Segregation or Integration?
the Dutch approach

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1. Introduction.

The Dutch Design Manual for Bicycle-friendly Infrastructure 'Sign up for the bike' provides the tools to designers for a proper design of infrastructure to meet the needs of cyclists. One of the important decisions to be taken is the question whether cyclists and motorists will be using the same carriageway or whether they will get there own space on the road. In this chapter we elucidate the approach in the Dutch manual.

Any road design should be based on a balance between the function, the form and the actual (or expected) use of the infrastructure. In other words: the design should allow the envisaged traffic flows and the expected manoeuvres. In relation to the matter of segregation or integration the question is, in which situation which solution is most appropriate.

First of all we start with a list of conceivable forms of integrated and segregated road profiles. In the discussion on integration and segregation we can distinguish between :

- No segregation but integration of different modes.
  - in two directions;
  - one way streets;
  - one way streets allowing cyclists in the opposite direction;
  - with or without (speed and/or intensity) restrictions for motor traffic.
- Visual segregation (road paint),
  - bicycle lanes (which have a bicycle logo on the pavement in order to give them a legal status);
  - virtual bicycle lanes (which have no logo and no legal status);
- Physical segregation.
  - bicycle routes following their own line;
  - Bicycle tracks alongside roads for motor traffic
    - unilateral in two directions (*)
    - unilateral in one direction
    - two-sided both in one direction (*)
    - two-sided both in two directions

(*) In the Netherlands these are the most common types.

A physical segregation can be achieved in various ways, e.g. by a verge between the carriageway and the bicycle track, by creating merely a difference in level between carriageway and bicycle track, or by putting a fence in between.

In this chapter we won't go into details concerning the design of the different solutions and their variants, but give the arguments and the criteria for the choice between integration, visual segregation and physical segregation.

2. Principle arguments pro and contra segregation and integration.

2.1 What is the problem?

Discussions about separation and integration have their starting point in the incompatibility of (fast riding) motor traffic and non motorised traffic (i.e. bicycles and pedestrians). This incompatibility has to do with insufficient safety for cyclists in the first place. As safety correlates with the number of encounters and the complexity of the traffic situation, this is very obvious. But also other quality aspects of cycling are affected by large numbers of fast riding motorists. The freedom of movement (making the manoeuvres you want to make) is decreased. The presence of much traffic asks for constant being on one's toes of the cyclists. And usually heavy used roads are not the most attractive one's to use either.

There are two approaches to overcome this incompatibility : integration and segregation. Both approaches have their own merits and draw-backs.

2.2 Integration.

The approach of integration tries to solve the problem by adapting the drivers' behaviour to the circumstances. As insecurity is caused by the number and the speed of motor vehicles, the solution is a decrease of the number of cars on the road, and an adjustment of their speed. Integration underlines the equality of all road users. All have the same freedom of movement. Moreover, no extra space is needed for traffic purposes.
On the other hand parking manoeuvres of cars can be aggravating and dangerous for cyclists. In narrow streets the cyclist can have the feeling that he/she is a living speed reducer (which might feel uncomfortable). The cyclist can be hard pressed by cutting in cars at overtaking manoeuvres.
More generally integration is asking for a certain attentiveness which is more required as intensities and speed are higher. So the approach of integration is hardly applicable on sections or in areas where it is not possible to limit the number of motor vehicles or to reduce their speed effectively. This has also to do with the function of the road. Some through road are meant for large volumes of traffic or for the use by heavy lorries. Physical speed-reducers loose their impact on ordinary cars when they are dimensioned for heavy lorries. And on bus routes these speed-reducers are not wanted.

2.3 Segregation.

The approach of segregation tries to solve the problem by giving the incompatible modes their own territory. This is a good solution on road sections where there is enough space for the different categories. (Segregated facilities usually take more space than integrated facilities.) At intersections the segregation can be realised by fly-overs (spatial segregation) or by traffic lights (segregation in time).
At road sections with segregated facilities cyclists are better protected, overtaking manoeuvres of motorists are easier, cyclist are less affected by congestion, and cycling becomes more comfortable as the need for alertness is decreased.
On the other hand the freedom of movement might be diminished, motorists will be more speeding, while their level of attention for cyclists will decrease. As very often there is no (real) segregation of crossing flows at intersections, the construction of bicycle tracks may lead to a decrease of accidents at the concerning road sections, but to an increase of accidents at intersections.

2.4 Balance of interests.

In the approach of segregation, the equality of modes is replaced by a balance of interests. Mostly only a limited quantity of space is available, which has to be divided among the different categories of road users. It is obvious that a category which is looked upon as less important, will have to give in, especially when the available space is not enough to meet all demands. On the other hand when space is available, segregation leads to large-scale solutions and it enlarges the barrier effect of roads.

In principle the approaches of integration and segregation can be complementary to each other.

- Segregation of modes (by means of tracks, fly-overs and tunnels) should be applied where reduction of speed of fast driving cars is not possible or desirable.
- Reduction of speed (by physical measures) is necessary where different modes have to share the same infrastructure (where segregation is undesirable or impossible).
- Simplifying manoeuvres are helpful in situations where modes inevitably meet each other, in order to make it easier to deal with the situation and to reduce the severeness of conflicts and collisions. This again implies speed reduction at these sites.

In principle it is not difficult to agree with this complementarity. But when in practice segregation is realised, often the free movement of cyclists is restricted. The interests of cyclists appear not to put enough weigh in the balance of interests. Too often segregation looks like aiming for the free flow of motorised traffic. Cyclists are banned to the side of the road, and in some European countries even to the pavement. At intersections it is even worse. The created facilities have a very poor quality. That is the reason why cyclists' organisations in some European countries oppose against obligatory use of segregated bicycle facilities. As long as planners don't give enough weight to the interests of cyclists to come to a bicycle friendly balance of interests, keen cyclists will have a preference for the integrated approach. The greater their skills to survive, the greater this preference. In fact this has more to do with the insufficient quality of the actual design (which often doesn't comply with quality requirements on aspects like comfort and directness) than with the principle of segregation. (A bad design will always be a bad design.)

But it is only fair to say that less self-confident cyclists will sooner ask for segregated facilities. A well designed bicycle track offers them the opportunity of unhindered and comfortable cycling. Moreover, bicycle tracks can contribute to the coherency and recognisability of a bicycle route network and for continuity of design at through bicycle routes. If the design of segregated facilities has sufficient quality, many objections against segregation will disappear. Alignment and width of segregated facilities are important aspects in this respect.

3. Criteria for incompatibility.

3.1 Critical speeds and intensities.

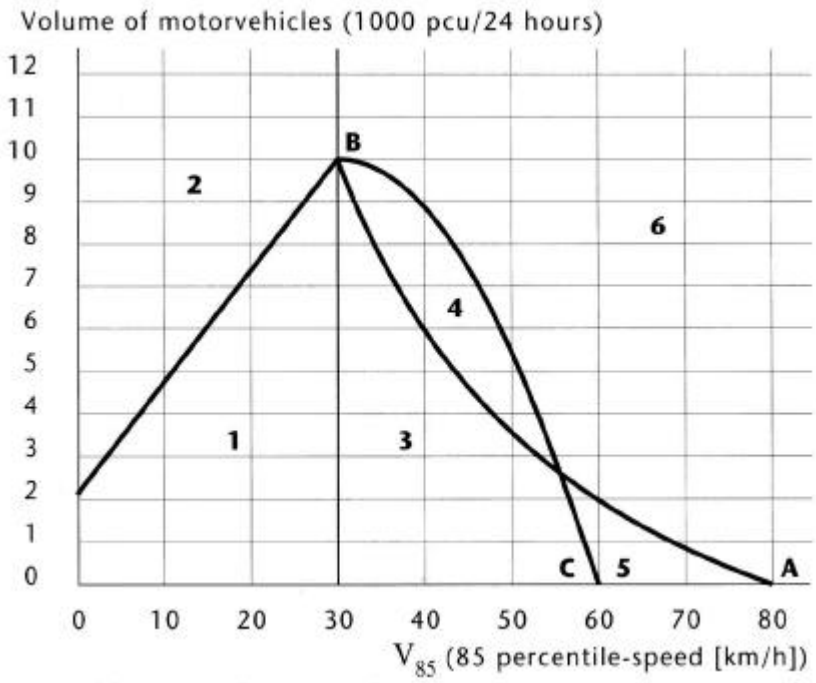
The speed and the intensity of the motor traffic are the main factors for the decision if and to which extent different modes have to be segregated. Both intensity and speed influence the number of overtaking manoeuvres, while the speed of the motor traffic is a main factor in the danger of these manoeuvres.

The intensity of the bicycle traffic is in principle not decisive for the question whether segregation is desirable or not. The danger on the road is not caused by cyclists, but by cars. If it is not safe for many cyclists, it won't be safe for a small number of cyclists either. The number of cyclists however has an influence on the urgency and the cost effectiveness of the constructing of a segregated facility. The more cyclists will use the facility, the more paying the investment is. And of course the number of cyclists will have an influence on the design as well. Widths will have an obvious relation to flow.

Apart from the intensity and the speed of motor traffic on the concerning road section in second instance also situational factor are jointly of importance, such as the parking situation, the distance between intersections et cetera.

Strange enough there is only limited research available into the safety of cyclists on different road-profiles with different combinations of car speed and intensity. Yet there is need for criteria. The following criteria have come about on the basis of practical experience and common sense. Recent results of research however of the Dutch Institute for Road Safety Research are in line with these criteria.

The next figure shows which kind of integration or segregation is necessary at what combinations of intensity and speed of the motor traffic. Note that the speed is indicated as the actual speed on the concerning road section not to be exceeded by more than 15% of the drivers (V_{85}). This might be something different than the legal speed limit.



Area 1 : V_{85} < 30 km/h. All modes can be mixed. The only reason to consider bicycle tracks or bicycle lanes is for the sake of continuity of design on connecting bicycle routes.

Area 6 : Speed and/or density of traffic flow make it an absolute necessity to segregate bicycles and motor traffic. Separated bicycle tracks are the only option.

Area 4 : Some form of separation is needed, but visual separation (bicycle lanes) can be acceptable as well.

Area 3 : In general a profile without segregation is acceptable, but depending from circumstances bicycle tracks or bicycle lanes can be desirable. (see below)

Area 5 : Bicycle tracks are desirable, but as densities are low, a mixed profile is acceptable. However, we advise against bicycle lanes.

Area 2 : This situation is merely theoretical.

3.2 Explanation of the shape of the diagram and the used values.

At speeds below 30 km/h overtaking manoeuvres cause little danger. Disadvantages of segregation (less manoeuvrability) will cancel the advantages (protection) easily.

The curve between A and B shows above which combinations of intensity and speed (some kind of) segregation is necessary. (This could be either a visual segregation, i.e.a bicycle lane, or a physical segregation, i.e. a bicycle track). The curve represents the following conditions :

- If 15% of all motor traffic has a speed of 80 km/h or more (85% of motor traffic has a speed up to 80 km/h), segregation becomes absolutely necessary, even if intensities are low. The differences in speed make it impossible for motorists to react adequately to the presence of cyclists on the road.
- The combination of an intensity of 10.000 private car equivalents or more of which 15% has a speed of 30 km/h or more also makes it necessary to segregate motor traffic and bicycle traffic.

We assume that intensity and speed equally contribute to the insecurity of cyclists. If so segregation becomes necessary if the product of intensity and speed is above a certain constant value. The curve which indicates when segregation becomes necessary has the mathematic shape of a hyperbola.

The curve between A and C shows above which combinations of intensities and speeds of the motor traffic bicycle lanes are an insufficient solution. Concerning the applicability of bicycle lanes the speed of motorists has more impact than concerning the question whether some form of segregation is needed. This is because the risk of a severe accident on a road section with bicycle lanes increases rapidly at higher speeds. Cyclists who, for whatever reason, leave the bicycle lane, are not expected on the carriageway by motorists. Therefore they won't react in time to avoid an accident. On roads with integrated modes car driver will anticipate more to cyclists.

The conditions are :
- When 15% of the motorists have speed of 60 km/h or above, bicycle lanes are advised against.
- When 15% of the motorists have a speed of 30/h or more in combination with an intensity of 10.000 private car equivalents, bicycle lanes are advised against as well. The chance that the bicycle lane will be abused is to big, and it becomes to difficult for cyclist to leave the bicycle lanes because of the many cars.

The shape of the curve is based on the assumption that for visual segregation the relation between speed and safety is much stronger than the relation between intensity and safety.)

3.3 Other factors to determine one's choice.

As far as the diagram is not decisive about the desirable degree of segregation, one can use the following (mainly situational) considerations :

- When there is much parking, we advise against bicycle lanes. These lanes will be abused as parking space.
- A bicycle track or lane can contribute to the coherency and recognisability of a bicycle route. If a road section is an important link in the bicycle network, this could be an argument in favour of a segregated facility.
- When there are many (large) intersections, bicycle tracks will loose their value. The comfort of untroubled cycling will be affected negatively by the necessity of being careful at intersections. (When only minor streets are entering the road, this is less a problem.)
- In case of one way streets with permitted cycling in the opposite direction, segregation (contra flow lanes or tracks) is more desirable than in other situations.
- When also trams use the road, physical segregation is desirable.

4. How to deal with the criteria.

From the criteria it can appear that in a given situation an integrated profile doesn't comply. This doesn't imply necessarily the construction of a bicycle track. The other possibility is to take away the source of the incompatibility by changing the composition of the traffic flow. From the criteria one can learn which characteristics of the traffic flow or the situation can be changed for the safety of cyclists :

- The speed of the motor traffic can be decreased (by physical measures);
- The intensity of the traffic flow can be diminished (by changing the circulation system);
- The parking situation can be altered;
- The intersections can be changed.

Whether one will choose for altering the characteristics of the traffic composition or for the construction of segregated bicycle facilities depends from several factors :
- The function of the concerning road section for both the motorists and cyclists;
- The spatial possibilities;
- The scenic or urban characteristics of the road;
- Other restrictive circumstances, like the presence of public transport and the necessary accessibility for the fire brigade and such;
- And last but not least : the coherence and continuity of the bicycle route network.

The mentioned considerations imply that on a connecting bicycle route the choice will be rather in favour of segregation. This for the matter of continuity and recognisability of the bicycle route. On the other hand on sections which are meant to open up the area, the choice will rather be for integration. This will make all destinations alongside the section accessible.

There is one more remark to be made. The diagram shows the acceptable options at different combinations of speed and intensities. 'Acceptable' doesn't imply that the outcome is always an ideal solution. Whenever integrated solutions are chosen, the quality for cyclists will be improved by reducing speed and flow of the motor traffic.

5. Intersections.

In the discussion about segregation and integration intersections play an important role. As stated earlier, segregated bicycle tracks loose much of their effectiveness (i.e. allowing for safe and unhindered cycling) when at intersections cyclists and motorists still have many conflicting manoeuvres. As one of the main points of segregation is to avoid encounters with motorists, also the design of intersections should be aimed at this goal.

Real segregation of modes on intersections can be realised by the use of fly-overs or underpasses, and by segregation in time, i.e. by the use of traffic lights. Both these methods have serious draw backs. Segregation in time by traffic lights will cause delay; in the distribution of green light the cyclists will have to compete with motorists. And if cyclists must have their own phase in the cycle of lights, waiting times will increase for all road users. This will make cyclists (and other road users) prone to hitting the red light more often. Fly-overs on the other hand are often a too large scale solution. Their application forces cyclists to make detours, and to bridge over differences in heights. Practical circumstances often limit their usability.

In the Netherlands there is a grown practice of a less comprehensive form of segregation at intersections: bicycle tracks or bicycle lanes are continued across the intersection, thus providing the cyclists their own space in the intersection area. However, cyclists still have to cross the stream of traffic at street level. Whether this partial segregation or designation is recommended depends not only on intensities and speeds on the crossing, but also on:

- the course of the bicycle connection(s) at the intersection;
- the presence of bicycle tracks and bicycle lanes on the feeder roads;
- the dominating manoeuvres at or near the intersection.

Advantages of this type of segregated facilities at an intersections are:

- Segregated facilities give cyclists their own space at the intersection, which allows them to overtake waiting cars and to pass by the intersection unhindered by other traffic;
- Segregated facilities can provide a protected position where cyclists can estimate the possibilities for crossing.;
- Segregated facilities at an intersection underline the continuity of the facilities at feeder roads;
- Segregated facilities allow for giving priority to cyclists in the adjustment of traffic lights.
- Designated facilities underline the presence of cyclists at the intersection and indicate where encounters can be expected.

But there are also serious draw backs:
- Segregated facilities lead to large scale solutions.
- Segregated facilities make the situation more complex and thus create only pseudo safety.
- Segregated facilities sometimes forces cyclists to split up a left turn manoeuvre in two separated crossing manoeuvres, which lengthens the riding curve, and might cause some delay as well.

Therefore only in case of high intensities of motorised traffic the advantages counterbalance enough the drawbacks of segregated bicycle facilities on intersections.

The solution of the roundabout should be mentioned here as well. The principle of a roundabout is to simplify manoeuvres at intersections in order to make it easier to deal with the situation. For the safety of cyclists low speeds at the roundabout are essential. The roundabouts 'new style' applied today in the Netherlands have a geometry (narrow curves, only one lane) which is aiming at reducing speed. In this circumstances integration on intersection is more often possible than otherwise would be the case. But also roundabouts with separated bicycle tracks are constructed. And again it is an ongoing discussion how the shape of the design should be and whether cyclists on the roundabout can have the same priority as motor traffic on the roundabout.

6. Conclusion.

'Sign up for the bike, (Dutch) Design manual for a cycle-friendly infrastructure' gives rather clear guidelines for the question in which situations cyclists should get their own segregated infrastructure, and when integration is a more appropriate solution. In this chapter we have discussed rather the principle than the elaboration of the principle. But it is only fair to say that these guidelines are most convincing in respect to road sections, because we know which form is appropriate for the

envisaged function of the road section and the expected use of it. For intersections, however, this is less clear. Though we certainly have some knowledge about the design of intersections, this knowledge is not all-embracing. A more fundamental approach of the design of intersections from the perspective of the cyclist still is needed.

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