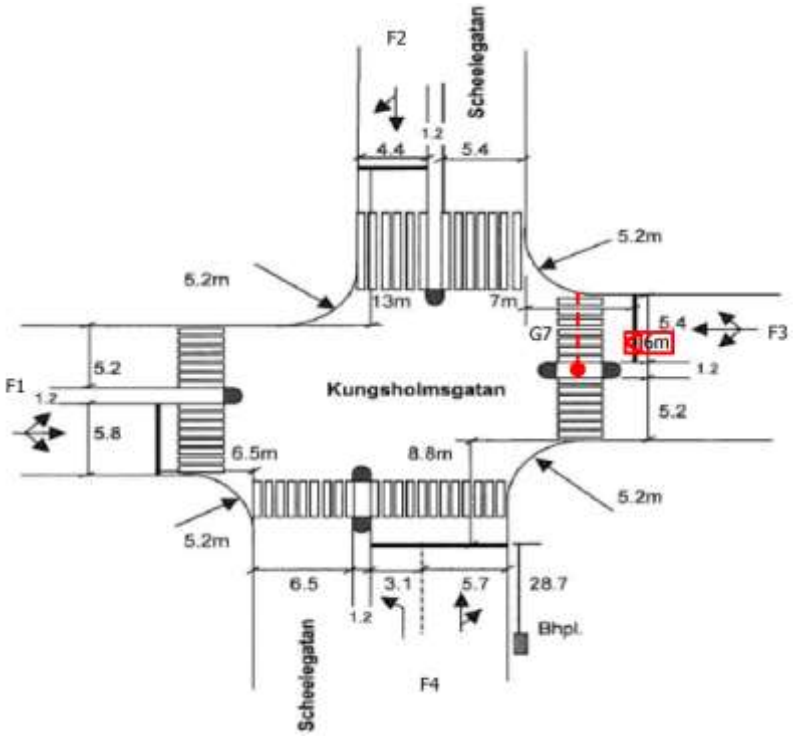
In Sweden, and many other countries, safety time is used instead. The safety time is defined as the time starting when one signal groups becomes red till a conflicting signal group is allowed to show green indication due to safety reasons. I.e. safety time does not include the amber period. Traditionally signal controllers do not work with safety time but with red period, not including the red-amber time, which is set in the controller. The red periods are calculated with 0.1 s accuracy and between all signal groups, conflicts with red periods < 0 is set to 0.1 since negative red periods is not allowed. The red periods are put in a conflict matrix of the red periods and included in the documentation of the traffic signal.
The red periods are calculated as:

$$\mathrm{R} = \frac{S_u}{V_u} - \frac{S_f}{V_f} - \mathrm{RG} - (\mathrm{G} - \mathrm{T})$$

Where:
R = Red period [s]
S_u= clearance length [m] including dimensioning vehicle (car = 6 m, bus = 15 m)
V_u = clearing vehicle speed [m/s]
S_f = approaching length [m]
V_f = approaching vehicle speed [m/s]
RG = Red-amber period [s] (1,5 seconds in Sweden)
G= Amber period [s] (4 s at 50 km/h, 5 s at 70 km/h and 3 s for bicycles in Sweden)
T= Passage time after change to amber [s] (equal to amber time but for bicycles, and the last term (G - T) can be ignored in our the red time calculations)

For vehicles we can use:
V_u = 10 m/s (36 km/h) V_f= 14 m/s (50 km/h)

In order to obtain the longest red times, we considered two different approaches.
In the first case, the pedestrian is already engaged in the crossing, and has to be able to exit it before the vehicle crosses it. The longest red times are therefore obtained when the pedestrian crossing is near the stop line for vehicles. This problem is schematized in the drawing below.



Graph 2 : Calculating the red period when G6 is exiting the intersection and F2 is entering it ($R_{G6\text{-}F2}$)

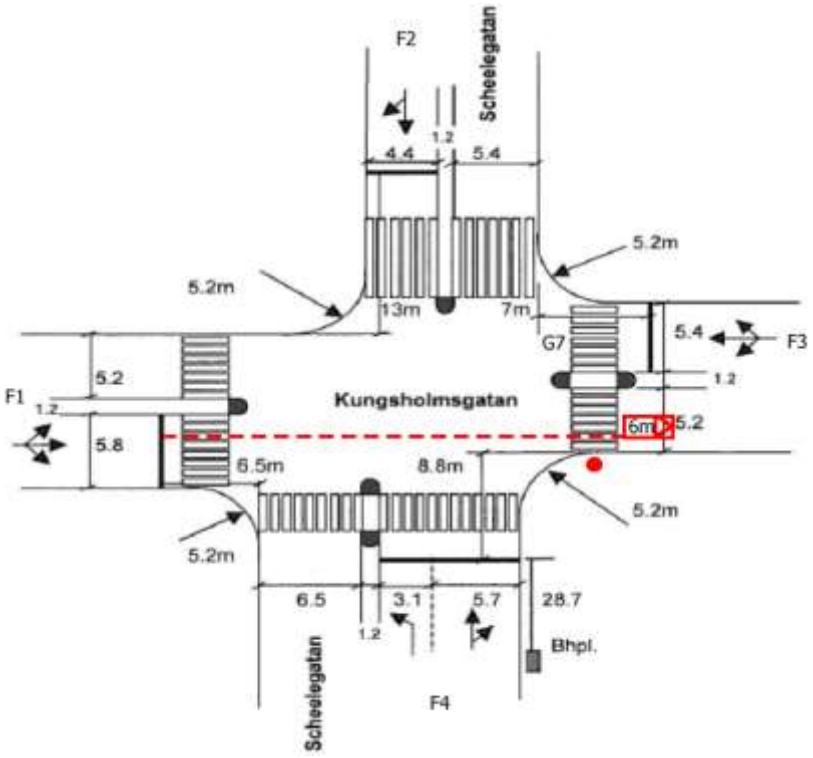
$$R_{G_7-F_3} = \frac{5.4}{1.4} - \frac{1}{14} - 1.5 = 2.29\text{s}$$

$$R_{G_5-F_1} = \frac{5.8}{1.4} - \frac{1}{14} - 1.5 = 2.57\text{s}$$

$$R_{G_8-4} = \frac{8.8}{1.4} - \frac{1}{14} - 1.5 = 4.71\text{s}$$

$$R_{G_6-F_2} = \frac{4.4 + 1.2 + 5.4}{1.4} - \frac{1}{14} - 1.5 = 6.29\text{s}$$

In the second case, the vehicle is already engaged in the intersection, and has to be able to exit it before the pedestrians start crossing. This is why the longest red times will appear when the pedestrian crossing is the furthest from the stop line for the vehicles. The drawing below illustrates this aspect.



Graph 3 : Calculating the red period when F4 is exiting the intersection and G6 is entering it ($R_{F4\text{-}G6}$)

$$R_{F_1-G_7} = \frac{6.5 + 6.5 + 1.2 + 3.1 + 5.7 + 7 - 1 + 6}{10} - 0 - 0 = 3.5\text{s}$$

$$R_{F_3-G_1} = \frac{6.5 + 6.5 + 4.4 + 1.2 + 5.4 + 7 - 1 + 6}{10} - 0 - 0 = 3.6\text{s}$$

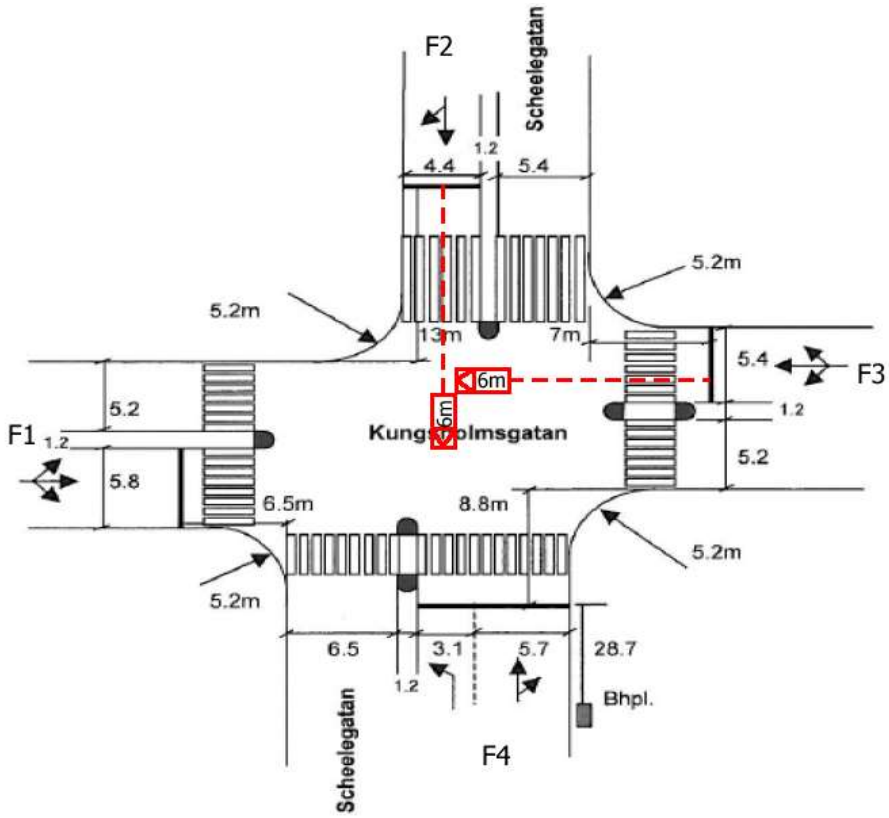
$$R_{F_2-G_8} = \frac{13 + 5.2 + 1.2 + 5.8 + 8.8 - 1 + 6}{10} - 0 - 0 = 3.9\text{s}$$

$$R_{F_4-G_6} = \frac{8.8 + 5.2 + 1.2 + 5.4 + 13 - 1 + 6}{1.4} - 0 - 0 = 3.86\text{s}$$

Q6. Calculate the red periods with respect to vehicle movements you think will have the longest red times. Calculate at least four and one per stage.

In this calculation, we regard the conflict site as in the middle of the lane. The longest red times are logically found when the exiting vehicle has a lot of distance to travel, whereas the entering vehicle has a small distance until the conflict point. Therefore, $R_{F1\text{-}F4}$ should be the longest one (F1 exiting and F4 entering).

The graph below illustrates how we calculated these time periods.



Graph 4 : Calculating the red period when F1 is exiting the intersection and F2 is entering it ($R_{F1\text{-}F2}$)

$$R_{F_2-F_3} = \frac{13 + \frac{5.2}{2} + 6}{10} - \frac{7 + 5.4 + 1.2 + \frac{4.4}{2}}{14} - 1.5 = -0.46\text{s}$$

$$R_{F_3-F_2} = \frac{7 + 5.4 + 1.2 + \frac{4.4}{2} + 6}{10} - \frac{13 + \frac{5.4}{2}}{14} - 1.5 = -0.44\text{s}$$

$$R_{F_1-F_4} = \frac{6.5 + 6.5 + 1.2 + 3.1 + \frac{5.7}{2} + 6}{10} - \frac{8.8 + \frac{5.8}{2}}{14} - 1.5 = 0.279\text{s}$$

$$R_{F_4-F_1} = \frac{8.8 + \frac{5.8}{2} + 6}{10} - \frac{6.5 + 6.5 + 1.2 + 3.1 + \frac{5.7}{2}}{14} - 1.5 = -0.75\text{s}$$

$$R_{F_3-F_4} = \frac{7 + \frac{5.4}{2} + 6}{10} - \frac{8.8 + 5.2 + 1.2 + \frac{5.4}{2}}{14} - 1.5 = -1.21\text{s}$$

$$R_{F_4-F_3} = \frac{8.8 + 5.2 + 1.2 + 5.4 + 6}{10} - \frac{7 + \frac{5.4}{2}}{14} - 1.5 = 0.19\text{s}$$

$R_{u\text{-}f}$	f								
u		F1	F2	F3	F4	G5	G6	G7	G8
	F1		—	—	0.28	—	—	3.5	—
	F2	—		0.1	—	—	—	—	3.9
	F3	—	0.1		1.21	3.6	—	—	—
	F4	0.1	—	0.19		—	3.86	—	—
	G5	2.57	—	—	—		—	—	—
	G6	—	6.29	—	—	—		—	—
	G7	—	—	2.29	—	—	—		
	G8	—	—	—	4.71	—	—	—	

Q7. Calculate the optimal cycle time.

- *Saturation flows*

Saturation flows are very important for traffic signals. They depend on geometry, traffic conditions etc. and are different at every location. Saturation flows for streams with secondary conflicts, eg. left turning or turning vehicles in conflict with pedestrians, also depend on the conflicting stream and can therefore only be calculated through an iterative process. Saturation flows are sometimes collected from the field, but normally are empirical values used or calculated from a base value with corrections.
In this case we use the following empirical saturation flows per lane recommended for the Swedish (Stockholm) urban environment:

Empirical saturation flows per lane recommended for the Stockholm urban environment	
Through movement	1800 v/h
Right turn without secondary conflict	1500 v/h
Right turn with pedestrians	1350 v/h
Combined straight & right turn with pedestrians	1600 v/h
Combined straight & left turn with opposing traffic	1500 v/h for both traffic
Flows together, i.e. saturation flow for left turning	(1500 – opposing traffic) v/h
Straight & left turn with pedestrians and opposing traffic	1350 v/h for both traffic
Flows together, i.e. saturation flow for left turning	(1350 – opposing traffic) v/h

No.	F2	F3	F4		F1
Illustration					
Saturation flow(v/h)	1600	1350	1067	1600	1350

- *Optimal Cycle Time*

The optimal cycle time that gives the least average delay can be calculated according to Webster's formula discussed in class:

$$c = \frac{1.5 * L + 5}{1 - \sum \frac{q_i}{s_i}}$$

Where:
C Optimal cycle time
L Lost time per cycle, here we choose 6 seconds per stage.
q/s Highest value of each stage
q Traffic flow
s Saturation flow

	Illustration	q	s	q/s	Max(q/s)
Stage 1		330	1600	0.20625	0.30438
		53	1067	0.04967	
		487	1600	0.30438	
Stage 2		166	1350	0.12296	0.32889
		444	1350	0.32889	

The optimal cycle time is calculated,

$$c = \frac{1.5 * L + 5}{1 - \sum \frac{q_i}{s_i}} = \frac{1.5 * 6 * 2 + 5}{1 - (0.30438 + 0.32889)} = 62.72s$$

Notice : We didn't take the same saturation flows for F3 and F1 as the one presented in class afterwards. Indeed, it was written: "1350 for both directions", so we thought that this would mean 1350 for the lane with both directions. Consequently, we don't have the same values for the optimal cycle time and green splits.

Q8. Calculate the optimal green splits for the intersection Scheelegatan – Kungsholmsgatan.

The optimal green split for a fixed-time signal, is proportionally to the highest (critical) ratio of flow to saturation flow for each stage.

$$g_i = (c - l) * \frac{\frac{q_i}{s_i}}{\sum \frac{q_i}{s_i}}$$

Where:
g =effective green time
q = traffic flow
s = saturation flow
c = cycle time
L = lost time per cycle, here we choose 6 seconds per stage.

Stage	Max(q/s)	$\sum \frac{q_i}{s_i}$	g_i(sec)
Stage 1	0.30438	0.63327	24. 38
Stage 2	0.32889		26. 34

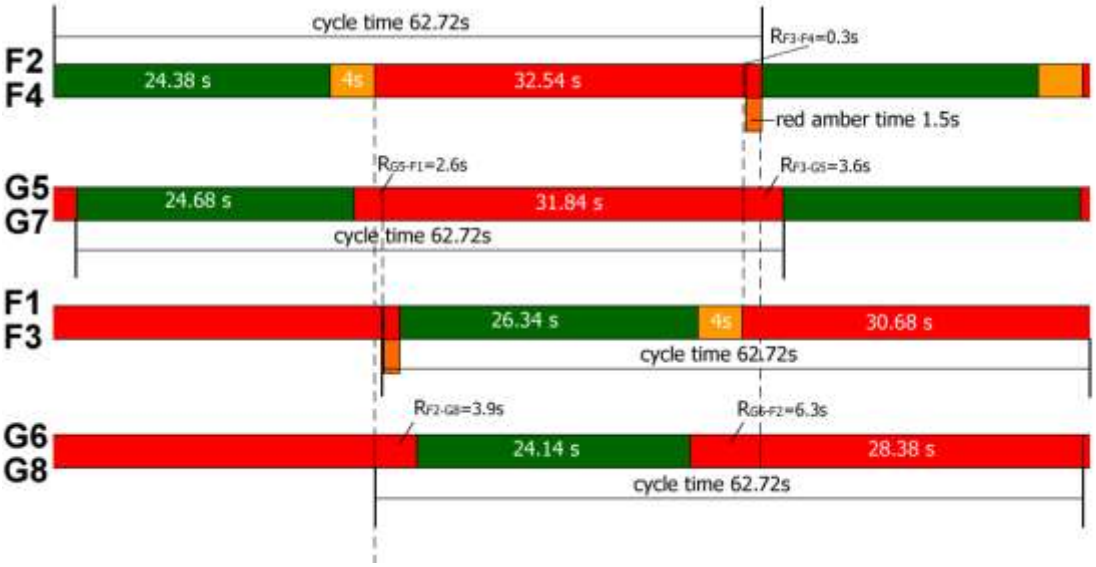
Q9. Suggest detailed signal timings for the intersection Scheelegatan – Kungsholmsgatan taking the minimum green periods, red periods and the optimal cycle time and green split calculations above into account.

The important aspects that we should absolutely take into account when creating a signal diagram of the intersection are:

- The optimal cycle time (c_{opt}= 62.72s)
- The minimum green periods for pedestrians so that they have enough time to cross
- The effective green times calculated for each stage
- And the red periods in order to let the vehicles or the pedestrians exit the intersection before the others enter it.

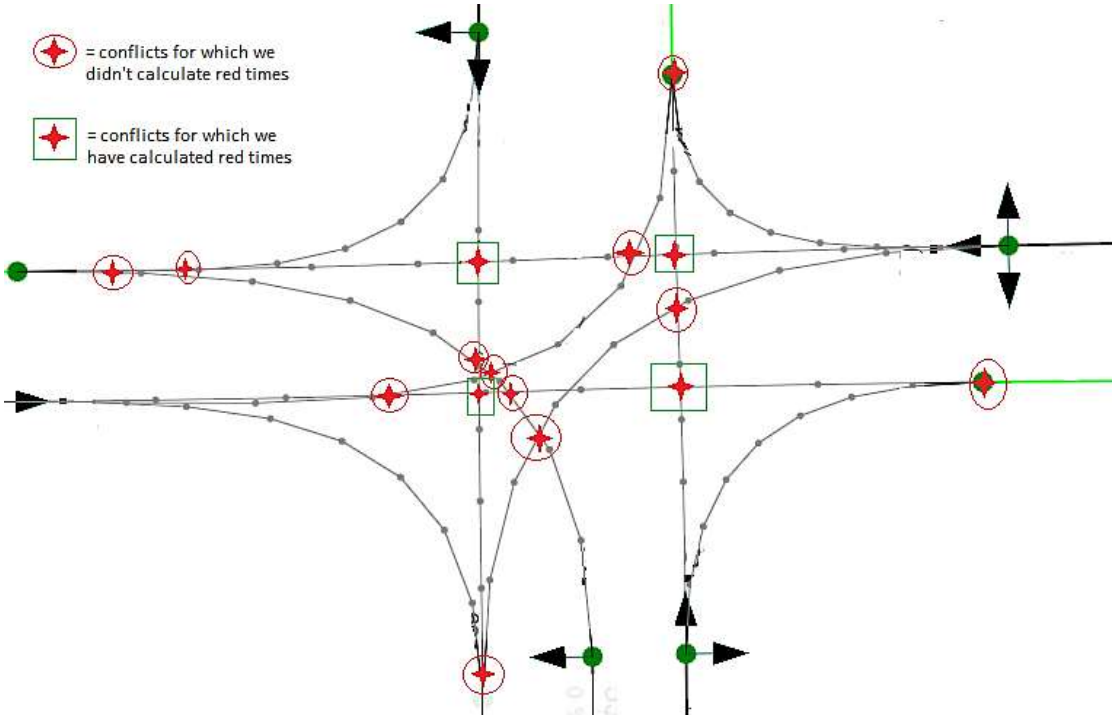
We considered that the red amber time was always approximately 1.5 seconds, and that the amber time was 4 seconds.
For each stage, we made sure that we had respected the necessary red periods in order to ensure safety. We always took the longest red periods that we could consider.
For example for the pedestrians G6 and G7, the green doesn't start directly after that F2and F3 switch to red. Indeed, the cars have first to exit the intersection. The longest red period that we have to consider is $R_{F2\text{-}G8}$ ($R_{F2\text{-}G6}$, $R_{F3\text{-}G8}$ and $R_{F3\text{-}G6}$ are lower). Therefore, we inserted a red period of 3.9 s before the pedestrians can start crossing, this for safety reasons. The same method has been used before F2 and F4 switch to red: a red period of 6.3 s has been implemented in order to let enough time for the pedestrians of G6 to cross.

Q10. Draw a signal diagram of the proposed plan.



Another possibility could have been to separate the pedestrian signals of G6 and G8, and G7 and G1. Indeed, the crossings don't need the same red time periods. For example, we can see that the red periods taken into account for G7 and G5 are only due to G5. This means that G7 could have shorter red time periods, and consequently more effective green time. But we didn't do it because we didn't find it necessary. Indeed, the green times considered are already far long enough to able the pedestrians to cross calmly. The minimum green periods for pedestrians lay between 9.17s and 16.5s, whereas the minimum green time implemented by ourselves is 24.14s.

Q11. Make a conflict matrix showing the calculated red times, mark any existing conflicts for which you not have calculated the red times.



In the conflict matrix quoted in Q4, we calculated the primary conflicts, regulated in the signal. These conflicts are at the right angle 90 degree, cars interacting with each other vertically. And often result in higher speeds and more severe damage. Such conflicts can be avoided by adjusting the minimum intergreen time between the end of one conflicting signal group and the start of another for safety reasons. Cars from a primary conflict won't run across the intersection from vertical directions at the same time. Here take F_2 and F_3 straight driving vehicles for example. If the vehicle from F2 already is in the intersection, F_3 should be allowed to enter the intersection no earlier than exactly the time F_2 has just passed the collision point.

The conflicts we didn't calculate in the matrix are secondary conflicts, presented in the figure above. Secondary conflicts mainly involve the interact collisions in merging and demerging process, inevitable under the signal control. Vehicle or pedestrians obliquely cross the intersection at the same time even under the control of signals and therefore stand in the ways for each other. As a result, vehicles or pedestrians from one direction should give way to the other direction and there will be delays in this direction. Here, F_1 straight and F_4 right turn is a typical merging secondary conflict while F_1 right turn , F_2 straight and F_3left turn consist a typical demerging secondary conflict. Another special conflict to point out here is the opposing left turn; say F_1 left turn conflicts with F_3 straight. Collision of this kind may occur in respect to situations that F_1 left turn drivers is still running under a red light when F_3 straight starts to run its green light.

Q12. Compare the manual calculation and the documentation.

At first, there is some difference between the cycle time we calculated and the documentation for the reason that we considered different saturation flows. As the same, we have different green times (which have been calculated thanks to the obtained cycle time). This is why the documentation handed out looks from the beginning totally different.
For the red period matrix, some of the values do not correspond; maybe we considered different segment length to calculate the red period (the map of the intersection didn't always give all length details, so we sometimes had to use average values).
As for the signal timings, we didn't separate each flow as in the documentation. What we considered was the simplified situation based on the fact that the signal timing is the same between F2 and F4, F3 and F1, G6 and G8, G7 and G1. But the method followed was exactly the same : we tried to implement as much green time as we could for cars and pedestrians, verifying that pedestrians had enough time to cross (above the minimum green time), but that the safety red periods were still present. As we considered exactly the same signals for G7 and G1 for example, we took into account the highest value of red period for safety reasons.
Finally, we didn't take into account the bus signal timing; this is what we need to improve.

Part B TRANSYT 14 Calculations

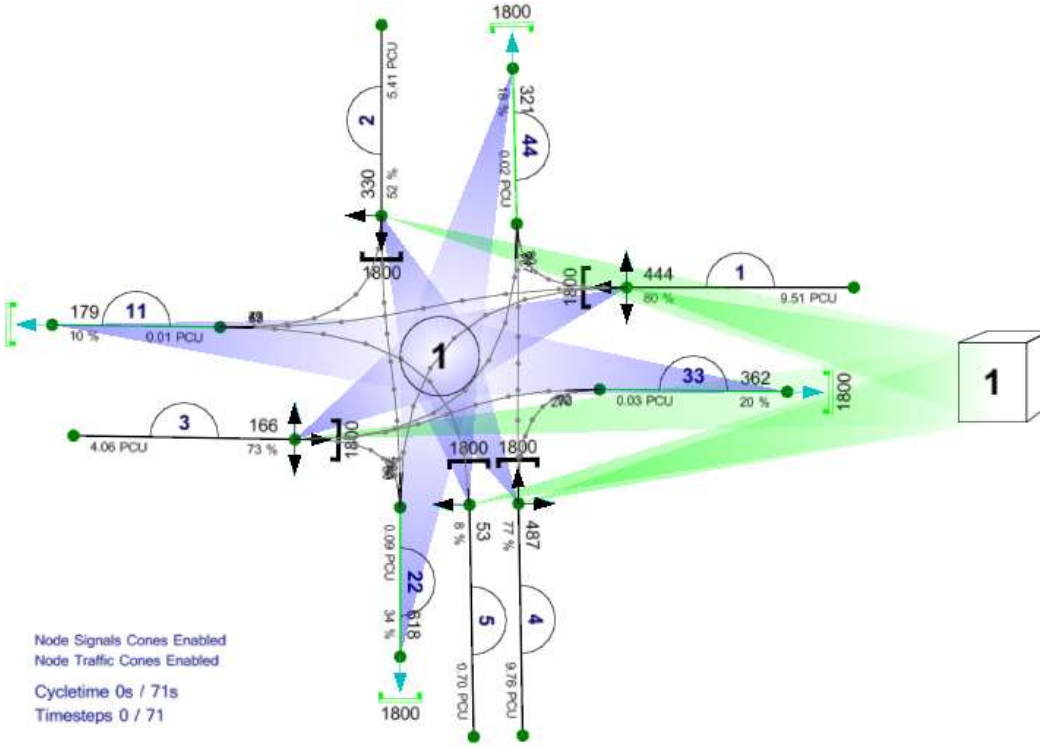
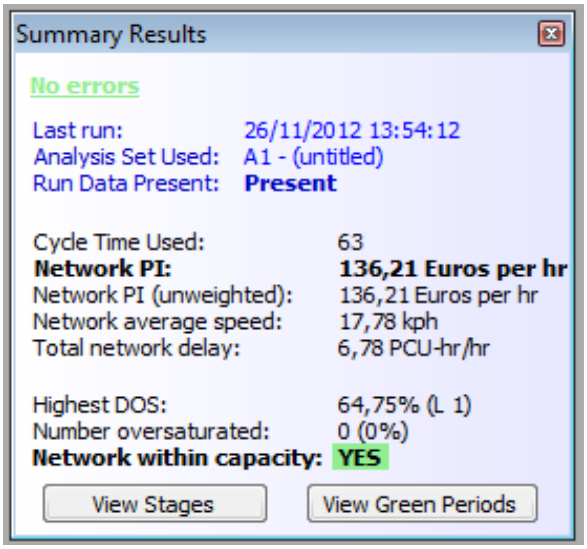


Figure 1 : Model of the intersection

First, we generated the model of the intersection.

In order to show the economics results clearly, here we changed the unit of cost from pounds to Euros. (14.2Pounds=17.5656Euros, 2.6Pounds=3.2162Euros)

Q18. Transyt results from hand calculations



- What is the cycle time used? 63 seconds.

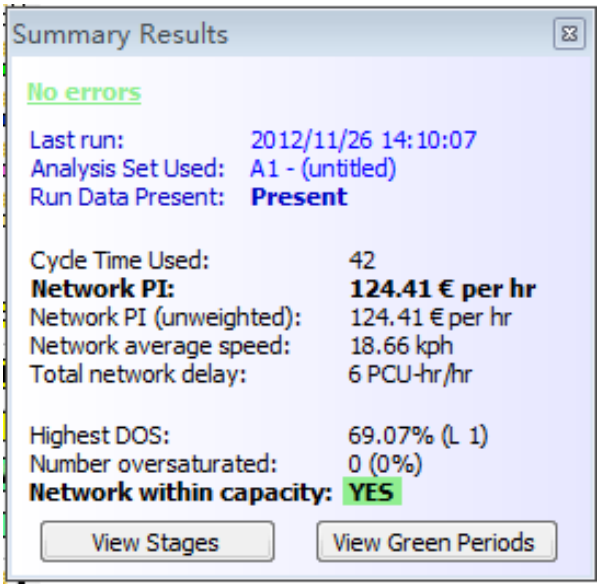
- What is the total network delay? 6.78 PCU-hr/hr

- What is the Network Performance Index? 136.21 Euros per hr

- Network Average Speed? 17.78kph

- Highest DOS? 64.75%

Q14. Transyt Optimized results



- What is the cycle time used? 42 seconds.

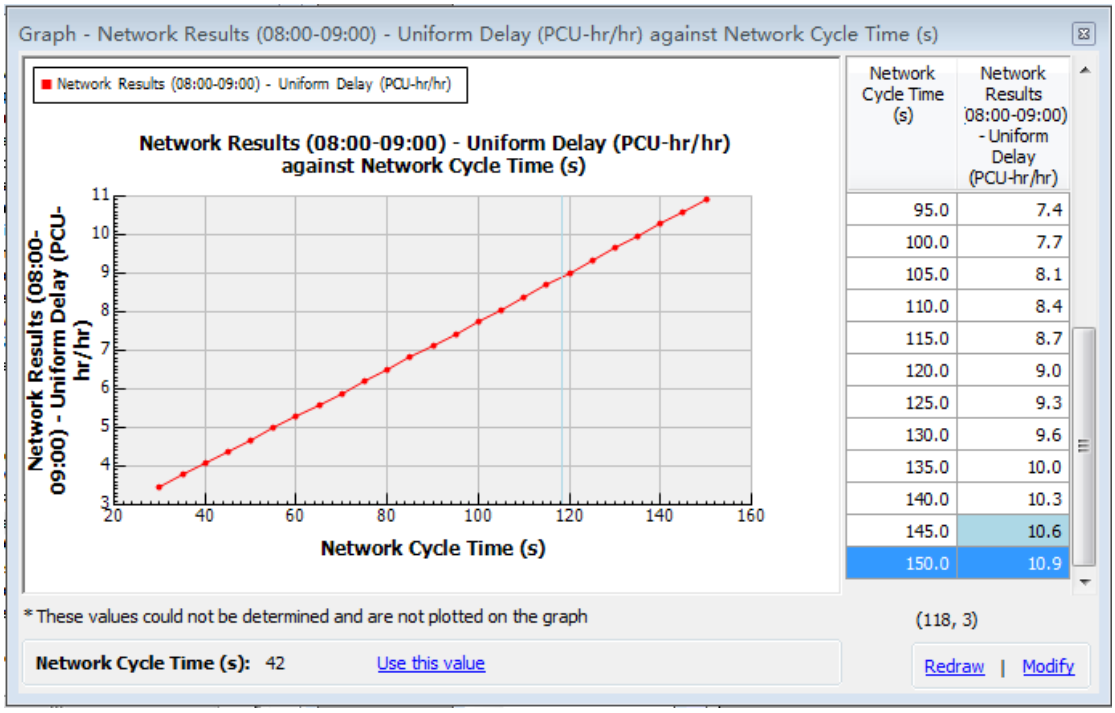
- What is the total network delay? 6 PCU-hr/hr

- What is the Network Performance Index? 124.41 Euros per hr

- Network Average Speed? 18.66kph

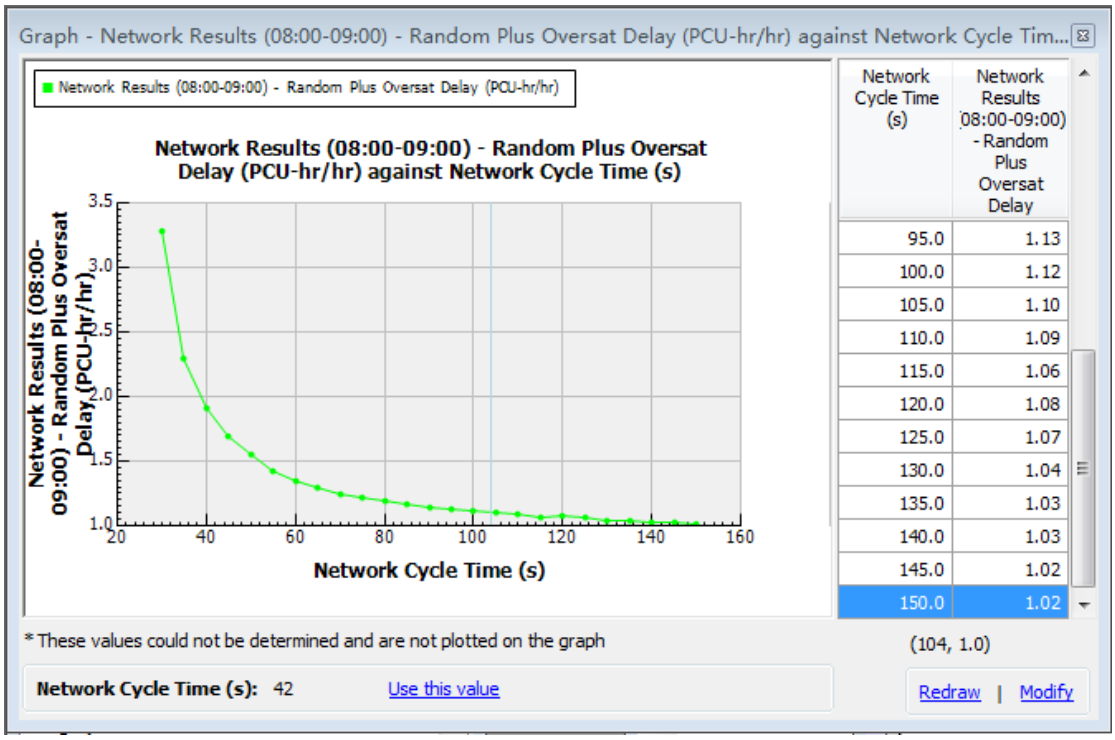
- Highest DOS? 69.07%

Q15. Plots



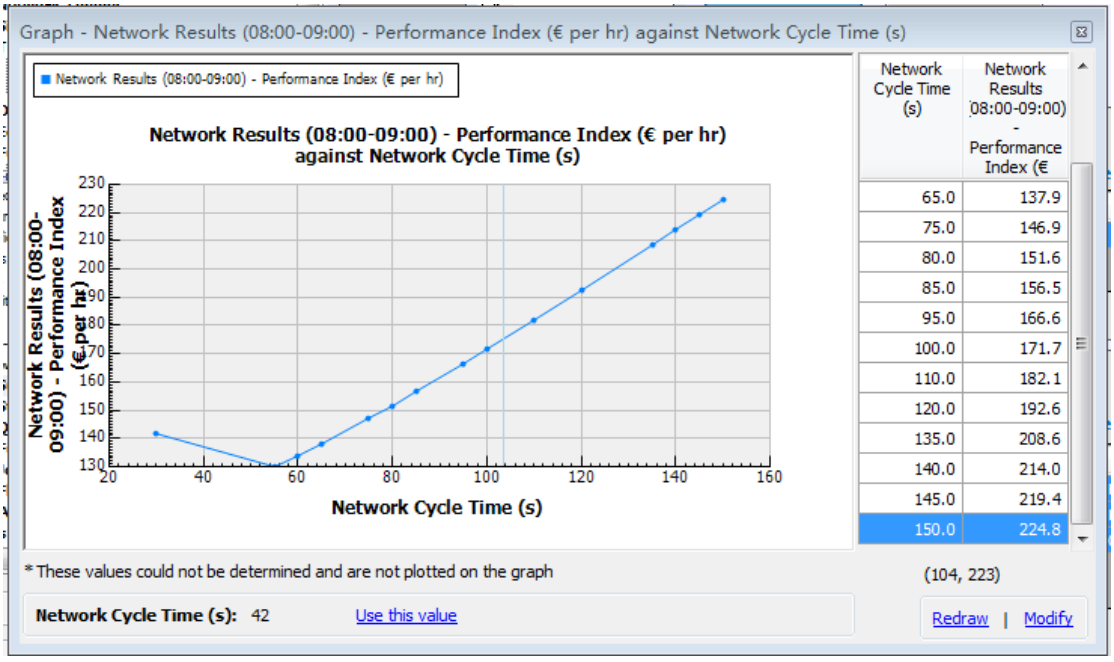
Plot of Cycle time and Uniform delay

According to the plot of cycle time and uniform delay, the uniform delay increases with the increase of cycle time. An increase of 15 second in cycle time causes the increase of 1 pcu-hr/hr.



Plot of cycle time and Random+oversaturated delay

According to the plot of cycle time and random+oversaturated delay, we found that when the cycle time is low, there would be large random and oversat delay. After increasing the cycle time to the optimized time, the slope of the curve is lessen, which means that when cycle time is high enough, the random and oversat delay could be lessen significantly. So it's important to make sure the cycle time is high enough for minimize the random and oversat delay.

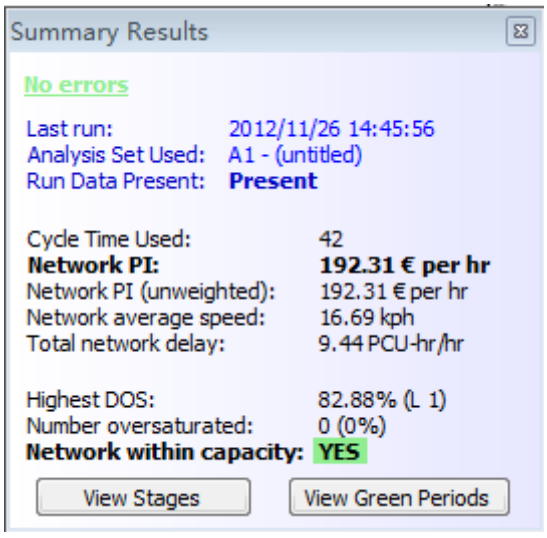


Plot of Cycle time and Performance Index

According to the plot, while increasing the cycle time, it first turned a trend to lessen the PI, after the optimized cycle time, it increased by a higher increased rate and never drop down again.

The challenge in order to get the optimized cycle time is among others to find the best balance between a low Performance Index, a low uniform delay and random plus oversat delay.

Q16 Increase the traffic flow by 20% (Use a copy of Transyt file from Q15). Run TRANSYT. Is the network within capacity?



- What is the cycle time used? 42 seconds.

- What is the total network delay? 9.44 PCU-hr/hr

- What is the Network Performance Index? 192.31 Euros per hr

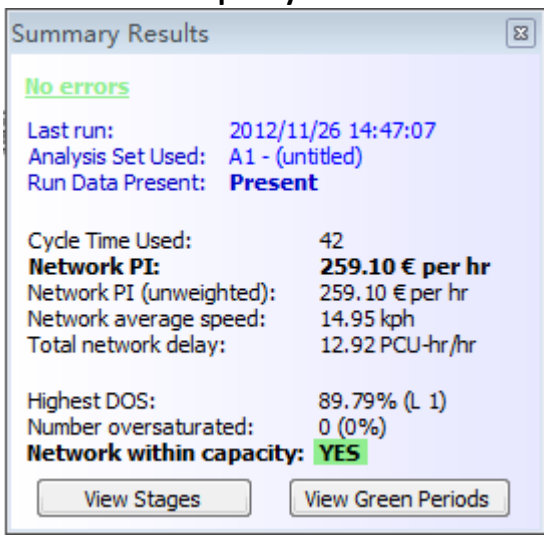
- Network Average Speed? 16.69kph

- Highest DOS? 82.88%

According to the result, it's within the capacity. Additionally, the network delay has increased as

well as the PI. The degree of saturation has been increased because of the flow increase. On the contrary, the average speed is decreased.

Q17. Increase the traffic flow by 30% (Use a copy of Transyt file from Q15). Run TRANSYT. Is the network within capacity?



- What is the cycle time used? 42 seconds.

- What is the total network delay? 12.92 PCU-hr/hr

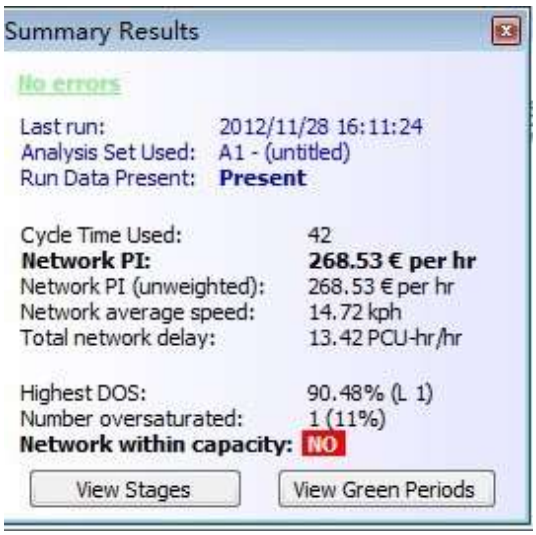
- What is the Network Performance Index? 259.10 Euros per hr

- Network Average Speed? 14.95kph

- Highest DOS? 89.79%

According to the result, it's still within the capacity. However, compare to the trend of average speed decrease, the performance index seems to be increase significantly.

In order to know the capacity of our model, we continued to increase the flow. It turned out that when we add the flow to 31%, it's over the capacity.



Increase of 31%

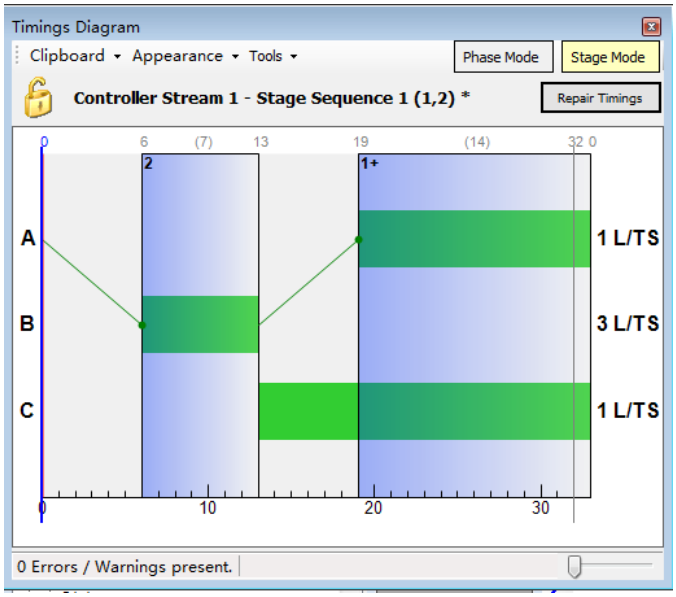
Q18. Modify the number of stages and create a new stage for arm 2. (Alternatively, extend the green time for the stage). Evaluate the new plan using Transyt. Discuss the viability of the modification.

Still considering an increased flow of 31 % (when the congestion appears) we consider two ways of improving the result.

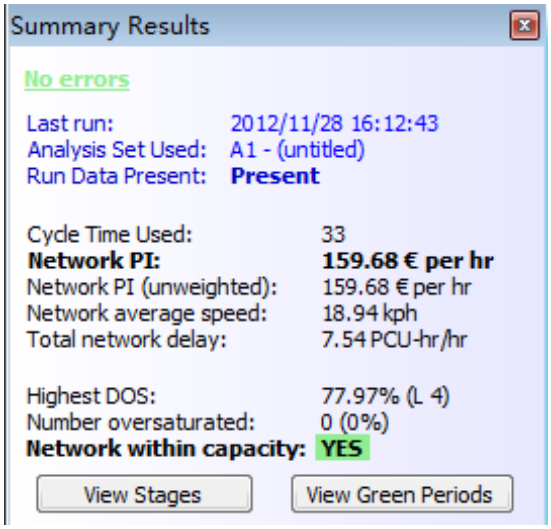
First, we added new phase C which enables to extend the green time of F3, for the reason that F3 has a large amount of left-turning flow. So we set the intergreen matrix as:

\	A	B	C
A	-	6	
B	12	-	6
C		6	-

Then, by running CYOP, we gained an optimized timing:



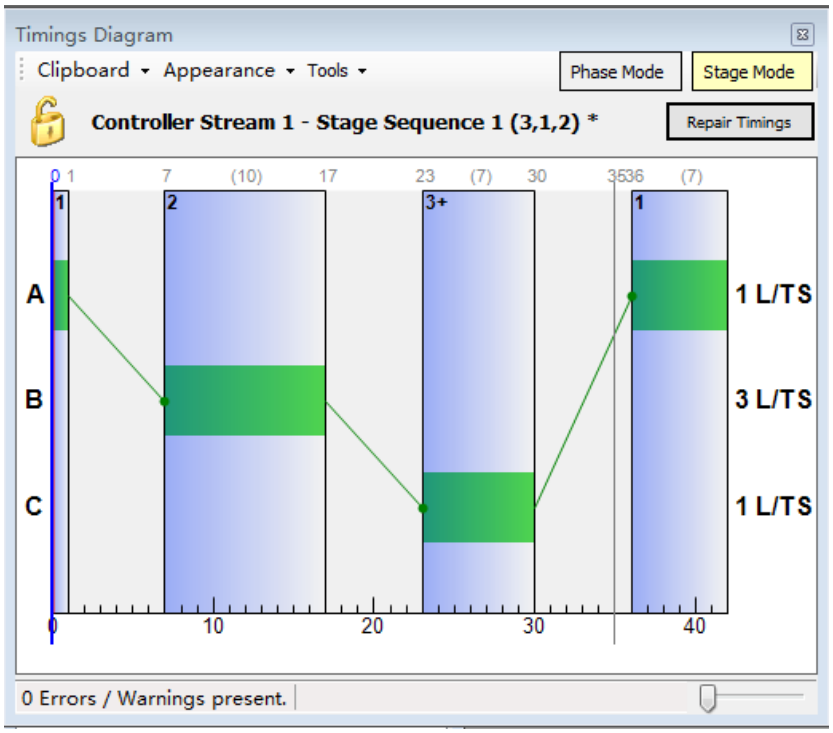
This is the result.

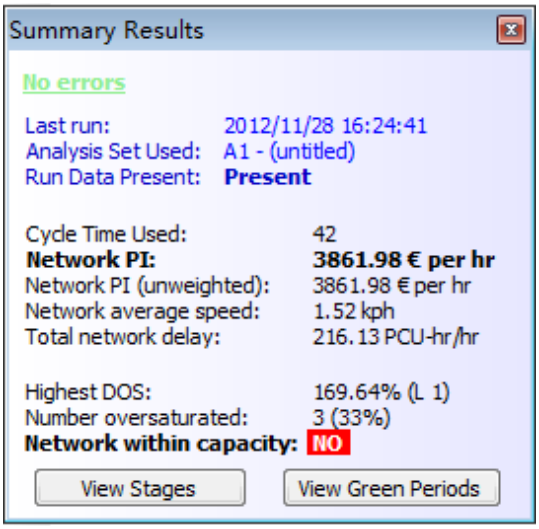


- What is the cycle time used? 33 seconds.
- What is the total network delay? 7.54 PCU-hr/hr
- What is the Network Performance Index? 159.68 Euros per hr
- Network Average Speed? 18.94kph
- Highest DOS? 77.97%
This measure has significantly improved the situation. Indeed, the network is now within capacity, the average speed has been increased, and the delays and the performance index have risen. Therefore, implementing this measure could be a great improvement for the intersection.

We also tried another way of enhancing the network. We added a new stage C. In this case, first the vehicles coming from F2 and F4 have green, then the vehicles from F1, and finally F3. Another way of explaining what we did is to say that we separated the green periods of F1 and F3 into two stages. Therefore, the vehicles coming from F3 or F1 that need to turn left don't have to give the priority to the opposing vehicles.

\	A	B	C
A	-	6	6
B	6	-	6
C	6	6	-





- What is the cycle time used? 42 seconds.
- What is the total network delay? 216.13 PCU-hr/hr
- What is the Network Performance Index? 3861.98 Euros per hr
- Network Average Speed? 1.52kph
- Highest DOS? 169.64%

In this case, the network exceeds the capacity. This can be explained by the fact that too much priority has been given to the vehicles coming from F1, whereas there are few vehicles coming from F1 which need to turn left. On the other hand, the demand flow is high in F3, above all for the vehicles turning left. Too little green-period time has been given for them.

Q19. Test different cycle times (80, 100, 120 sec) at every flow level analyzed 100%, 125% and 135%. Is the network within capacity?

Table 1 — Results of different cycle times under different flow levels

Cycle Time(s)	Flow(hr/h)	Network PI(€ per hr)	Net Average Speed(kph)	Total Network Delay (PCU-hr/hr)	Hightest DOS	Network Within Capacity
80	100	151.6	16.85	7.7	63.66%	Yes
80	110	177.21	16.39	9.02	67.83%	Yes
80	120	207.12	15.85	10.57	74%	Yes
80	135	265.96	14.82	13.65	80.73%	Yes
100	100	171.63	15.8	8.87	63.25%	Yes
100	110	199.26	15.39	10.31	67.83%	Yes
100	120	230.92	14.92	11.96	72.20%	Yes
100	135	290.11	17.07	15.09	79.29%	Yes
120	100	192.59	14.84	10.08	62.98%	Yes
120	110	222.62	14.46	11.66	66.45%	Yes
120	120	256.68	14.04	13.46	72.49%	Yes

120	135	318.62	13.29	16.75	78.35%	Yes

As we can see in table 1, within the same cycle time, the performance index value, the total network delay and the highest DOS value increase as the flow climbs from 100 hr/h to 135 hr/h, remaining within the network capacity while the network average speed declines continuously. In contrast, with the same flow, the performance index value and the total network delay change accordingly to the cycle time while both the highest DOS value and the network capacity behave in quite the opposite way.

Therefore, we can conclude the trends as; with the growth of flow or cycle time, the performance index value and the total network delay will rise while the network capacity will fall down. Changing patterns of the highest DOS remains uncertain, either increase with cycle time up or flow down.

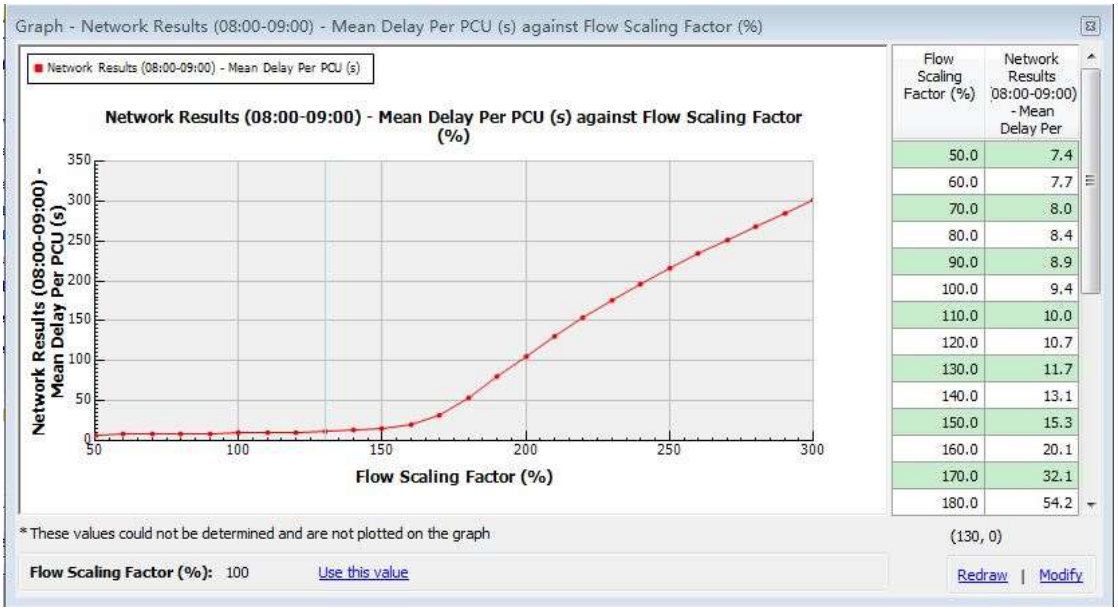


Figure 2 : Plot of mean delay with flow scale(cycle time =80s)

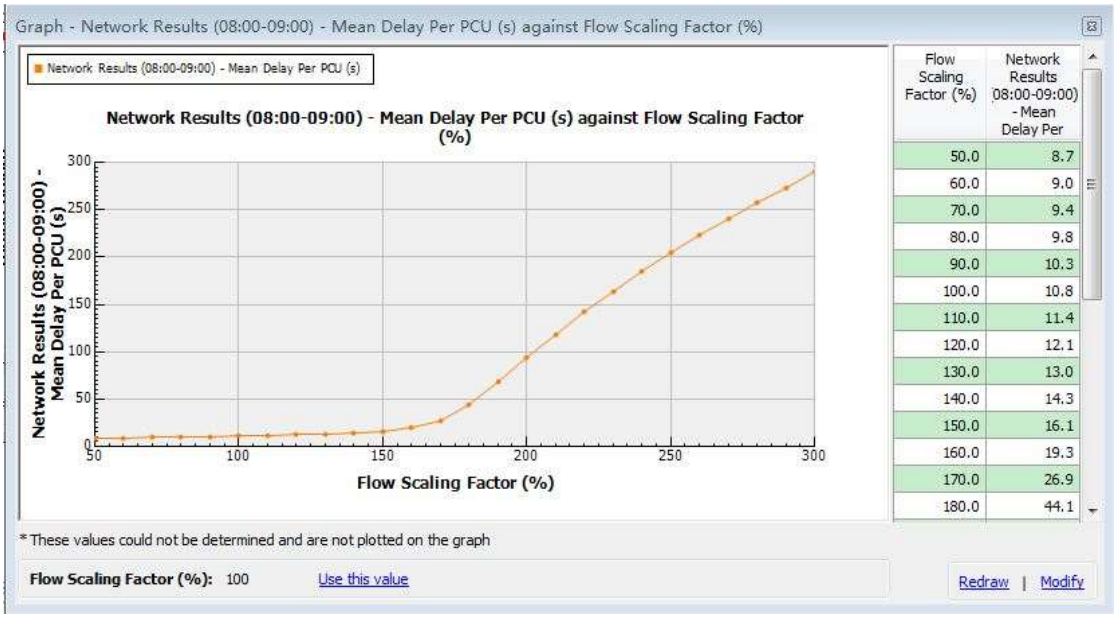


Figure 3 : Plot of mean delay with flow scale (cycle time =100s)

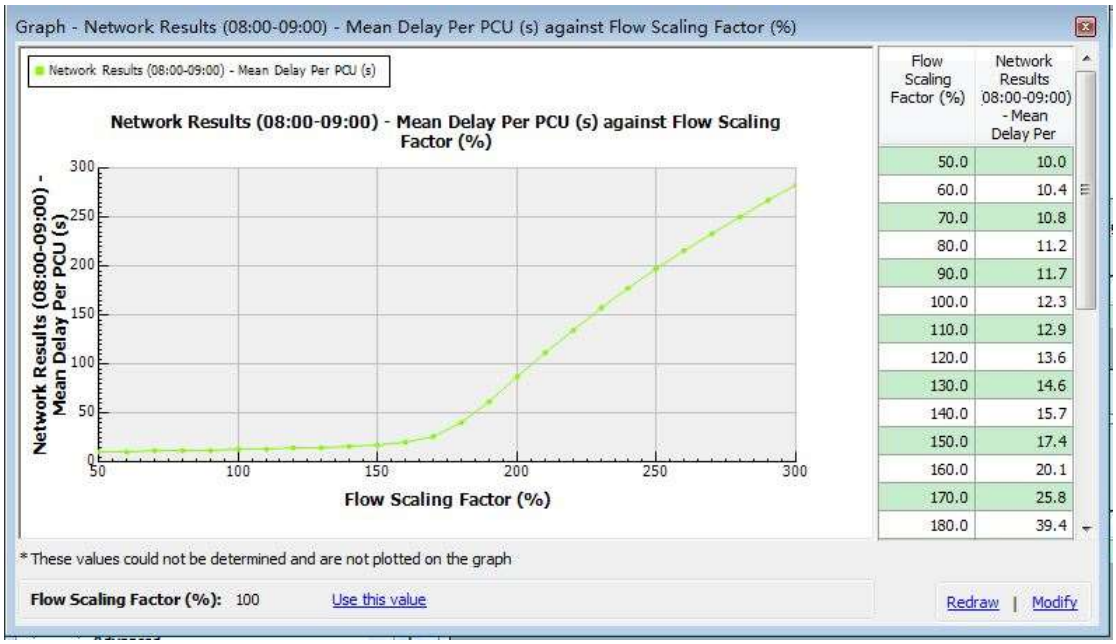


Figure 4 : Plot of mean delay with flow scale (cycle time =120s)

Apparently, all plots have similar interfaces, indicating that the mean delay increases with higher flow scaling factor. The mean delay remains steady and slowly increases to about 150% flow scale. After the scale 160%, from which point the flow exceeds network capacity, the rate of increase accelerates and to some extent behaves nearly like a linear function.

Q20. Look on results (In the congested scenario Q17) and suggest qualitatively what measurements can be introduced in order to improve the intersection traffic

performance. Write at least a paragraph and explain ideas in detail.

Apart from the modification of signal timings, we can also do some geometric changes for this intersection.

According to the results, when the flow scale increases, the traffic would exceed the capacity, resulting in lower speeds and longer delays in the system. Combining with the red time calculation results, pedestrian movements are dominant factors in designing the signal timing. Therefore, pedestrian movements should be separated to improve the system capacity. The pedestrian flow in G7 direction is quite large and the G7 pedestrian movement limits the movement in F3 direction, of which the vehicle flow is the highest. Pedestrians' overpass and underpass can be built for G7 crossing in order to reduce the influence of G7 on F3.

What's more, it would be useful to separate the flow F3. As it's already mentioned before, the left turning vehicles occupy a lot of the lane and block the other vehicles wanting to go straight or turn right. If possible, it would be much better to create a new left-turning lane for F3.

Part C : Analysis of Signal Timings with Microscopic Simulation

Q21. Use the output files from VISSIM and report the delays in each direction and the uniform delay for the whole intersection.

Using the micro simulation software VISSIM, we implemented our signal plan realized in Q10. Doing this, we could directly see the impact that such a signal plan has on the traffic in the intersection. The software also enables us to calculate some values such as the uniform delay for the intersection or the delays for each direction.
Below you will find the results given by our signal plan.

Total travel time [h], All Vehicle Types	2.886
Average delay time per vehicle [s], All Vehicle Types	24.192
Total delay time [h], All Vehicle Types	1.633
Average stopped delay per vehicle [s], All Vehicle Types	15.412

We also managed to calculate the delays for each direction.

Delay for all vehicles										
F1 straight	F1 left	F1 right	F4 straight	F4 right	F4 left	F3 straight	F3 right	F3 left	F2 straight	F2 right
0.0	35.6	30.2	12.4	12.6	35.3	19.1	24.9	24.5	11.7	11.7

This table shows that the highest average delays for a lane appears to be for F4 and F3. This is imortant to consider afterwards in order to propose some possible improvements. But as we can also see, F1 has a huge delay for right and left turning vehicles. Fortunately, very few vehicles coming from F1 are turning left or right (the flows are only respectively 24 and 50 veh/hour) : this is why it doesn't have any significant impact on the queues.

Q22. Propose some possible improvements in the signal timings.

Observing the operation of the intersection through animation, it appeared to us that the vehicles coming from F3 and F4 often presented long queues, which is confirmed by the calculated delays for all vehicles.



Figure 5 : Congestion of the intersection with the original signal plan

Therefore, we thought about blocking the vehicles coming from F2 during the end of the green period of F4 (and the same for F3 considering F1) so that the vehicles could turn freely on the left. The resulting signal plan is shown below.

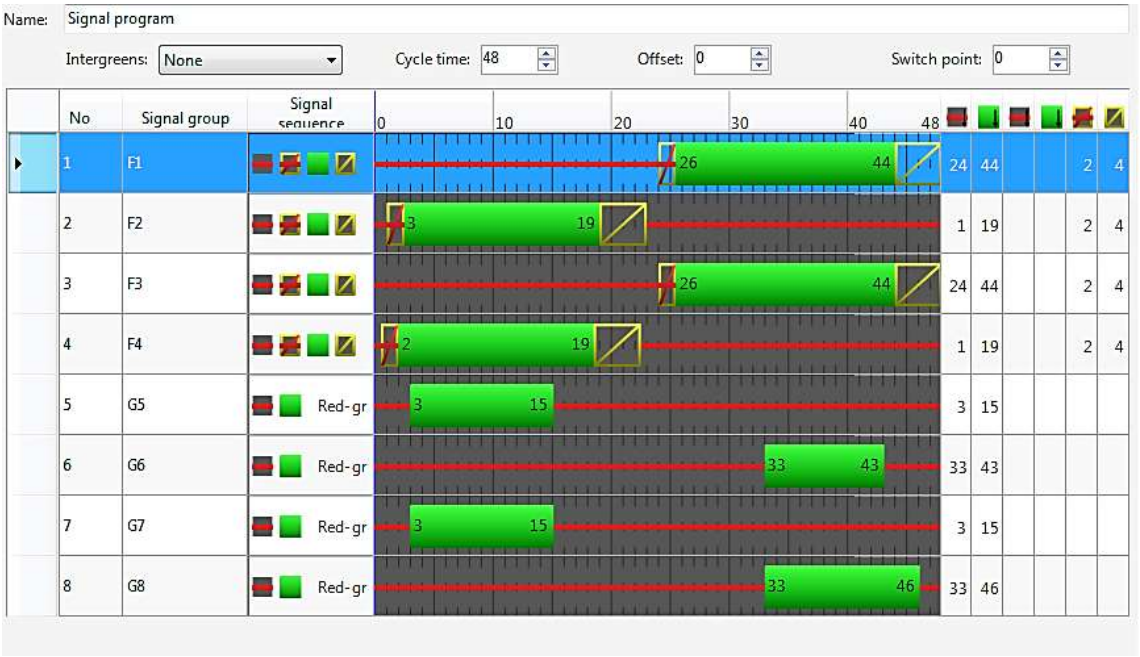


But when we tried it, it occurred that the delays were longer than the previous signal plan. This is due to the fact that we increased the red periods, so it is still logical for the delay to be longer.

	Before	After
Total travel time [h], All Vehicle Types	2.886	3.109
Average delay time per vehicle [s], All Vehicle Types	24.192	29.691
Total delay time [h], All Vehicle Types	1.633	1.979
Average stopped delay per vehicle [s], All Vehicle Types	15.412	16.953

Another obvious improvement to do would be to create a bus stop where cars can still pass before the F4 approach. Indeed, we can directly see that when a bus approaches and stops 100 meters before the intersection, it blocks all the cars behind him and creates a huge queue. But we didn't know how to change this aspect on VISSIM.

We then decided to try reducing the cycle time. Indeed, the optimal cycle time calculated in TRANSYT 14 was only 42s (but without pedestrians). We therefore thought that it would be interesting to reduce it. We tried several cycle times and it happened to be that the best one we found was a cycle time of 48 seconds (a bit higher than the 42 calculated maybe because of the presence of the pedestrians). We also reduced the time for pedestrians crossing, because they used to prevent the cars from crossing easily and had a large impact on queues. We still paid attention to the red periods and the minimum green periods for cars and pedestrians.



	Before	After
Total travel time [h], All Vehicle Types	2.886	2.698
Average delay time per vehicle [s], All Vehicle Types	24.192	23.118
Total delay time [h], All Vehicle Types	1.633	1.503
Average stopped delay per vehicle [s], All Vehicle Types	15.412	13.747

The observations are without a doubt very positive: both travel time and delay are significantly reduced. This solution combined with the creation of a new bus stop would be even better!

Conclusion

From this project, we have explored three ways of signal design.

We now know how to do manual calculations and how to follow the manual design procedure step by step, in order to get a rough estimation of the capacity and signal timings. However, the formulas we used are only suitable in order to get an overview, and not suitable when dealing with deeper problems and concrete planning.

Moreover, these calculations are not always really accurate, and therefore is TRANSYT interesting to use. We also have estimated an optimal cycle time, but this time using performance index to optimize it. From this procedure, we explored the relationship between cycle time and many factors. This helped us to understand much better congestion and delay problems. Also, we had tried some improvement suggestions for the traffic such as extending the green time for one approach, or creating a new stage.

However, when the intersection is approaching capacity, modification of signal timings alone may not be an adequate solution. We have suggested some geometric improvements such as creating new lanes and over/underpass for pedestrians.

Other improvements have also been found using VISSIM. This micro-simulation tool enables the user to get an overview of what really happens at the intersection at the vehicle level. Thanks to this software, we have been able to point out several problems: the long queues at the F3 and F4 approaches, pedestrians preventing the cars to turn for a too long time, a bus stop preventing the cars to pass… As TRANSYT had shown, the hand-calculated cycle time is too long, and using a shorter one enables to reduce the delays and travel times.

Using these three different methods is interesting in order to get a global overall of the intersection traffic.