International Transport Forum

Cycling Safety: Key Messages

International Transport Forum Working Group on Cycling Safety

Preliminary Findings

OECD

INTERNATIONAL TRANSPORT FORUM

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These key messages result from the International Transport Forum working group on cycling safety chaired by Niels Tørsløv, Director of the Traffic Department for the City of Copenhagen. The final report and messages will be released in September 2012.

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CYCLING SAFETY: KEY MESSAGES

1. Setting the Groundwork for Safe Cycling

Bicycles belong in the urban mobility mix

Bicycles are an essential part of the urban mobility mix. They use no fossil energy, deliver important health benefits, and improve the liveability of cities. In low income regions the bicycle offers perhaps the only affordable way of getting to work, to earn income and to access basic living needs. In high income urban areas the bicycle is becoming more popular or returning to popularity. In some cases cycling dominates the urban traffic mix.

The attraction of the bicycle resides in its ability to provide an affordable and seamless door-to-door mobility service – it is as versatile as walking but can cover greater distances at faster speeds. It represents an alternative to cars and allows for greater freedom of movement than scheduled public transport services. Bicycles are well suited to respond to the great number of short trips that are typical for urban mobility. That many cities are introducing advanced public bike systems is a clear indication of that bicycling is becoming a central part of the mobility solution in many urban settings[1]. Beyond public bike sharing systems, there are a number of pro-cycling policies and frameworks that are being implemented throughout ITF countries. Crucially, however, while there are many reasons to promote cycling, (improved) safety is not foremost among them.

Cyclists are vulnerable road users.

Road traffic is inherently unsafe. Traffic infrastructure is seldom designed with safety as a starting point and though efforts are made to accommodate the wide range of behaviours displayed by road users, errors and unpredictable or impaired actions often lead to crashes. The kinetic forces involved resulting from the differences in mass and velocity of crash opponents largely dictates the severity of the outcomes. Crash outcomes are especially severe for vulnerable road users such as pedestrians and cyclists who lack by far the same level of protection mandated for, and offered to, car and other vehicle occupants. Single bicycle crashes are also a source of injuries through falls and collisions with obstacles and can result in serious injuries, especially for elderly cyclists and those unprotected by helmets. Studies investigating the comparative risk of injury for cyclists versus car occupants find significantly higher risks per unit of exposure for cyclists: e.g. 7.5 times higher injury risks in Norway (Elvik, 2009) and 5.5 times higher fatality risk for the Netherlands (CBS, 2008)

[1] It should be noted that the same level of freedom offered by the bicycle may also be offered by powered two-wheelers, either electric or fossil-fuelled. This report does not address these vehicles though they face important safety challenges.

The road traffic system is not designed for cyclists

Part of the "built-in" unsafety of cycling is that the road system has, with some notable exceptions, not been designed for cyclists. More precisely, the road system has not been designed for mixing well-protected, heavy and high velocity vehicles with unprotected, lightweight and slower road users. Furthermore, the traffic system does not typically account for the specific characteristics of cyclists and bicycles. Cyclists are highly flexible and sometimes unpredictable road users, riders display very different abilities, cyclists seek to minimise energy expenditure, bicycles can be easily de-stabilised and are relatively difficult to see because of their size (in daytime) and their poor or lack of night-time lighting. Though cycling is an important component of urban mobility, cyclists are often seen as intruders in the road system.

Do policies that increase the number of cyclists contribute to more unsafety/crashes?

This is an important question because if cyclists are vulnerable and the road system is not designed for cycling, then pro-cycling policies could conceivably expose a greater number of people to potentially dangerous conditions. The short answer to this question is that when the number of cyclists increase, the number of crashes, both fatal and non-fatal, may increase as well – *but not necessarily so* if attention is paid to good policy design. Furthermore, the incidence rate of cycling crashes may decrease, *especially if accompanying safety-improving policies are implemented.* A fuller answer to this question must address four crucial variables whose understanding is essential in the cycling safety debate:

- The linkage between cycling, safety and health
- The safety in numbers effect
- The strong under-reporting bias in cycling crash statistics
- The lack of adequate exposure data

Cycling, safety and health are undissociably linked

A discussion of the impact of cycling on road safety should not be isolated from a broader discussion of the overall health impacts of cycling. Indeed, if we are concerned that increasing the number of cyclists may increase crash numbers or risks, it is because of the deleterious effects of crashes on cyclists' health. Crashes, however, are not the only vectors that can impact cyclists' health – exposure to air pollution can negatively impact cyclists health just as cycling-related exercise can (greatly) improve cyclists' health. Pursuing *increased safety* for cycling makes sense no matter what the balance of positive/negative health outcomes (since these policies expressly reduce the negative outcomes linked to crashes) but this balance is essential in helping frame efforts to *increase cycling*.

Cycling significantly improves health

We discuss further on the evidence on cycling crash rates and severity. Here, we discuss the balance of non-crash related health impacts of cycling. The most important point to retain is that cycling, as a form of moderate exercise, can greatly reduce clinical health risks linked to cardiovascular disease, obesity, Type-2 diabetes, certain forms of cancer, osteoporosis and depression. Taken separately and even more so when effects are cumulative, these conditions exact a high human and economic cost on society. This health improving-effect is robust across different studies and in different geographic contexts (Table 1). There is evidence that the range of morbidity-reducing effects are greater than that of mortality-reducing effects – not only does cycling reduce disease-related *deaths* but it also contributes to substantially better *health*.

Table 1: Quantified relative risk of all-cause mortality for cyclists compared to non-cyclists

Relative risk expressed as a ratio of *all cause mortality of cyclists* compared to non-cyclists after controlling for confounding factors (age, gender, education, etc.) – e.g. a relative risk result of 0.70 indicates that a cyclist has a 30% reduction in risk of death than a similar non-cyclist.

Location	Relative mortality risk (cycling/non-cycling)	Confidence interval	Study
Copenhagen, DK	**0.72**	0.57-0.91	Anderson *et al*, 2000
China	**0.79**	0.61-1.01	Matthews *et al,* 2007
China (high activity)	**0.66**	0.40-1.07	Matthews *et al,* 2007
Finland	**0.78**	0.65-0.92	Hu *et al*, 2004
Finland (high activity)	**0.69**	0.57-0.84	Hu *et al*, 2004

Cyclists register higher doses of particulate matter than car drivers

On the other hand, cyclists' health is negatively impacted by exposure to air pollution – especially fine particulates and ozone. This risk, at least when compared other urban travellers (car, bus, metro), has often been downplayed by the finding that average concentrations of suspended particulate matter (especially fine particulate matter) are rarely significant between cyclists and car drivers – and slightly higher on average for car occupants. However, this finding ignores a crucial variable – ventilation. Cyclists breathe more often and more deeply than car occupants. Thus while ambient levels of particulate matter may be similar, actual particulate deposition within the lungs of cyclists is much higher – by several orders of magnitude. Controlling for real measured ventilatory effort, one study found that inhaled μg $PM_{2.5}$/km and μPM_{10} is 400% to 900% higher for cyclists compared to car occupants travelling on the same trajectory in the same traffic and meteorological conditions (Int Panis et al, 2009). This finding suggests that cyclists' health could be improved by locating bicycle facilities away from road traffic where indicated – especially for sections where cars are accelerating (hills, long straightaways).

Recommendation 1:

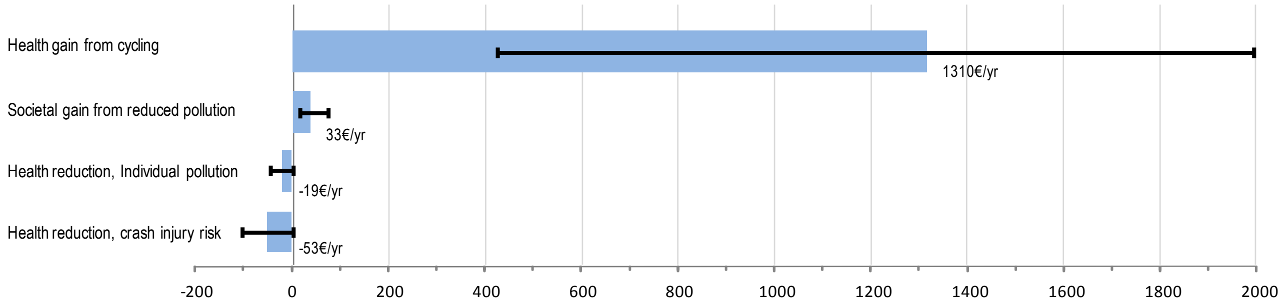
Where it does not reduce the quality of cycling networks, bicycle facilities should be located away from road traffic when feasible – especially for sections where cars are accelerating (hills, long straightaways).

On balance, the positive health impacts of cycling far outweigh negative health impacts

Reviewing evidence from studies looking at the full spectrum of cyclist health impacts (including crash-related injuries and air pollution) while controlling for exposure and crash under-reporting, indicate that the estimated health benefits of cycling are on average substantially larger than the relative risks compared to driving a car for individuals shifting their mode of transport (de

Nazelle, et al, 2011), (Rabl and de Nazelle, 2012), (de Hartoog et al. 2010), (Int Panis, 2009) and (Rojas-Rueda et al. 2011).

Figure 1: Estimated mortality costs and benefits per individual switching from car to bicycle for work trips* in large European cities



* 2x5km daily roundtrip, 5 days per week, 46 weeks per year

Error bars represent upper and lower (%% confidence intervals.

Source: Rabl and de Nazelle, 2012

Monetisation of incommensurate health impacts allows for comparison of these along a common scale. For large European cities, (Rabl and de Nazelle, 2009) find that on average the positive health gains for an individual resulting from a switch from car to bicycle commuting add up to €1343 per year (Figure 1). They find the negative health impacts, including those linked to crash-related mortality, result in a loss of €72/year – or 19 times less than the benefits. The principal finding that the health benefits from cycling dwarf all other variables is robust to a range of assumptions regarding specific variables and monetary values. Considering *morbidity* in addition to *mortality* would likely increase the numbers for individual and societal air pollution-related impacts by approximately 50% and increase the number for the health gain from cycling by more than 50%. At the same time, costs related to non-fatal bicycle accidents would be significantly higher (estimated, for instance by (Aertson et al, 2010) to be €0.125/km in Belgium) implying a cost of €286/yr – or 5.5 times more than in the scenario outlined in Figure 1.

"Safety in Numbers": Cyclist safety is linked to the number of cyclists in traffic but causation is uncertain.

Many researchers and observers have noted a correlation between cyclists' numbers and increased safety expressed as a decrease of the incidence rate of severe/fatal crashes involving cyclists. The "safety in numbers" effect has been cited widely but *correlation* does not imply *causality* and there are numerous possible explanations for the observed effect. At the centre of the phenomenon is the observation of non-linearity of risk: an increase of exposure (numbers, volumes, etc.) results in a less than proportional increase of the number of crashes (Eenink et al., 2007). This implies that if the number of vehicles increases, the crash rates will go down. The risks of cyclists are also non-linear, that is to say an increase in numbers results in a non-proportional increase of crashes (Elvik, 2009).

"Expectancy" is one way of explaining this non-linearity. That is to say: if a road user expects the presence of another road user, or can predict the behaviour of that other road user, one may expect lower risks (Houtenbos, 2008; Räsänen and Summala, 1998). In this respect, it may be more precise the re-cast "safety in numbers" as "awareness in numbers" (Wegman in Mapes, 2009). An alternative explanation for the "safety in numbers" phenomenon is that cycle-safe traffic systems attract large numbers of cyclists – large numbers of cyclists in countries such as the Netherlands, Denmark and Germany are associated with high densities of bicycle facilities (Bhatia & Wier, 2011). There is no solid evidence that low fatality rates can only be explained by 'numbers' alone. Critically, if policy simply adds more cyclists to the system without other risk-reducing measures, than greater unsafety may result.

Recommendation 2

Insufficient evidence supports causality for the "safety in numbers" phenomenon – policies increasing the number of cyclists should be accompanied by risk-reduction actions.

Authorities lack the factual basis with which to assess cycling safety or the impact of "safety-improving" policies

In the course of this review of cycling safety, it has become clear that most national authorities and many regional/municipal authorities simply lack the basis on which to assess both cyclists' safety and the impact of "safety-improving" policies. At the core of safety assessment is the calculation of crash incidence rates (typically split into fatal crashes and others of varying degrees of severity). Schematically; safety (expressed as the crash incidence rate) is the quotient of the number of crashes divided by a measure of exposure or bicycle usage.

$$\text{Safety (Incidence Rate)} = \frac{\text{Number of crashes (fatal, severe, less severe)}}{\text{Measure of exposure (trips, kms, hrs)}}$$

In many cases both numerator and denominator are inadequately measured or may be missing altogether.

Cycling crashes are significantly under-reported

Under-recording of bicycle accidents is an essential problem for cyclist safety analysis. The underlying reason of under-recording is that personal injury accidents are not systematically registered. In the context of the present report, it should be kept in mind that the analysis that follows in this report is based solely on data of recorded bicycle accidents. Under-recording is not limited to bicycle accidents or certain countries, it is in a certain way inevitable and concerns all types of vehicles and all countries (OECD-IRTAD, 2011). Under-reporting is less prevalent when considering *fatal* crashes involving cyclists though there are discrepancies in criteria for attributing post-crash deaths to specific traffic incidents. Poor coordination between police and hospital record-keeping also contribute to inexact crash-related fatality data.

Recommendation 3

Efforts must be made to harmonise definitions of bicycle accident terminology so as to be able to make reliable international comparisons on cyclist safety.

Under-reporting of *non-fatal* cycle crash related injuries is much more prevalent and hampers road safety assessments. Under-reporting complicates the analysis of long-term trends and poor or biased recording hides the true picture of cycle safety. In particular, underreporting hampers assessment of the social implications of bicycle accidents (both in quantity and quality) and misinforms policy making. In the absence of an objective point of reference and comparison, it is also difficult to set quantified goals for reducing the number of cycling road accident victims.

There is evidence that among all road crash participants, cyclists are the least recorded (Broughton *et al*, 2008); (De Mol and Lammar, 2006). Even injured pedestrians are better recorded. There are numerous reasons for this. When there are no seriously injured persons or immediate physical complications (whiplash injury, light concussion, etc.), parties involved generally do not inform the police or, when informed, the police does not always go on the spot. When only vulnerable road users such as cyclists are involved, it is less probable that the police intervene than for car crashes. Another reason for under-recording is that the fewer people involved in a non-severe crash, the smaller the likelihood of records being filed (Elvik and Vaa, 2004), (Vadenbulcke *et al*, 2009).

How severe is under-reporting of cycling crashes? Quite severe – a conservative assessment for Europe finds that police records only capture 50% of hospital admissions for traffic-related cycling injuries (De Mol and Lamar, 2006). Another assessment for the United States finds this figure to be only 10%. (Pucher and Dijkstra, 2000). An in-depth prospective cohort-based study for Belgium confirms strong underreporting of non-fatal crash-related injuries finding that only 7% of non-severe bicycle crashes were recorded in police statistics (de Gueus et al, 2012), (Vandenbulcke et al, 2009) – a low figure confirmed in other studies (Van Hout, 2007), (Elvik and Mysen, 1999).

Recommendation 4

National authorities should set standards for, collect or otherwise facilitate the collection of data on non-fatal cycling crashes based on police reports and, in either a systematic or periodic way, on hospital records.

Lack of bicycle usage and exposure data hinders safety assessment

Most countries and/or cities are ill-equipped to assess cycling safety because of a lack of accurate and detailed information on actual bicycle usage. This lack of exposure data is a real hindrance to understanding the current status of cycling safety and complicates the assessment of the impact of policies on cycling safety. This makes it difficult to answer questions such as how safe is cycling, and how does cycling compare to other modes of travel? Without information about distances cycled in different countries it is difficult to compare the safety of the cycling systems in those countries. Crucially, exposure-based injury rates allow authorities to understand if policies improve safety by *reducing exposure* (e.g. by decreasing bicycle use) which, given the benefits of cycling would be a bad thing or if they increase safety by decreasing crash-related injuries for a same level of usage.

Arguably, the best measures of cycling exposure are distance, or time, cycled. In the absence of this information, proxy exposure measures can be used, but these are far less accurate. For example, length of cycling infrastructure in a particular country might give an indication of how much cycling occurs in that country. However, of course it is possible that a country has a great deal of cycling infrastructure, without this infrastructure necessarily being used much. Other proxy measures include number of bicycles owned (some of which go unused) and population (many of whom don't cycle). Rates calculated using the less accurate indicators of exposure should be treated with caution.

Recommendation 5:

National authorities should set standards for, collect or otherwise facilitate the collection of accurate, frequent and comparable data on bicycle usage.

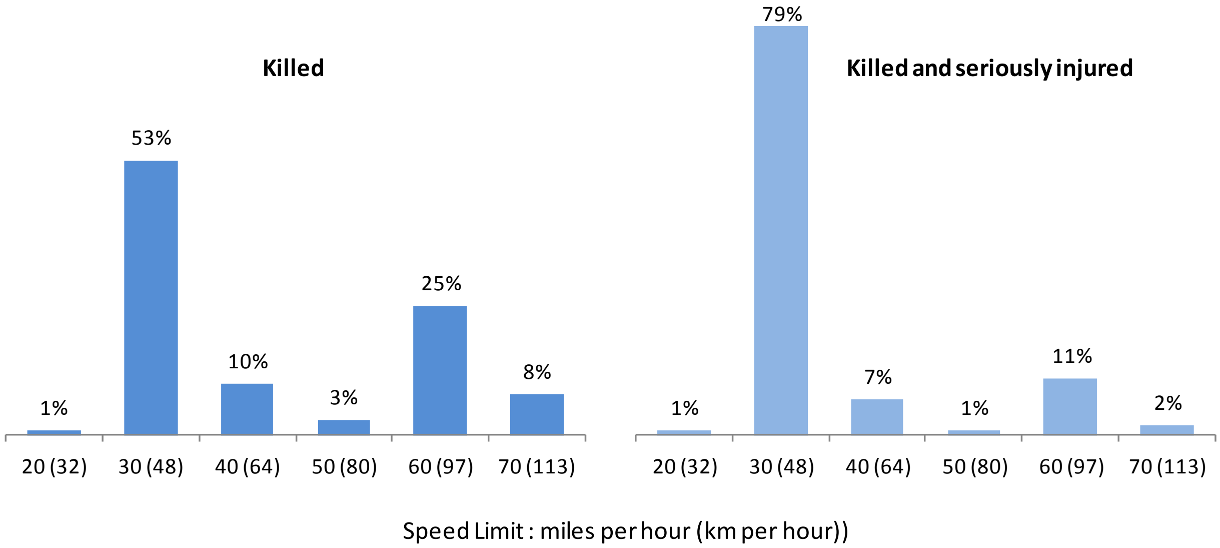
2. Review of evidence on cycle safety status and trends - What do the numbers tell us?

The Working group collected data from countries on cycle crash statistics in order to assess the status and evolution of cycle safety in those countries. However, it is important to recognise that data were returned by a fairly restricted number of member countries. Several of these respondent countries are recognized as providing an excellent cycling environment, while even the worst of them are fairly good. Given this and the caveats on underreporting and lack of accurate exposure data noted above, we can say the following based on the working group's scan of cycling safety amongst working group countries:

Crashes most likely when exposure is greatest, severe crashes most likely when traffic speeds were above 40 km/hr are high and at night.

Crashes involving cyclists seem to be relatively constant over time according to the working group member survey results but the rates differ greatly from country to country. Based on the data from the small number of respondent countries, cycling crashes are most likely when exposure is likely to be greatest: during peak travel periods (in the morning, middle of the day, and afternoon), during the week in countries where cycling is a typical mode of transport (and otherwise on the weekend), during seasons when the weather is most conducive to cycling or when the cycling surface is dry. That most cycling takes place at these times is most likely simply a reflection that those times and surface conditions are most suitable for cycling.

Figure 2: Percentage of cyclists killed, or killed and seriously injured, at different speed limits in the UK for the year range 2005-2007 (data from Knowles et al., 2009).



The general pattern was for most fatal and injury crashes to occur in low speed limit zones (40-50km/hr, and 60km/hr in Australia), which is likely to reflect greater cycling exposure in these speed limit zones. For fatal crashes in particular, there was a second peak in 70-80kmph zones, presumably reflecting higher chance of fatality for crashes occurring at higher speeds (see Figure 2). The impact of traffic speed on cycle crash risk and severity highlights the value of speed management as "hidden infrastructure" that protects cyclists.

Recommendation 6:

Speed management acts as “hidden infrastructure” protecting cyclists and should be included as an integral part of cycle safety strategies.

Though there is likely to be relatively little cycling at night, a fairly high percentage of fatal crashes occur at night in several countries and particularly the USA (NHTSA, 2009), (Knowles et al., 2009). Thus, there is an argument for directing resources to improve cycling safety towards not only towards peak periods but to improve safety at night as well.

Collisions appear to more common than single bicycle crashes but this finding may reflect reporting bias.

Collisions appear to be more common than falls, and collisions with motor vehicles most common of all. Although this is may partly reflect a sampling bias in the police-recorded data, because collisions with motor vehicles are likely to have the most serious outcomes and thus warrant attention in interventions to improve cycling safety. Indeed, (de Geus et al, 2012) find that for non-fatal minor accidents recorded in a prospective cohort study of Belgian cyclists, “slipping” represents 33% of all crashes and 36% (with collisions with cars representing 11% of crashes and 19% of injuries). This is consistent with that study’s conclusion that such minor crashes are underreported in police records. Another study of cyclists reporting to emergency departments in California, New York, and North Carolina (Stutts and Hunter, 1999) found that 70% of the bicycle injury events did not involve a motor vehicle, and 31% occurred in non-roadway locations (such as sidewalks, parking lots, or off-road trails), although bicyclists struck by motor vehicles in the roadway tended to be the most seriously injured. Spain appears to have a particular issue with collisions with trains – which appear to almost always be fatal. In counties with high bicycle traffic (Belgium and Denmark) crashes with other cycles account for 5% of injury crashes (but fewer fatal crashes).

Cyclists seem to be at fault in less than half of all crashes,

Cyclists are probably at fault in less than half of all crashes. Cyclists were reported to be at fault in 60% of fatal crashes in Australia, and 40% in Spain. However, these percentages may exaggerate the role of cyclists, given that the cyclist is not available to give their point of view. In Denmark, where the operationalisation of fault is more objective (not having right of way) the percentage is lower (24%). In the UK, crashes are more often deemed to be the fault of the cyclist, whereas crashes in which the cyclist was killed or seriously injured are more often deemed to be the fault of the motorist (Knowles et al., 2009). Another study (Rowe, and Bota, 1995) report that amongst cyclist fatalities in Ontario, bicyclist error was the most common cause of crash for bicyclists aged less than 10 years (79%), bicyclists aged 10 to 19 years (55%) and bicyclists aged 45 years or more (44%), whereas motorist error was the most common cause of crash for bicyclists aged 20 to 44 years (63%).

Recommendation 7:

Cyclists should not be the only target of cycling safety policies – motorists are at least as important to target.

Metropolitan areas dominate in terms of crash numbers; rural crashes are disproportionately fatal or severe in several countries.

Overall crashes are more common in metropolitan than non-metropolitan areas. For fatal crashes, Belgium, France and Spain demonstrated a reversal in this pattern, whereas crashes were roughly evenly distributed across metropolitan and non-metropolitan areas in Australia. For injury crashes all respondent countries adhered to the general pattern, although Belgium and Spain have a higher proportion of injury crashes in non-metropolitan areas than other countries. These patterns are likely to reflect where the most cycling occurs, in combination with the density and speed of traffic in these areas. Thus, Belgium, France and Spain may have a greater proportion of cycling in non-metropolitan areas than the other countries, and crashes in these areas might often be fatal due to high traffic speed. Recent UK data showed that while almost three quarters of killed or seriously injured cyclists were injured on urban roads, almost half of cyclist fatalities occurred on rural roads, indicating that while the frequency of injuries is greater on urban roads, the severity tends to be greater on rural roads (Knowles et al., 2009).

Crashes are generally less common on cycling-specific infrastructure than on infrastructure that is not cycling-specific

Overall, crashes are less common on cycling-specific infrastructure than on infrastructure that is not cycling-specific – although arguably the cycling-specific infrastructure carries more cycle traffic. This may partly be an artefact of the data source in most countries being police-reported crashes – which sometimes exclude crashes that do not occur on the roadway. Nonetheless, the data may also reflect a safety benefit conferred by various aspects of cycling-specific infrastructure – such as separation from traffic, lower speeds and speed differentials, and fewer intersections (see below) – particularly for differences between on-road lanes and on roads not marked with bicycle lanes (since both would be recorded in police-reported data). The most recent UK data shows that 97% of cyclists involved in collisions resulting in a serious injury or fatality were on the main carriageway and only 2% on a marked cycling lane on the main carriageway (Knowles et al., 2009). However, it is noteworthy that in Denmark injury crashes are more common on on-road bicycle lanes than on roads not marked with bicycle lanes – perhaps reflecting exposure.

A disproportionate number of crashes occur at intersections, including intersections between cycling infrastructure and roads

A fairly high proportion of crashes occur at intersections -- between approximately 20 and 50% for fatal crashes, and 20 and 60% for injury crashes. In the UK almost two thirds of cyclists killed or seriously injured were at intersections (Knowles et al., 2009). Given that cyclists spend a great deal more of their time cycling not at an intersection, these percentages suggest the risks posed by intersections. - indicating the risk posed by intersections and the need for care when designing intersections to be “readable” by all traffic participants and cycling-friendly. This is a consistent finding of the cycle safety literature – e.g. (Int Panis et al, 2009) find an increased crash risk for cycle facilities at intersections whereas streets where contra flow cycling is allowed reduce this risk.

Recommendation 8:

Cycle safety policies should pay close attention to intersection design – visibility, predictability and speed reduction should be incorporated as key design principles.

3. Taking action to improve cycle safety

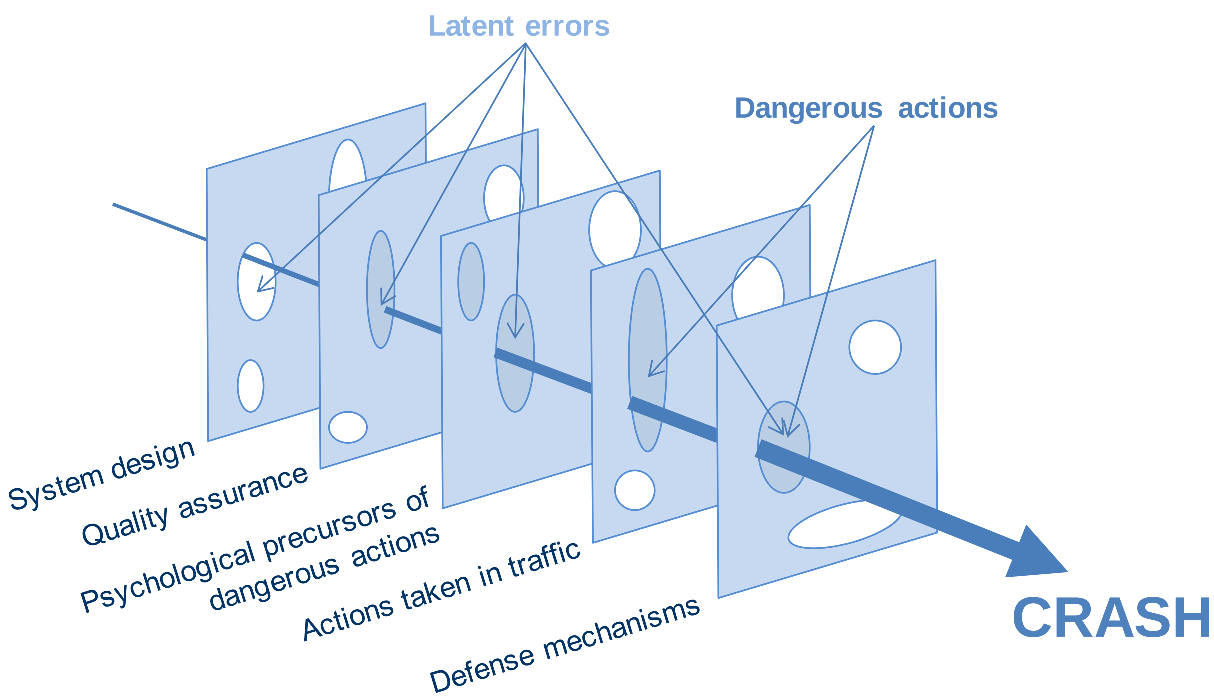
Apply “Safe system” principles for cycle safety

Authorities have often approached cycling safety (or all traffic safety) in a piecemeal approach – focusing on cyclists, other traffic participants and, rarely, on the entire traffic system. Reaching high levels of safety for cyclists (and other traffic participants as well) requires a different approach that seeks to design (or re-design) the system to accommodate cyclists and to account for their characteristics – especially where policy would seek to preserve or increase cyclists’ numbers. If the system is unsafe for cyclists, policy should focus on changing the system, not simply securing cyclists in an inherently unsafe system. The “Safe System” approach extends beyond cyclists only and has been recommended as a general safety planning approach for all traffic classes. In a Safe System Approach the road transport system should incorporate strategies for better management of crash forces, and should accommodate human error (OECD, 2008). The Safe System Approach aims at reduce or eliminate crash risk by avoiding latent errors and dangerous actions in all phases of the traffic transport system (Figure 3).

Recommendation 9:

Authorities seeking to improve cyclists’ safety should adopt the Safe System approach -- policy should focus on improving the inherent safety of the traffic system, not simply securing cyclists in an inherently unsafe system.

Figure 3: Schematic representation of the development of a crash



At the heart of the Safe System approach are 4 key principles:

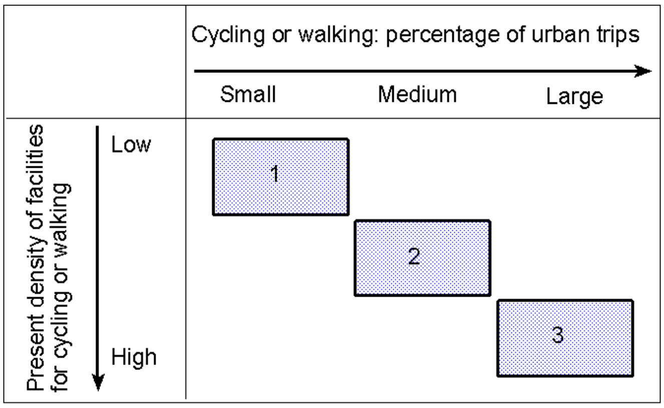
- **Functionality**: The functionality of the traffic system is important to ensure that the actual use of the roads conforms to the intended use. This has been worked out by dividing the road network into three categories: through roads, distributor roads, and (residential) access roads. Each road or street is supposed to have only one function; for example, a distributor road should not have any direct dwelling access.

- **Homogeneity**: Homogeneity is intended to avoid large differences in speed, direction, and mass by separating traffic types and, if this is not possible or desirable, by making motorized traffic drive slowly. Based on this principle, bicycles should be physically separated from motorized traffic unless motorised traffic speeds are quite low.

- **Predictability**: The design of the road and its surroundings should increase the recognisability, and therefore the predictability, of the traffic situations that may occur. Undesirable traffic situations can thus be acknowledged and avoided in time.

- **Forgivingness**: Finally, if a crash cannot be avoided, the fourth principle, forgivingness, is meant to prevent a serious outcome of the crash.

Figure 4: Adapting bicycle facilities to bicycle trip density (Danish Road Directorate, 1998)



- **area 1:** low density of facilities & small share of cycling
- **area 2:** medium density of facilities & medium share of cycling
- **area 3:** high density of facilities & large share of cycling
-

Safety measures are not all transferable or applicable in different environments

Municipalities and regions differ in the share of cycling in the modal split. They also differ in the degree to which they provide facilities for cyclists. The type of cycle facilities offered should depend on the share of cycling -- the more cycling, the more bicycle facilities (Danish Road Directorate, 1998). Facilities typical for a high share of cycling do not fit in a traffic environment with a low share, while facilities belonging to a low share are not compatible with a high bicycle share (Figure 4). Setting facilities within their context can help avoid “over” or “under” investing in safety.

Recommendation 10:

Authorities should match investments in cycle safety to local contexts, including levels of bicycle usage and account for cyclist heterogeneity.

Policies must account for cyclist heterogeneity

User or cyclist heterogeneity is important to account-for as well when planning safety interventions. There is no single type of cyclist - there are old and very young cyclists, experienced and inexperienced cyclists, commuting and recreational cyclists, etc. High impact safety policies should be tailored to reach as many types of cyclists as possible or, alternatively, seek to target specific cycling publics. We should also recognise that our member countries present sometimes drastically different urban traffic contexts, what works for Copenhagen will not necessarily work for Mumbai.

Dual but interlinked goals: increase safety and increase perceived safety

Cities are simultaneously seeking to entice citizens to start cycling while at the same time keeping those already cycling safe - and how well a city does this has a direct impact on getting even more cyclists onto the road. Safety is central to making cycling irresistible - and by safety, we need to understand that this has two components; actual crash rates and their severity and, crucially, the perceived safety of users. If citizens don´t feel safe cycling – then they will not ride if there is an alternative they perceive as safer. If on the other hand citizens feel confident about cycling routes and the safety they offer, the more they will take the advantages of the cheap, fast and reliable mobility offered by bikes. Addressing both objective and perceived safety improvements will require slightly different but necessarily coordinated approaches.

Recommendation 11:

Cycle safety plans should address safety improvement and the improvement of *perceived* safety.

Non-infrastructure measures can improve safety, but they should not be the sole focus of policy

This report reviews a number of non-infrastructure-related safety measures. Some of these have documented safety effects on crash reduction (e.g. night-time lights and reflective devices for cyclists), other have less documented evidence or unclear findings even though they intuitively would seem to reduce crash risk (e.g. convex mirrors covering lorry drivers' spots). This suggests that more robust investigation of the crash-reduction effect of certain polices are still called for. Taking a Safe-System Approach implies that traffic participants should not be the *only* focus of safety-improving measures, however.

Helmet usage reduces the severity of head injuries cycle crashes but may lead to compensating behaviour that otherwise erodes safety gains.

One area that has received vigorous research focus is on the safety impact of bicycle helmet usage and helmet-wearing mandates. As discussed below, these two must be treated separately.

Studies addressing the safety impact of helmets can generally be split into two groups: those that focus on the way in which bicycle helmets change the injury risk for *individual* cyclists in case of a crash and those that focuses on the generalised safety effect of introducing measures (typically campaigns and/or legislation) to increase helmet usage among cyclist. The first group generally finds that wearing a bicycle helmet reduces the risk of sustaining a head injury in a crash (head injuries are among the most severe outcomes of cycle crashes) though recent re-analysis of previous studies suggests that this effect is less than previously thought (Elvik, 2011). To be clear -- these studies indicate the possible reduced risk of head injury for a *single* cyclist in case of an accident. The effects must not be mistaken for the safety effects of mandatory helmet legislation or other measures to enhance helmet usage.

The safety effect of mandatory helmet legislation as such has been evaluated in far lesser studies than the individual risk in case of an accident. The safety effect of mandatory helmet legislation is a result of a series of factors:

- reduced **injury risk** (due to increased helmet usage)
- increased **crash risk** (due to an often claimed change in behaviour amongst cyclists who take up wearing helmet)
- **less cycling** (leading to a reduced number of accidents and injuries, but also to a higher accident risk for those who still bike)

Whether bicyclists change behaviour, when they start to use a bicycle helmet seems very uncertain (and difficult to prove), but it is evident that mandatory helmet use might reduce the total number of bicyclists. It is also possible that cyclists who continue to bike might represent a behaviour which is different from the behaviour of those who stop biking. In the end this could very well lead to an overall change in behaviour.

Infrastructure and infrastructure-related measures help resolve issues linked to the visibility of cyclists, predictability at intersections and differences in traffic speed.

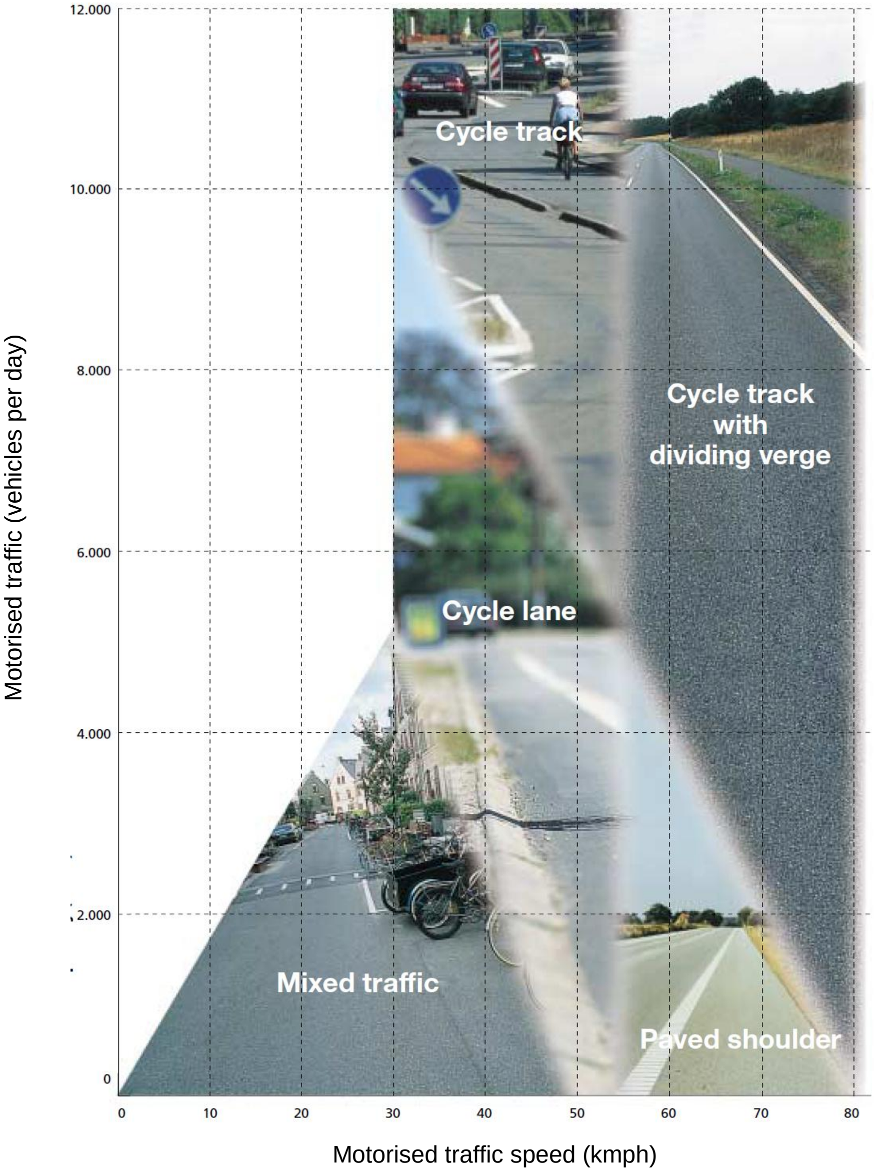
This report reviews evidence on the safety-improving effect of different type of cycle infrastructure and infrastructure treatment (e.g. lane painting). Adequate infrastructure that matches levels of cycle use is a pre-condition for improving cycle safety in the Safe System approach. Cycle infrastructure (just as any road infrastructure) must meet minimum requirements for sight distances for both cyclists and motorists.

Another fundamental design consideration is whether to separate cycle traffic from other road traffic. In this matter motor vehicle speed is a very decisive factor. According to the ”Safe System Approach” described above, bicycles should never cross motor vehicle traffic, where motor vehicle speed exceeds 30 km/h. In most countries the situation on the road network is very far from this scenario, and for most road authorities a full implementation of the Safe System Approach will only be possible to achieve incrementally. Emphasis should be put on separating bicycles from motor vehicles on the roads with the highest speed levels and the highest traffic volumes, and slowing down traffic speed at intersections. However, a generally accepted theory is, that the physical separation on road sections make bicyclists and car drivers pay less attention to each other when they approach junctions. This is likely to be the case, especially where the design of the cycle track is “hiding” the bicyclist from turning cars.

An example of a guideline to determine the type of bicycle facility is shown in the diagram on Figure 5. The type of facility is chosen from a mixed criteria of (motor) traffic volumes and (motor) vehicle speed. The guideline is usable for planning new roads as well as improving existing roads, but it does not in every means comply with the Safe System Approach (e.g. cycle tracks on high-speed roads).

Intersection design and treatment is perhaps the most important infrastructure-related safety intervention. Ensuring that all traffic participants are visible, engage in predictable manoeuvres and that differences in traffic speeds are minimised are key elements of good intersection design.

Figure 5: Guide for planning bicycle facilities on all-purpose roads (Denmark).



Cycling infrastructure is important, targeted design even more so

The findings above suggest that, for the countries concerned, there is need to deploy further cycling infrastructure that delivers both objective and perceived safety improvements. This report recommends a number of safety-improving measures on the design of streets, intersections and crossings. Clearly, though, these interventions need to be targeted given limited resources. For instance the introduction of a bike lane on a single street might not improve safety if intersections and crossings are not redesigned as well. And if such new measures a not sited on popular routes chosen by cyclists, such investment can be wasted. New or improved infrastructure can also spur more cycling - and fertilise public demand for more and better solutions. Ultimately, specific interventions should be matched to specific safety shortcomings. The trouble-shooting table below matches this report's findings on infrastructure-related safety impacts and specific safety problems.

Table 2: Cycle infrastructure and safety troubleshooting table

Accident problem	Hypothesis	Possible solutions
Road sections		
Accidents with bicyclists being run over from behind	Speeds are too high	Speed reducing measures Narrowing of lanes with edge line
	Narrow, dense traffic	Bicycle lanes/bicycle and pedestrian path
	Darkness, moist weather	Road lighting Campaigns on the use of bicycle lights
	Road side parking	Prohibit parking/stopping
Accidents with bicyclists hitting parked cars	Narrow roads	Markings (parking lane) Prohibit parking
Accidents with bicyclists hitting pedestrians	Accidents concentrated	Refuge/verge Raised pedestrian crossing
	Wide street, accidents spread out	Centre island
Entrances to private properties		
Bicyclists on bicycle track are hit by cars coming from the entrance	Sight distance from yield position not adequate	Close entrance Improve sight distance
	Bicyclists are overlooked (lack of attention because of dense and fast traffic)	Close entrance Speed reducing measures, reduce number of lanes
	Bicyclists go in the wrong direction	Sight distance improved in both directions
Right turning cars/lorries hit bicyclists going straight ahead on bicycle track	Inadequate sight distance (in mirrors)	Prohibit right turn Prohibit stopping Remove trees and other obstacles from verge Remove or narrow verge Truncated bicycle track Close entrance
Priority junctions in general		
Accidents with left turning vehicles hitting bicycles driving straight on bicycle track	Inadequate sight distance/Parked cars along bicycle track	Improve sight distance along bicycle track Prohibit left turn Prohibit stopping
	Insufficient orientation	Blue bicycle markings Speed reducing measures
Roundabouts		
Bicyclists are hit by entering	Speeds to high	More narrow design

Accident problem	Hypothesis	Possible solutions
vehicles		
	Problem with sight distance/Signs and other obstacles are blocking view	Improve sight distance Replace signs and obstacles
	Bicyclists are overlooked	Bicycle markings on road Change of roundabout design/priority
Bicyclists are hit by vehicles leaving the roundabout	Speeds too high	More narrow design
	Problem with sight distance/Signs and other obstacles are blocking view	Improve sight distance by removing verge Replace signs and obstacles
	Bicyclists are overlooked	Bicycle markings on road Change of roundabout design/priority
Signalized intersections		
Turning cars hit bicyclists	Bicyclists are overlooked	Coloured bicycle markings Avoid pre-green for right turning vehicles
Right-angle collisions in far end of big intersections	Insufficient clearance phase for slow bicyclists	Increase amber phase
Bicyclists turn left in front of straight going traffic	No waiting area or signal for cyclists	Establish waiting area Separate signal/phase for bicyclists
Bicyclists cross on red	Long waiting time	Retime signal
Right turning cars/lorries hit straight going bicyclists	Inadequate sight distance (in mirrors)	Staggered stop line for cars Remove verge Cut back bicycle track
	Sight distance OK, but insufficient orientation	Separate regulation Cut back bicycle track Pre-green stage for cyclists Avoid pre-green for right turning cars

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