

# Workshop: Best Practice of Metropolises

## Fr1/B1: Green waves for Cyclists in Copenhagen

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In the City of Copenhagen both politicians and officials recognise cycling as a very important means of transport. As car ownership increases steadily, it is important to urge people to use their cars less, and fortunately many car owners cycle to work. Cycle traffic is growing faster than car traffic, thanks to a continuous effort to improve cycling infrastructure.

The Copenhagen Cycle Policy has a target goal to substantially increase cycling travelling speed:

"Cycling travelling speed on trips of over 5 km shall increase by 10%" Target figure, Cycle Policy 2002-2012

### 1. Green wave - pilot study

In 2004, a provisional green wave - adjusted to a cyclist speed of 20 km/h - was established through 13 signalised intersections on Norrebrogade. Norrebrogade is one of the old radial streets into the centre of Copenhagen. It serves many purposes, amongst these being the central shopping street in a dense and trendy living area. Norrebrogade is also a major cycling route from the suburbs to the centre. Closest to the centre, 30,000 cyclists use this street every day, which during rush hours creates congestion on the cycle tracks.

The green wave increased the cycle speed. As compared to the normal situation with approx. 6 stops in the morning when cycling to the centre, practically no stops at traffic lights were observed, when the green wave was working. Time savings amounted to some 12%. From a cyclist point of view, it is very clear, that the green wave makes the cycle tour into town faster and much more pleasant.

#### 2. How to make a green wave

When there are two or more signalised intersections in a street, they should be coordinated to provide a green wave. However it's often impossible to make a green wave in both directions at the same time. The reason for that is fixed parameters such as the distance between the intersections and the cycle time of the traffic light. The cycle time is based on the traffic intensity. The cycle time of a traffic light should be as short as possible because of the waiting time in general. In Copenhagen the cycle time is typical 80/(100) sec. during rush hour and 60-70 sec. during daytime and in the evening.

Normally the traffic flow in a street gives a picture of which direction to give the best conditions in the green wave. In radial streets in a city there is usually more traffic towards the city centre than from the city centre in the morning. It's therefore reasonable to give the traffic towards the city the best conditions in the green wave in the morning. In the afternoon there is usually more traffic from the city centre than to the city and it's therefore reasonable to give the traffic from the city centre than to the city and it's therefore reasonable to give the traffic from the city centre the best conditions in the green wave.

The question of which direction to give the best conditions in the green wave is not the only issue when planning a green wave. Cars, buses and cyclists are not moving with the same speed. So it's important to decide witch traffic group you want to give the best conditions in the green wave. Graph nr. 1 shows a street



with 5 signalised intersections. The vertical lines show the intersections. The pale and dark green shows the time of which the traffic lights are green. The pale green shows the green time in direction A, and the dark green shows the green time in direction B. The wide horizontal lines shows the cycle time of the traffic lights, in this case 80 seconds. The X-axis shows the length of the street (m), and the Y-axis shows the time (sec.).

The diagonal lines in the graph show the speed of a car, bus and a bicycle. The speed limit in the street is 50 km/h. The cars and buses are driving 45 km/h, and the cyclists are driving 20 km/h. In this street the green wave is made to fit the cyclist in direction A.



Graph nr.1. Street with 5 intersections. Green wave illustrated in direction A.

The cyclist (blue line) is driving through all the traffic lights with no stops. The car (black line) has to stop at traffic light nr. 2 and the bus (red line) has to stop at traffic light nr. 2 and nr. 3, but the bus also has to stop at all the bus stops (20 sec.) which makes it slower than the car.

So the green wave for cyclists should be working in theory, but only if the cyclists move at the right speed (20 km/h). Unfortunately there are some circumstances that can interfere with the cyclists speed; congestion on the cycle tracks, bus passengers on/off the bus, vans delivering goods to shops etc.



Congestion on cycle track







Bus serving customers.

Van parked on cycle track, delivering goods.

Graph nr. 2 shows the traffic both in direction A and direction B. Here it shows the difficulty of making a green wave in both directions at the same time. The cyclist in direction B has to stop at traffic light nr. 4 and nr. 2, the car in direction B has to stop at traffic light nr. 4, 3 and 1, the bus only has to stop at traffic light nr. 4.



Graph nr. 2. Green wave illustrated in both direction A and B.



## 3. Green wave on Norrebrogade

In the autumn 2006, a permanent green wave for cyclists was established on Norrebrogade through 12 signalised intersections. The distance is 2.2 km. long and starts/ends 1.3 km from centre. Closest to centre approximately 30,000 cyclists use the street every day as compared to 17,000 cars. In the other end of the street there are 16,000 cars and 15,000 cyclists. Only 20 % of the cars in the street are driving through the street where as 80% of the cars has a destination in the street or in the area nearby. There are many buses in this street, nearly one bus every minute. One of the two bus lines in the street (5A) are the most used bus line in Copenhagen with nearly 60.000 passengers daily.

The green wave is adjusted to a cyclist's speed of 20 km/h. In the morning 75 % of the cyclists in the street drives towards the city. In the afternoon the difference in the traffic flow is not so clear - 56 % of the cyclists drives from the city. In the morning (6:30 am - 12 noon) the green wave is adjusted to cyclists driving towards the city, and in the afternoon (12:00 noon - 06:00 pm) the green wave is adjusted to cyclists driving from the city.

To measure the travelling speed of the cyclists a GPS- and GIS-based technology was developed. Two modes of cycling performance were used. The "floating bike" mode, supplied with cycling in "fixed mode" (20 km/h) adapting as closely as possible to cyclists' behaviour in traffic.

The cyclist floats with the stream in so-called "floating mode". When enough cyclists are not present, the floating mode measurements are supplemented with measurements in "fixed mode". These are performed when basically cycling 20 km/h – in accordance with cordon speeds in Copenhagen. Floating mode reflects reality best, but is only useful, when many cyclists are present (during rush hours, on major streets).



PDA and GPS equipment on a bike.

The car speed is also measured by GPS, but the car simply just follows the traffic flow. The buses have their own GPS-tracking system from which it's possible to get data.



The graph (nr. 3) below shows the cyclists speed before and after the green wave was established.



Graph nr. 3. Speed profiles for cyclists on Norrebrogade before and after a green wave was established

Speed profiles (Graph 3) registered before and after the green wave was established, summarise the improvements obtained for the cyclists on Nørrebrogade. It becomes very clear, that the green wave makes the cycle tour to the centre of town in the morning faster and much more pleasant.

Table 1.	Time and stop	saved after	establishment	of the green	wave - cyclists.
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	Saved stops	Saved min./sec.
Green wave to centre in the morning	6	2:29
From centre in the morning	1	0:35
Green wave from centre in the afternoon	3	1:13
To centre in the afternoon	0	0:36

The table above shows the cyclists benefits of the green wave. But what are the consequences for the cars and buses? To find the consequences for cars, we measured the car speed before and after the green wave was established. The graphs below shows the speed profile of the cars.







Graph nr. 4. Speed profiles for cars on Norrebrogade before and after a green wave for cyclists was established.

Graph nr. 4 shows that the green wave hardly had any influence on the cars to city centre in the morning. The table below shows the consequences in number of stops and time.

Table 2. Time and stop saved after establishment of the green wave - cars.

	Saved stops	Saved min./sec.
Green wave to centre in the morning	1	0
From centre in the morning	1	0:30
Green wave from centre in the afternoon	1	0:48
To centre in the afternoon	0	0:30

At writing this paper data from the buses are not processed but data will be ready for presentation at VeloCity 2007.



## 4. Green wave on other streets in Copenhagen

Recently another green wave was established on Farimagsgade through 4 signalised intersections. Farimagsgade is not a radial road so the traffic intensity are more or less the same in both directions. Therefore the green wave is aimed to fit both directions at the same time. Considering both directions at the same, result in a fairly good green wave in both directions but not perfect.

Graph nr. 5 and 6 shows the speed profile for cyclists on Farimagsgade before and after the green wave was established. The graphs shows the speed profile for both directions.





Graph nr. 5. Speed profiles for cyclists on Farimagsgade before and after a green wave was established - direction: north.







Graph nr. 6. Speed profiles for cyclists on Farimagsgade before and after a green wave was established - direction: south.

## 5. Next step

Green waves for cyclists are an easy way to increase cycling speed and the costs are low. However it's important to consider the consequences for both buses and cars when planning a green wave for cyclists. Especially safety and environmental aspects should be investigated. A green wave for cyclists could cause a heavy congestion for cars and buses, and in worst case reduce safety.

At the moment Norrebrogade and Farimagsgade are the only streets were the green wave is adjusted to a cyclists speed. But there are other streets in Copenhagen with the same amount of cyclists as Norrebrogade, so we are planning to establish 2-3 more green waves for cyclists in Copenhagen.