Principles of cycle planning

John Franklin
Cycling Skills & Safety Consultant

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What is a bicycle?

The bicycle's a simple machine that we all know. But familiarity doesn't always mean we know as much about something as we might. So with cycle planning. We may all think we know what's needed to ride a bike, but if cycling is to be not only possible, but practical, pleasant and popular, then there are many things to be considered that may not be intuitive.

It's a widely held view among cyclists that the outcomes from planning for cyclists in recent years leave a lot to be desired. And very often it's because of an apparent unawareness of some fundamental principles about cycling. This paper therefore goes through some of the basic principles about cycles and cycling that should be known and applied by anyone engaged in cycle planning, or indeed in transport planning more generally. It also refers to *Cycle Infrastructure Design* with which you should all be familiar, but please note that some parts of this document have been criticised for being insufficiently robust on standards.

Conservation of momentum

The bicycle is the most efficient form of transport known to man, and one of the most versatile. But a weakness is that the energy for propulsion comes entirely from muscle power, which is limited. If moving the bicycle demands more energy than the body can comfortably provide, cycling becomes hard work, tiring and unpleasant.

Every time a cyclist has to stop and then re-start, it uses up as much energy as is required to ride an additional 100m. So routes that repeatedly require cyclists to give way are never going to create popular cycling environments. Similarly, one-way systems can increase the energy demands and make cycling less attractive.

The strong personal desire to minimise effort is why direct, energy-efficient and speedy routes are needed if cycling is to be popular, and why some people will cycle where they shouldn't if the legal alternative is too long or stressful.

Table 1 shows typical cycling speeds. Note that very few people cycle at less than 10 mph. Below this speed, balance is more difficult and cycling less comfortable. Above about 10 mph, however, a bicycle becomes largely self-steering, requiring only slight body movement to maintain stability.

Sports cyclist	20 - 30+ mph
Confident commuter	15 - 20 mph
General utility/commuter	10 - 15 mph
Children	10 - 20 mph
Leisure rider	10 - 15 mph

Table 1: Typical cycling speeds (on the level)

People automatically ride in the way that is most energy-efficient for them, and it is not widely appreciated that each cyclist has his or her own optimum rate of pedalling, or cadence. We would all recognise that making someone ride faster than they prefer will be tiring for them, but obliging someone to ride slower than their preferred speed for any significant time can be as uncomfortable.

The road network accommodates the range of cycling speeds very easily. If other infrastructure does not do likewise, people will either shun it, or are likely to ride at speeds that are unsafe for the circumstances.

Surface quality

Rough or uneven surfaces destroy momentum, making cycling harder work, and they also impair comfort and safety. Cycle tyres are narrow, pressures may be twice those of cars and bikes have minimal suspension. Good surface quality is more important for cyclists than for any other road user.

Upstands are a real problem. Cycle paths should *not* meet roads with dropped kerbs, but the road surface should be continued into the path to a perfectly flush join back from the junction itself. This is normal practice in road building and used to be normal for cycle paths too *(see photo lower left for best practice – notice also radiused kerbs)*.

Upstands crossed obliquely are a common cause of injury to cyclists. Just 3mm is sufficient to deflect a cycle wheel and throw its rider.

Observation and visibility

The ability to see clearly around you is essential for safe cycling, and in particular to be able to see others with whom you might conflict. Looking ahead is easy and most of the information that a cyclist needs about traffic conditions can be gained through eye movement alone, which is quick and has no effect on the stability of the bicycle.

Looking wider than this, however, requires head movement, which is slower and affects stability. It is more difficult to balance and control a bicycle when not looking ahead, and many people when cycling are not good at seeing what is going on behind them.

They are vulnerable when circumstances require them to move to the right, perhaps simply to go ahead where there is a left-turn lane.

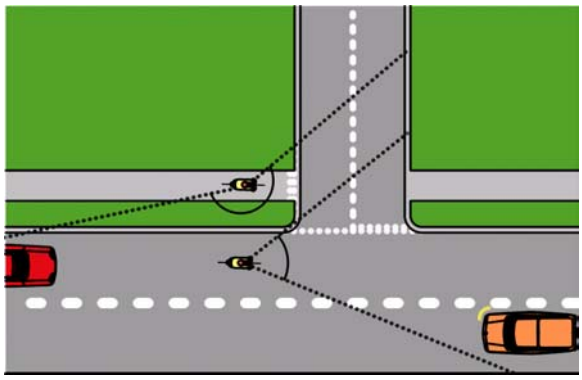


Figure 1

The difficulty of looking behind on a bike has important consequences for road-side paths and explains their poor safety record. Figure 1 shows how the road cyclist can use positioning to emphasise his presence and may then concentrate his attention ahead. The path cyclist, however, cannot exert any influence on drivers behind, and needs to look through a very large arc for possible conflict. This is difficult to do, even if you stop. Many people simply give a cursory glance and take the chance.

When planning for cycling, it is important to minimise the need for cyclists to look behind.

Personal space

The amount of lateral space available to a cyclist is very important for comfort and safety. For less confident people in particular, traffic passing too close is unpleasant and stressful.

Riding along, a cyclist takes up about 0.75m of lateral space at any time. However, bicycles move from side to side in the process of maintaining balance. The overall envelope of space needed by a cyclist under optimum conditions is about 1 metre *(Figure 2)*.

When a cyclist moves off from a standing start, or stops and dismounts, or travels slowly, more room is needed. Cyclists also have to move sideways where there are surface defects and the weather, particularly a strong wind, can make it more difficult to keep to a straight line. Extra space is needed for all these things and to provide a margin for error and natural 'drift'.

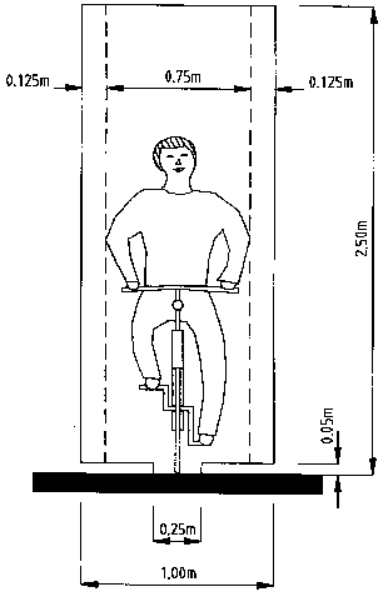


Figure 2

On a free-flowing road with traffic but no parking, a confident cyclist will ride with his front wheel at least 0.75m from the road edge, or 0.5m at elbow height.

It's a pretty good rule of thumb that other drivers give a cyclist as much room as the cyclist gives to the kerb; hence they pass about 0.5m from the off-side of the cyclist's personal envelope.

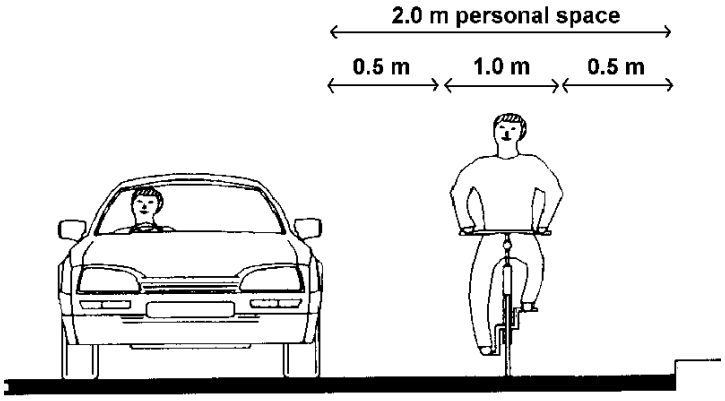


Figure 3

Adding it all up, the cyclist gets about 2m of personal space to accommodate the physical requirements of the bicycle and personal comfort. and that meets most people's requirements on a 30 mph road *(Figure 3)*.

If anything you do when planning for cyclists results in a cyclist getting less space than this, then you will most probably make cycling more difficult, less comfortable and perhaps less safe.

At traffic speeds above 30 mph, or where there are high-sided vehicles, a cyclist needs additional space to take account of the more pronounced slipstream and suction effects of traffic that affect steering. Personal space for cycling needs to allow for both traffic and weather conditions.

Road profiles

Road profiles relate the space available along a road to the requirements needed for safe and comfortable overtaking. Profiles are usually classified as spacious, narrow and critical.

A spacious profile *(Figure 4)* is one where there is plenty of room for motor vehicles to pass a cyclist leaving as much personal space for the cyclist as is appropriate for conditions. Spacious profiles can still lead to problems for less confident cyclists turning right if traffic speeds are high, but in most cases they result in a comfortable cycling environment.

Tight road profiles *(Figure 5)* are where there is insufficient space for a motorist to pass a cyclist to such a degree that this is obvious to everyone. Other traffic is obliged to wait behind until more space is available. Tight profiles lead to lower traffic speeds and may be safe, but cyclists can find them intimidating, being under pressure to move out of the way.

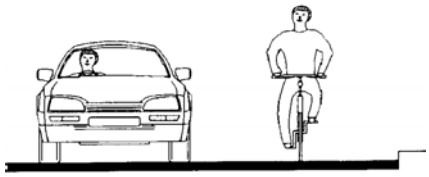


Figure 4

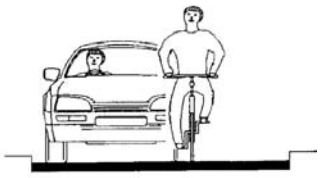


Figure 5

Critical profiles *(Figure 6)*, which lie between spacious and tight, are the most problematic. There is insufficient space for a cyclist to be passed safely, but drivers do not always recognise this. They try to get past by driving close to the cyclist. Sometimes a confident cyclist can use positioning to deter this, but this may result in aggression if the driver perceives the cyclist's behaviour as unreasonable. It is important to avoid critical profiles at all times if cycling is to be pleasant and popular.

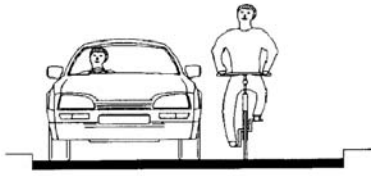


Figure 6

Cycle Infrastructure Design states that cyclists should be overtaken with a minimum passing distance of 1.5m at 30 mph. This requires 4.3m overall for a car to overtake a cyclist and 5.05m for a bus or HGV. From these space requirements, it follows that the critical profiles to avoid are between 2.75m and 4.25m at 30 mph.

Additionally, with regard to space for cycling, it is important to recognise the needs of people who use large cycles: tricycles, tandems, recumbents, bikes with child and goods trailers. Each of these has an important role in meeting the needs of people who wish to cycle, especially for families and people with disabilities. The cycling environment should seek to accommodate all types of machine in the same way that the roads accommodate all types of motor vehicle..

Risk and vulnerability

Risk when cycling is much misunderstood. Cycling is a very safe mode of transport, and one that becomes safer the more people who cycle. The fact that people who cycle regularly live longer and healthier lives than those who don't says it all.

So please don't get hung up about cycling safety and go for an over-protective approach to cycle planning – try to keep the risk in perspective.

Of course, many people have come to believe that cycling is anything but safe, and there is much that could and should be done to make cycling safer. It is very important to address perceptions about safety if we are to get more people to cycle. However, as professionals it is imperative that, in dealing with the perceptions, you understand the facts and you do not inadvertently make reality worse.

It is not traffic per-se that causes conflicts for cyclists, but crossing, turning and weaving movements, especially in situations where people have many distractions of their attention. Controlling speed through junctions and ensuring that crossing distances are short are important ways of minimising the vulnerability of cyclists. So, too, is encouraging co-operation and involving all road users in sharing responsibility. When road users share space, are aware of each other's presence and can predict behaviour, problems seldom arise.

The main cause of cycling casualties is not motor traffic but bad surfaces, probably accounting for more than 80% of injuries. In some towns, the most important thing needed to improve safety is to mend the roads.

Another common type of crash involves the opening of a vehicle door into the path of a cyclist. This is a problem made worse by many cycle lanes. Lanes such as the one illustrated on the left direct cyclists into the very area they should be avoiding. *Cycle Infrastructure Design* recommends a buffer zone of 0.5m to 1.0m

In queues of traffic, cyclists are also vulnerable to the opening of a nearside door; passengers often taking less care than drivers. Again, cycle lanes seem to be increasing this type of casualty.

Most cycling casualties, especially those that are not on the carriageway, are not recorded by Stats 19. In my work as an Expert Witness to the courts on cycling, around three-quarters of the cases I have dealt with have involved cycle facilities, a proportion grossly disproportionate to where most cycling takes place even when one takes account of the greater complexity of facility claims and thus the need for expert evidence. The greatest error you can make in planning for cycling is to assume that cycle facilities are inherently safer than cycling on the roads, for while the hazards may sometimes be different, they are often less predictable and can be just as life threatening.

On the right are shown the top five causes of facility injuries in cases that I have dealt with in recent years. These are not just bumps and scratches; each of these categories includes a fatality.

- Surface defects (33%)
- Visibility (22%)
- Cycle lanes (22%)
- Collisions with pedestrians (14%)
- Collisions with hardware and other obstructions (11%)

Table 2: Cycle facility crashes

It is for good reason that so many cyclists rebelled at the suggestion, when the latest Highway Code was in draft, that cyclists should use facilities where provided and why they are so often ignored. It is important to respect the judgement of users and to understand the fundamental limitations of planning for cyclists apart from motor traffic.

Cyclists and pedestrians

Cyclists and pedestrians are often considered together. Both are vulnerable road users, but that is as far as the similarity goes.

Table 1 showed typical cycling speeds. Notice how much greater are all these speeds compared with the 3 - 4 mph at which pedestrians walk. The minimum speed for cycling is 2.5 times that of a pedestrian, while faster cyclists travel at more than 5 times the speed, much closer to the speed of motor traffic.

The energy 'cost' to a cyclist of stopping and re-starting is 80 times that for a pedestrian. The rolling wheel of a cycle is much less tolerant of poor surfaces and cannot simply 'step up' when a change of level is encountered. Cyclists cannot turn on the spot, move sideways or stop suddenly – 3 characteristics on which a lot of pedestrian safety critically depends.

In fact, cyclists have very little in common with pedestrians and facilities designed for pedestrians are rarely suitable for cycling.

It is time to consign the shared-use footway to history. *Cycle Infrastructure Design* notes that: "Creating space for cyclists by taking footway space is generally the least acceptable course of action." Also: "Off-road cycle routes in urban areas tend to be the least desired option, and it is usually better to cater for urban cyclists on-road."

The most fundamental shortcoming of cycling policies in many places, in my view, is that too often planning for cycling has been considered as something more analogous to planning for pedestrians than to planning for vehicles. This inevitably results in a low quality cycling environment:

- Facilities unsafe at typical cycling speeds, but still slower and more tiring than roads
- Safety that relies on cyclists behaving as pedestrians
- Problems of upstands and obstructions (lampposts, signs, etc)
- Frequent changes of level

Cycle networks

There is often emphasis on building 'networks' of cycle routes. Except for the special case of leisure routes, cycle networks are much less important for cycling than is sometimes thought.

Most people will not go out of their way to use cycle routes and there is usually a poor mismatch between cycle networks and the places where most people cycle. The fact that a particular road or path is part of a network linking all the way to Inverness is of no importance whatever at the local level, and in most cases nor is the fact that it continues to the other side of town. For the most part, people need the ability to make local journeys easily.

For reasons explained earlier, cyclists have a strong inherent desire to minimise energy, and that means that they will take the most direct route they can. Cyclists and pedestrians are the least 'routeable' of all the transport modes: their need is not for distinct networks, but fully permeable towns, where every road is a cycle route and there are no unreasonable barriers to free and safe movement.

It can be frustrating when schemes are sometimes driven by the desire to 'complete a link in a network', particularly when this results in the acceptance of low standards, just to get something in. Schemes should only be implemented where there is a need, a clear benefit to cyclists as a whole and the ability to produce a high quality result.

Cycle training

A very positive development is the growth in availability of cycle training in the UK. Modern cycle training is based on the principles of vehicular cycling and teaches cycling technique in a similar way to teaching someone to drive a car: how to integrate with traffic rather than to keep away from it. It teaches people to respond dynamically to the changing traffic situation around them, rather than to follow a rigid set of rules, for this is the safest and most efficient way to cycle.

It is very important that cycle planning does not undermine or inhibit safe cycling technique by requiring cyclists to ride in a non-vehicular manner.

The single most important skill taught is positioning, through which cyclists can exert the greatest influence over their safety. The aims of positioning are to ride where you can best see and be seen; where you may deter others from putting you at risk; and where bike control is easiest.

In practice, good positioning means riding relative to – and often within – the moving traffic lane *(Figure 7)*, *not* relative to the kerb, and to keep away from the places of greatest risk such as by the give-way lines at side roads and roundabouts. This practice has important consequences when planning for cycling, and in particular the provision of facilities such as cycle lanes which can restrict the ability of cyclists to manoeuvre safely.

It is also very important for safe cycling that cyclists follow the same rules as everyone else. That way there is no ambiguity as to how a cyclist should behave and how others interpret his or her actions. If special infrastructure requires cyclists to behave differently to when cycling on the roads, it will undermine cycling standards and safety. This is another important reason why cycling infrastructure must be vehicular in design and not based on pedestrian practice.

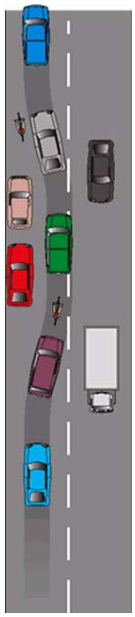


Figure *7*

The road network

The overwhelming majority of cycling takes place on the general road network and it is unlikely that any alternative could be provided that would better meet the needs of cyclists in terms of access, ease of use or safety. Planners and engineers have far more potential to encourage cycling when designing ordinary roads than by implementing cycle-specific infrastructure.

Cycle Infrastructure Design notes: "The road network is the most basic (and important) cycling facility available, and the preferred way of providing for cyclists is to create conditions on the carriageway where cyclists are content to use it, particularly in urban areas".

So what are the main problems?

I've already mentioned that cyclists need sufficient space to operate. One of the greatest space-related hazards today is the centre island which results in a critical profile for cycling. They are a considerable deterrent to cycle use, even when traffic speeds are not high. Where pedestrians need to cross, use of a zebra or controlled crossing would better meet the needs of both pedestrians and cyclists.

Lane widths have an important impact on the perception of safety, and narrow lanes can be very stressful. Conversely, widening the nearside lane on multi-lane roads can be a very useful way of giving cyclists extra space without imposing the constraints of a cycle lane or disadvantaging anyone.

Sometimes there is too much space around. Large radii at junctions can encourage higher speeds while making it more difficult for drivers to see cyclists. At the same time there is more 'unprotected space' for cyclists to cross where they may feel vulnerable.

Large roundabouts are an example of this problem. The use of tighter, continental geometry – as recommended in *Cycle Infrastructure Design* – can help to reduce risk, or use some other form of traffic control.

A general reduction in vehicle speeds would be the best action to allow more people to cycle and there is increasing pressure from communities for area-wide 20 mph zones. But it is not just absolute speed that is important but also the way that vehicles are driven. Places where drivers continually brake and accelerate are sometimes more intimidating for cycling than free-flowing roads with higher speeds.

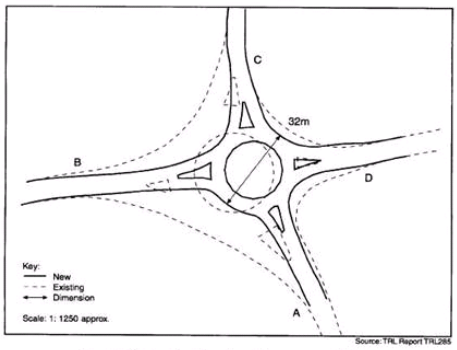
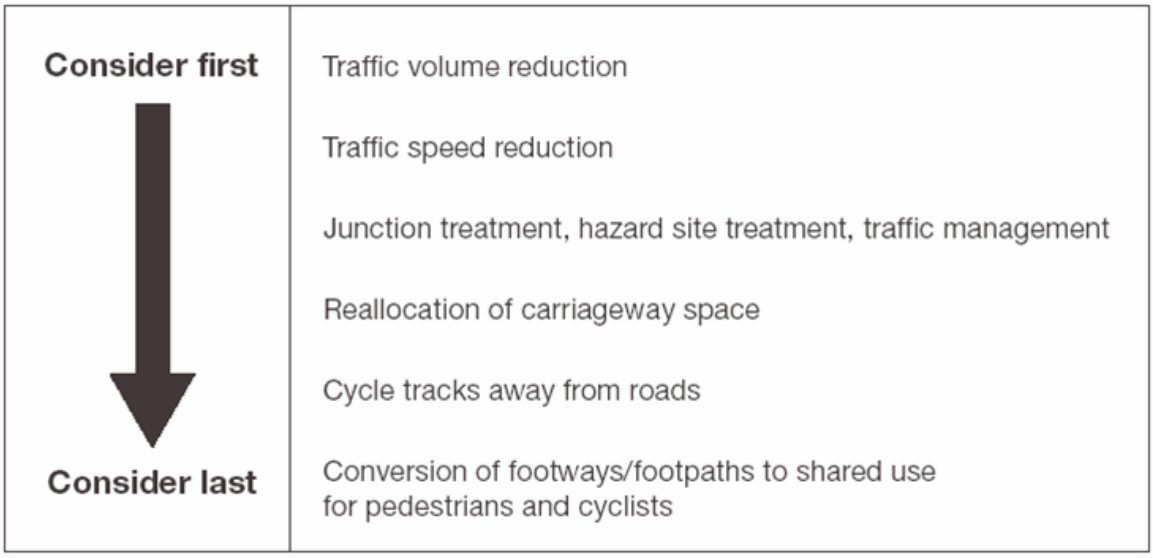


Figure 11 Continental redesign of roundabout geometry, Abingdon

A common hazard is the overtaking of cyclists by drivers who then cut in to turn left. Sometimes road design *(see left)* encourages drivers to do this by making it easy to leave the through road fast. Motorists would need to drive more carefully if their path was less direct.

I've mention that cyclists need direct routes. In an increasing number of countries, cyclists are being exempt from one-way restrictions to improve permeability by bike. People are pragmatic: if its easier to get somewhere by bike than by car, many will do so.

Hierarchy of provision



Cycle Infrastructure Design repeats, upfront, the Hierarchy of Provision when planning for cyclists. What you should consider first – traffic volume and speed reduction, junction treatment and traffic management measures – have much more potential for wider benefit than options lower down. However, please don't assume that if you can't do something higher up, then you *should* do something lower down. In many cases a 'do nothing' option is preferable to inappropriate cycle facilities that may make cycling more difficult and lead to hostility and aggression towards the many people who will not prepared to use them.

Although people vary, *Cycle Infrastructure Design* notes that for most utility cyclists, convenience (in terms of journey time or distance) is their most important consideration.

Cycle facilities

That brings me to the role of cycle facilities in providing a better environment for cycling.

The most useful facilities are those that enable shorter or quicker journeys, or open up access not available to other traffic. Exemptions from traffic management restrictions, links between minor roads and, of course, cycle parking are all examples of things that help cycling. Routes away from traffic can sometimes provide useful shortcuts or pleasant places for leisure trips.

Much more controversial are facilities alongside roads. I explained earlier how much more difficult it is to see turning traffic from a cycle track than from the road.

And I also emphasised the importance of personal space. This is one reason whey many cyclists do not like cycle lanes. Unless cycle lanes provide within themselves all the personal space a cyclist needs – that is, they are at least 2m wide – cyclists will often be passed more closely than would otherwise be the case and research shows that motorists often overtake faster too. Just as important, lanes narrower than 2m give misleading messages to motorists about the amount of space that a cyclist needs, not only where there is a cycle lane but also where there isn't. In this way, they can be detrimental to the wider co-operation on the roads that is so important.

Cycle lanes can sometimes make it easier for cyclists to pass stationary traffic, but that does not override the need for them to be safe, which means wide. Approaching junctions, they can encourage cyclists to ride up the inside of left-turning vehicles – one of the principal causes of fatalities – and are therefore best avoided where left turns or long vehicles are common.

Cycle lanes should never cross side roads, as they direct cyclists into the very place where risk is greatest. It is essential that cyclists are never encouraged to ride where their safety depends critically upon others obeying the rules.

Cycle Infrastructure Design notes: "Cycle lanes are not always suitable and may encourage cyclists to adopt inappropriate positioning if the lanes are poorly designed. Designers need to decide whether a cycle lane is going to help or not. If so, its alignment should ideally reflect guidance and training on safe techniques (Franklin 2007) for manoeuvres undertaken by cyclists." As the author of the reference to which this refers, it is my view that there are few instances in urban areas where cycle lanes allow cyclists to position properly.

Where lanes are to be provided, *Cycle Infrastructure Design* supports the need for them to be 2m wide. The concession of an absolute minimum width of 1.5m is unsatisfactory, acceptable only if there is a further 0.5m of adjacent hatching (which in any case is useful in making it clear that this is not a general traffic lane).

Some people suggest that we need cycle tracks and lanes for less experienced people and children. But you should always ask yourself whether less skilled riders can really be expected to deal competently with hazards that more experienced cyclists find so difficult.

Research shows that where there is separate infrastructure: "Most bicycle accident victims are older people and children. They are put at risk by the complexity of cycle paths on the one hand and on the other hand by their over-confidence that their safety on cycle paths is substantially greater than on the road." [Viennese state research]

That is not to say that cycling infrastructure is never appropriate. However, there are probably few aspects of traffic engineering where getting the detail right is so important.

The Dutch example on the right shows how cycle tracks should be. A decent verge, centre lines, a good and unobstructed surface and a separate footway for pedestrians. Good forward visibility, no close vegetation and signs to warn of all hazards are also important as, of course, is safety and ease of use at junctions.

A cyclist should at all times expect to receive a similar level of service to that on a road.

Audits

If you are designing infrastructure for cyclists, imagine yourself driving along it in your car. If there's anything that would cause you concern as a motorist, go back to the drawing board and put it right! It's important that you value the expectations of cyclists as highly as those of motorists.

All highway and cycling schemes should be subject to a safety audit, and it is important that these properly assess the impact on cyclists. Personal space, inter-visibility, relative speed, surface quality and the implications for good cycling practice are all important aspects of conducting a cycle-conscious safety audit.

Key audit criteria

- Personal space
- Road profiles
- Inter-visibility + distractions
- Relative speed
- Surface quality
- Impact on vehicular cycling

More generally, there is a need to audit the existing road network to see where changes could benefit cyclists. In keeping with the Hierarchy of Provision, you should be looking principally to see how the roads can be made more cycle-friendly rather than where you might introduce cycle facilities. In my experience, audits that measure personal space and assess the profile of roads give the most useful results.

Conclusions

So what are the priorities for cycle-friendly towns and cities?

- Don't treat cyclists as pedestrians. Pedestrian infrastructure has no place in creating a popular cycling environment and will always deliver poor value for money.
- Focus on short journeys and make the overall urban environment right for cycling rather than work against it. This is the priority. It means following the Hierarchy of Provision, lower speeds, cyclist compatible junction design, good permeability and direct access. In most cases it should not mean cycle-specific infrastructure.
- Adopt an evidence based approach to cycle planning. Implement schemes because there is good evidence of likely benefit and it is wanted by cyclists, not just to 'do something' or complete a network. Do what you do to a high standard – always use vehicular design.
- Develop good audit procedures to identify the main barriers to cycling, to assess all road and development schemes for their impact on cyclists, and to discover what has actually happened after the event.
- Always remember, cycling needs to be safe, comfortable and speedy. All three are priorities if more people are to cycle

Quotations

I end this paper with two quotations. The first is by the American, John Forester, but it has its roots when John cycled in Bristol as a child and is just as relevant to the UK today:

"Cyclists fare best when they act and are treated as drivers of vehicles
– same roads, same rights, same rules"

The second quotation is from Ernest Marples, a former Minister of Transport who was himself a cyclist:

"If you make conditions right, there's a great future for cycling.
If you make them wrong, there's none."

John Franklin
john@cyclecraft.co.uk
http://www.cyclecraft.co.uk