Advanced vehicle technologies, autonomous vehicles and cycling

European Cyclists' Federation

Ceri Woolsgrove, Policy Officer c.woolsgrove@ecf.com

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Executive Summary

This is a discussion document looking at the current status of the developments in the motor vehicle technologies such as Cooperative/Connected Intelligent Transport Systems, AEB and sensing technologies and autonomous vehicle technologies. It will discuss their status and possible effects on cycling.

Here are some basic conclusions

- There are 'autonomous vehicles' technologies which must be put in place ASAP to make major improvements in motor vehicle safety such as Intelligent Speed Assistance, Automatic Emergency Braking for cyclists, Blind spot detection for large vehicles
- We should use the hype surrounding autonomous vehicles to argue for those technologies that are necessary for driverless vehicles and can be a major road safety tool into motor vehicles as soon as possible
- The safety benefits for cycling of new vehicle technologies seem to be on the whole positive particularly with both the current crop of new technologies and also with the future 'idea' of the autonomous vehicle. There are safety issues such as risk compensation, artificial intelligence and liability issues, driver distraction, and mixing of equipped and non-equipped users with vehicles equipped with autonomous vehicle technologies. There are however also huge possible benefits; with fully autonomous vehicles the safety of cyclists and pedestrians will be built into the cars software making vision zero a real possibility. With some of the now available technologies such as Intelligent Speed Assistance and Advanced Emergency Braking we have a great opportunity to reduce speed and stop crashes from happening
- There are some possible threats to cycling not just with regards to safety but also in terms of modal shift and congestion. Advanced vehicle technologies may also challenge funding opportunities for cycling and walking
- There is no understanding yet of how C-ITS and connected vehicle technologies can presently or would in the future incorporate active non-equipped modes like cycling and walking
- Some transport solutions involving advanced technologies could have deleterious effects on urban areas, e.g. platooning. Although there are also some major opportunities to aid transport management bringing advantages to active modes by redirecting motor vehicles away from residential, urban areas or by efficient charging and enforcement mechanisms
- Enforcement; vehicle/driver registration and roadworthiness could be greatly improved with the idea of a 'virtual number plate' bringing together all necessary information for the driver to remain within the law and for enforcement authorities to police law breakers

Connected/Cooperative Intelligent Transport Systems, autonomous vehicles and cycling

This is a discussion paper that will be looking at new motor vehicle technologies emerging from the fields of Connected Intelligent Transport Systems and autonomous/driverless vehicles. It is a document that will be looking at the progress of motor vehicle and infrastructure technologies, and which would eventually lead to autonomous vehicles. It is connected to the Smart Cities theme but is significantly separate to deal with separately. The main technologies that are at the moment really being developed are technologies that are being developed mainly for use with the motor vehicle, between vehicles and between vehicles and infrastructure, these technologies are part and parcel of what will be the autonomous vehicle. It is often speculative as we are talking about vehicles or technologies that are not yet realised.

There has been a huge jump over the past five years or so in the complexity and useful function of vehicle technologies in the fields of sensing, braking, speed management, driver assistance etc. However, rare in the field of technology development there is an endpoint in view with this current trend in automobile development that is the driverless or autonomous vehicle. It is important not to confuse the concepts of Connected/Cooperative-ITS and autonomous driving. C-ITS technologies are just one of many breakthrough technologies that will be used for fully autonomous driving. C-ITS means Connected or Cooperative Intelligent Transport Systems and is the term that is used to describe those technologies that allow vehicles and infrastructure to connect and communicate with each other, it is claimed that it will be an important tool to achieve full automation but is also currently being used. The main technologies used are specific ITS wireless systems[1] that allow vehicles and infrastructure to talk to each other at very low latency and high immediacy which naturally lends itself to critical accident avoidance stations and responses.

Though this document will be looking at safety as the main issue, these technologies, particularly C-ITS technologies, will and can currently be used to provide information to drivers, transport managers and enforcement agencies, for example;

- Congestion charging and road pricing will be able to be done automatically.
- Road works, congestion and weather updates are automatically available.
- Signal violation informing whereby drivers will be immediately picked up for running red lights
- For the near future parking management in cities (the parking place has sensors which detects a vehicle is present and then can inform a central database about parking availability to other vehicles. Parking spots can be reserved and the driver can be charged.
- Enforcement agencies will be able to ticket and fine drivers, be aware of infringements and have access to a 'black box' immediately. Number plates would become virtual and accessible across the network rather than visual plates.

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[1] EEE802.11p/ETSI and ITS -G5 wireless systems

So there are informative non-driving aspect to C-ITS as well as the specifically 'driving' technologies such as Intelligent Speed Assistance ISA, Automatic Emergency Braking AEB and eventual full automation.

Autonomous vehicles

Autonomous vehicles is the phrase that is on everyone's lips in Brussels, understandably since the EU is where vehicle regulation is carried out, but regardless of whether this is hype or genuine developments it is something that everyone in the transport sector will have to confront and form an opinion on, including cycling. The stages to full automation have been outlined with more or less consistency according to the following levels of development. There are about 5 levels of automation, below is a simplified version[2],

Level 1.   Driver Assistance - Simple assisted systems like Electronic Stability control or more active systems like Active Cruise Control

Level 2.   Partial automation systems like lane keeping with the car autonomously steering within centre lane. But still definitely hands on the wheel.

Level 3.   Conditional automation with specific safety critical systems, and the car senses when conditions can be returned back to the driver

Level 4.   High Automation - Driver does not need to monitor the dynamic driving task nor the driving environment at all times; must always be in a position to resume control

Level 5.   Full automation - No driver attention needed

Some of these levels have today been achieved, such as Adaptive Cruise Control, Lane keeping Assistance, parking assistance, etc. Most experts would agree that level three has currently been attained comfortably. There are debates as to how long it will take to achieve full automation with optimistic guesses at 5 years to the more pessimistic never! An average guess would be around 20 years for the first production of an autonomous vehicle. With the current state of technologies and automation, automation for consumer available vehicles has a very long way to go, particularly in the urban environment. In the EU the developmental pattern seems to be that vehicles will become more and more automated bringing the technologies step by step into new high end vehicles (AEB, parking assist etc.) with, over time, driving tasks being further and further eliminated from the driving task until eventually full automation is achieved. The US seems to be moving in a different way with companies not traditionally involved in vehicles looking at current testing of fully autonomous vehicles (Google car etc.) using sensing camera/lidar/radar systems and almost willing the driverless car into life through repeated use on the road.

However it is foreseen that the first autonomous vehicle will not be used by the usual car driver/consumer. Rather it maybe first used for public transport services or transit vehicles (at airports for example) with dedicated lanes and street spaces, while the first fully autonomous drive-

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[2] A fuller table can be found here http://cyberlaw.stanford.edu/blog/2013/12/sae-levels-driving-automation

anywhere vehicle being used by taxi companies, car sharing, or Uber style companies with limited coverage to certain areas thereby requiring less extensive mapping; mapping being a major issue since maps for full autonomy will have to have very fine and extensive details.

Given that in the EU vehicle technology advancement is being propelled by the motor vehicle manufacturers the prioritized technologies will also be those that are more likely to protect their customer, the driver, and make the driving experience more comfortable, rather than focus being given on protection to those outside the vehicle[3]. Bearing this in mind, and the more complex urban environment, cities and urban areas will probably be slower to see new safer vehicle technology than motorway driving.

Advanced Vehicle Technologies for VRU road safety

This section will outline some of the technology developments that are leading towards the autonomous vehicle since there are really interesting developments within the fields of autonomous vehicle technologies which could have great potential for cycling safety, and for road safety in general in urban and rural areas and that would be available more or less now. We have to be careful about assuming that this will be a linear pathway from level 1 to level 5. There will have to be a major qualitative jump between driver assistance systems as outlined below and then full automation. Full automation means that the car will always be 'on', it will have to drive in *all conditions*, have access to hugely intricate maps, and overcome some seriously complicated artificial intelligence ethical issues. The technologies below are then necessary but not sufficient components of autonomous driving, and though can be brought under the same roof should not be seen as 'the' autonomous vehicle technologies. However I feel that in order to reign in the hype concerning driverless cars, to make the paradigm useful for today and as a way of rooting our analysis in something that is tangible they are outlined here.

1. **GPS/telecommunications warning systems for the Motor Vehicle[4]**. it is a warning signal for the driver. Problems being that it relies on the cyclist also having the device on the bicycle with the same take-up and adoption problems. Due to high latency this would not be able to be used in conjunction with automatic braking or collision avoidance systems, these systems would be informative only. Useful for warning the driver that cyclists are present though there can be problems with over reliance on the system and distraction for the driver. Here there is more use for safety advantages for cyclists though less so in *safety critical* situations, this is more informational for the driver rather than autonomous crash avoidance or response. Again some of these issues will be looked at in the discussion.

2. **GPS/telecommunications warning systems for the cyclist**. There are some very basic developments with regards to bicycles and positioning systems for use in safety warning systems with similar technologies as above. A device on the helmet or the bike tells the

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[3] Having said that EuroNCAP will be including 'VRU' specific testing procedures over the next two or three years to achieve 5 star safety ratings.
[4] https://www.thebikeshieldapp.com/#works

smartphone and then the cloud (which is updated as to where the bike is by GPS), the car is told where the bike is and the helmet or handlebars also get a buzz if the car is nearby. First thoughts on devices like this is that the cyclist will get a buzz and not know where it is coming from, and with the cyclist mingling with all sorts of vehicles if all cars have this tech the helmet will be constantly buzzing and the cyclist will be petrified! Volvo seem to be the first to bring out something like this out[5], however there doesn't seem to be a great deal of testing or thought into it. Currently cyclist interaction with this sort of technology is restricted to journey information, GPS positioning, geographical feedback, bike theft detection, air pollution updates etc. and there are strict limits here for safety and particularly for safety critical situations with some possible safety threats

3. **Camera/sound/laser/lidar/radar sensing type technologies** can be informative[6] or also able to be used with regards to automatic braking and collision avoidance[7] and some pedestrian systems are already on the market[8], and are indeed part of the pedestrian protection testing for EuroNCAP and which will include cyclist Advanced Emergency Braking AEB by 2018. This means that it will become increasingly difficult to get a five star rating if a car does not include more sophisticated AEB systems including cyclist AEB. Cyclist automated braking seem to be developing slower with claims that there are too many false positives (the driver is falsely warned). However there are some manufacturers which already purport to have cyclist AEB on board (Jaguar XE, Volvo XC90 for example) which does question the idea that the technology is the problem in fitment of cyclist AEB.

Other interesting possible use could also be for reducing 'dooring'[9] incidents where the door handle gives haptic feedback if a cyclist is passing, with the Volvo explicitly claiming that their sensing system can also be used for dooring warning systems. If 'bundled' into other sensing systems the cost may also be minimal.

There are also bicycle versions of this that can and are being developed. TNO for example are developing a bicycle[10] that senses vehicles approaching from behind and buzzes the handlebars or saddle. The idea is that elderly people can fall from their bikes when surprised by overtaking manoeuvres that has surprised them. The sensing system gives a pre warning that an overtaking is imminent.

We would also see a huge benefit for HGVs and buses to have these sort of fitments particularly with the idea to reducing blind spot or 'right hook' crashes and indeed there are one or two being used or tested currently[11] [12]

4. **Cooperative/connected ITS** Here we are talking about interconnected (motorised) vehicles based around technologies such as the 802.11p G5 standard. This technology connects vehicles and infrastructure with low latency and is seen as a major missing link within the 'autonomous vehicle' paradigm (between those that have the equipment on board of course i.e. not cyclists) as a way to overcome sensing camera/radar deficiencies. There has been a wireless standard that has been made specifically for interconnected Vehicle to

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[5] http://www.bloomberg.com/news/articles/2015-01-05/this-bike-helmet-can-tell-you-when-cars-get-too-close
[6] An example here http://road.cc/140795
[7] https://www.youtube.com/watch?v=dNz8GPomaio
[8] http://www.euroncap.com/en/vehicle-safety/the-rewards-explained/autonomous-emergency-braking/
[9] http://newsroom.jaguarlandrover.com/en-in/jlr-corp/news/2015/01/jlr_bike_sense_200115/ though this seems to not be available anymore
[10] https://time.tno.nl/en/articles/smart-bicycle-results-in-fewer-accidents/
[11] http://www.bristolpost.co.uk/City-bus-drivers-test-cyclist-warning/story-20535579-detail/story.html
[12] https://tfl.gov.uk/info-for/media/press-releases/2014/august/new-bus-sensor-technology-trial

Vehicle (V2V) and Vehicle to Infrastructure (V2 I). Vehicles and infrastructure are essentially completely linked to each other and 'talk' to each other. The problem for cyclists and pedestrians is that they are not connected here and cannot be brought into this network. This is troubling given the expense, reliance and importance of the C-ITS network that is being seen as the missing link for autonomous vehicle and transport management development and yet does not include the 40-60% of road users.

Problems with false positives through camera and sensing technologies and cyclists not being equipped with the technology could also be overcome by the use of infrastructure technologies whereby camera and radar technologies sit at junctions provide clearer pictures and provide position of cyclist/pedestrian which is then fed back through C-ITS to the vehicle. This overcomes the sensing false positives and the lack of C-ITS equipment on the cyclist/pedestrian.

There is the possibility of C-ITS technologies being put on the bicycle use and it could be possible to have a device in the bike which would be able to be detected by a car which would mean cyclists would then be part of this interconnected network, albeit in a reduced form whereby the only information given would be position. There is a project in Helmond that is testing C_ITS for bicycles at a particular road junction. This would mean that the car picks up the presence of a bicycle instantly and knows the exact trajectory and enables emergency braking overcoming all of the problems with sensing technologies, and there are other less complex designs include basic sensing systems such as Cycle Alert[13]. However with an on board power source perhaps more advanced concepts of the technology could be used with pedelecs/eBikes. The power source enabling the same equipment as cars with a dashboard providing more detailed information all around, including congestion, pot holes etc. as well as providing more detailed information to cars and infrastructure. Advantages and problems with this are discussed below

5. **Intelligent Speed Assistance** ISA is a reasonably mature technology and a form of C-ITS is available already in one form or another in many cars. Trials with ISA have been carried out in ten European countries: Austria, Belgium, Denmark, Finland, France, Hungary, The Netherlands, Spain and Sweden. A study in the Netherlands showed that ISA was successful in reducing speed limits. Up to 30% of drivers exceed speed limits on motorways, up to 70% on roads outside built-up areas and as many as 80% in urban areas. But when asked if they thought they broke the speed limit, drivers replied that they broke the limit 28% on motorways, 19% on main roads between towns, 13% on country roads and 7% in built-up areas[14]. Clearly there is a mismatch with what drivers do and what they think they do. ISA could be a great way to enforce speed limits. ISA is a system which informs, warns and discourages the driver to exceed the statutory local speed limit. GPS allied to digital speed limit maps allows ISA technology to continuously update the vehicle speed limit to the road speed limit. There are three types of ISA:

   o Informative or advisory ISA gives the driver a feedback through visual or audio signal
   o Supportive or warning ISA gives haptic pressure on accelerator pedal

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[13] http://road.cc/content/news/78299-new-system-uses-sensors-bikes-warn-lorry-drivers-when-cyclists-are-present
[14] http://www.etsc.eu/documents/PRAISE%20Thematic%20Report%208%20Driving%20for%20Work%20Managing%20Speed.pdf

     o   Intervening/mandatory ISA prevents speeding by reducing fuel injection and would require a "kick-down" by the driver if he or she wishes to exceed the limit.

Of all the technologies within autonomous vehicle development this seems to hold immediate hope for improving cycling safety. Speed is a major cause of crashes with cyclists and a major cause of increasing the seriousness of those crashes and ISA is a mature technology that has been piloted and proven to work.

Vehicle technologies and General Safety Regulations

ECF is an advocacy organisation, however it is difficult to have a concrete position on technologies that are evolving quickly and in the cases of the fully autonomous vehicle, not yet existing. However during 2017 the European Commission will be proposing changes to the General Safety and Pedestrian Safety regulations within EU vehicle type approval. This will be looking to mandate new safety technologies and features in all new EU vehicles. Included will be pedestrian, cyclist AEB and Intelligent Speed Assistance (ISA), HGV/truck AEB and direct vision specifications amongst many others. Transport Research Laboratory (TRL) were commissioned to prepare a research document[15] looking at the cost-benefit of the most attractive possibilities of which those two technologies scored highly. We very much believe that the technologies that are essential to the future development of autonomous/driverless vehicles, which could have a huge positive benefit on cycling safety and which are available currently should be prioritised within this upcoming legislation[16]

Opportunities and threats of C-ITS /autonomous driving with regards to cycling

With regards to many other developing technologies there are some that are more advanced than others and to take a clear position on a vehicle that does not currently exist would be foolhardy, however just as foolhardy would be to ignore its inevitable development. This section then is often speculative, it has taken on board suggestions by ECF members and is something that cycling advocates could use as a frame of reference to hang opinions, warnings, decisions and look out for lobby opportunities.

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[15] http://bookshop.europa.eu/en/benefit-and-feasibility-of-a-range-of-new-technologies-and-unregulated-measures-in-the-field-of-vehicle-occupant-safety-and-protection-of-vulnerable-road-users-pbNB0714108/;pgid=Iq1Ekni0.1ISR0OOK4MycO9B0000BAJ9tQVy;sid=OT_-Ap3uO3P-V8j2wGFgpf_Lm_yCUpo9P-w=

[16] https://ecf.com/what-we-do/road-safety/motor-vehicle-regulation-safer-cycling

Threats for cycling of current advances in motor vehicle technologies?

Here we put forward some of the problems that may affect cycling with the development of advanced vehicle technologies and autonomous driving, not only with regards to safety but also more generally in the transport sphere itself

- ■ C-ITS will entail infrastructure development and demands on transport funding from public authorities. When money is tight, why should money be spent on this sort of infrastructure which at the moment may not have any benefits for cyclists and pedestrians? There has been little attempt to include cycling and pedestrians within a C-ITS network and little discussion as to what this means for cyclists/pedestrians. We know what works; good cycling infrastructure sensible driving/cycling and police enforcement, why move money from what works to unknown technologies with limited urban benefits and a vehicle that doesn't yet exist?
- ■ Almost all of the proposed benefits that C-ITS/ autonomous or semi-autonomous vehicles would bring could be better served by concentrating on modal shift to active modes and public transport to solve current transport problems
  - o Congestion – Genuine congestion busting in cities requires modal shift to cycling/walking and public transport which is what most public authorities now accept. Money should be spent therefore on cycling infrastructure rather than expensive infrastructure to facilitate more private motor vehicle use. Increasing motor vehicle efficiencies through C-ITS would lead to greater congestion; increase supply brings increase demand
  - o Safety – we know how to make cyclists safer and that involves good infrastructure, good road rules and policing, and good education. Why should money be spent on expensive ITS infrastructure when we could be spending it on good cycling infrastructure? It will be very difficult for the car using just sensing/camera technology to be 100% safe in collision against cyclists and C-ITS technologies will not work with non-equipped users
  - o More human and liveable cities – related to the other two, but also at the level of actual interaction between road users. Urban driving is safer when there is an interaction between road users, eye contact and signalling for example, which could be lost with a higher proportion of actions being done by the driver.
- ■ With regards to full automation C-ITS will be essential. Radar and camera systems have too many problems to be reliable, there are many false positives for them to take on the role of hands free driving, we have seen this with the problems that HGV lorries are having providing good workable sensing and braking systems for blind spot turning onto cyclists. They will not pick up pedestrians stepping out from behind a van; or know to slow down where children are playing (braking distance will still be an essential factor regardless of critical braking technologies). Meanwhile GPS/telecommunications have latency issues, in order to have *automatic/critical* braking the signal of danger has to be immediate and GPS/telecoms communications like the navigation uses will not be quick enough. This means that C-ITS and G5 standard technologies *will be essential to autonomous vehicles*, but this requires all road users to be equipped, including pedestrians and cyclists. However

the devices that are necessary for connected motor vehicles are not attached or worn by cyclists and pedestrians. Cyclists and pedestrians are unequipped road users. This means that in a more and more connected transport system active modes of transport will always be locked out. What is the consequences of this for transport planning? We have had years of building transport infrastructure and planning urban areas as if they were thoroughfares for motorised transport, cyclists and pedestrians were pushed to one side as nuisances to be gotten out of the way. Over the last 10-15 years the motor vehicle hegemony has begun to be successfully challenged and to some extent reversed; urban areas are to be seen as places where people work, live and play. However with a new technology that is motor vehicle specific being championed and *only* relevant to motor vehicles this means that once again road and infrastructure planning will be championing the use of motorised transport at the expense of locking out active modes.

■ Platooning – This seems to be a major selling point of autonomous and connected vehicles, particularly with regards to freight and heavy goods vehicles. The idea that vehicles will be able to move in trains bumper to bumper at high speeds would be the road haulage industry dream but evokes a dystopian nightmare for those that have to live or work in those areas. Will some roads be off limits to cyclists and pedestrians, would key direct routes around cities be set aside for platooned motorists vehicles only? Again are active modes shunted away from important roads.

■ Modal shift – By making privatised motorised transport easier to use we stimulate supply of the resources facilitating car use which increases demand. If we see a shift from active modes and public transport to car use we will end up with more congestion, worse air pollution and CO_2 emissions and increasing health problems associated with a sedentary lifestyle, as well as road safety issues.

■ There is a huge hype of the autonomous vehicle which is sucking the oxygen out of debate on what is really needed in the transport sector. To be fully autonomous a vehicle must make a huge leap from the current set of driver assistance systems to a genuine driverless car. Occasional assistance to full continuous driving is a leap of qualitative difference and should not be seen as part of an inevitable evolution to driverless vehicles. We will be stuck with these vehicles that we currently have with minor improvements for a while and there is no inevitability about driverless systems (even less so in urban areas). Should we stop the driverless hype and look at real genuine solutions for urban mobility that we know work.

■ With regards to safety in particular;
  o With partially automated cars there are problems of risk compensation, drivers assuming that the car will look out for all potential problems. We have seen already that there are risks with the semi-autonomous level driving activities, a Tesla car involved in a fatal crash after its driver assistance system was unable to identify the difference between a white lorry and the white clouds behind it[17]. It is this semi-autonomous state that could bring major issues particularly with regards to the assumptions made by the driver on the level of autonomy. Currently it is easy; do not be distracted, concentrate! But with semi-autonomy how is this defined for the driver? Even more difficult, how would this be defined in law and road codes?

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[17] http://www.independent.co.uk/life-style/gadgets-and-tech/tesla-crash-autopilot-driverless-model-s-death-experts-defend-technology-a7113431.html

- o It has been shown that it takes almost 20 seconds for a driver to get back to full attention at the wheel if an emergency situation does arise and the driver has to take control of the vehicle during an emergency situation that the vehicle cannot deal with. This will become more and more important as less and less tasks are undertaken by the driver
- o This further isolation from the road environment of the driver can be dangerous. Urban driving often uses gesturing, hand signals, nodding, and other human gestures to negotiate busy urban roads particularly in interactions with pedestrians and cyclists. Cars are becoming further divorced from the environment that they travel in, 70 kph does not feel like 70 and 100 does not feel like 100. Engines are quieter and car interiors feel more like living spaces or offices. This will increase with less actual driving being undertaken and car design becoming increasingly focussed on comfort rather than the driving. This is a problem that the industry needs to address; high end car adverts are already portraying the car as a second office
- o Risk assumptions will also be an issue for those outside the vehicle, those outside the vehicle assuming the car will have to stop leading to increasingly risky manoeuvres
- o Uptake of the technology may be slow and there could be a problem with only some of the vehicles being equipped, how do we know which are equipped and which are not? Will our behaviour have to change in the presence of different vehicles, if so which are equipped, which are not? Managing vehicles that are fundamentally and qualitatively different in driving conditions will be a challenge
- o Taking evasive action from a crash may mean putting other road users at risk during that manoeuvre. Who chooses which the car should hit? There are a myriad of questions concerning artificial intelligence and interactions amongst different road users.

Benefits for cycling of current advances in motor vehicle technologies?

- It will enable public authorities to genuinely control traffic in and around cities, particularly for managing demand side congestion policies, such as road pricing, congestion charges etc. Supply side congestion interventions such as traffic-light control could be used to prioritise active modes and public transport over cars, though care has to be taken when using supply side interventions to facilitate car use which may lead to greater congestion
- C-ITS and the emerging driverless technologies can be used to redirect traffic away from residential, urban areas and as a way of better managing traffic, including congestion charging, restricting access etc. Public authorities are increasingly aware of the damaging externalities of private motor vehicle use in cities and are looking for more advanced ways of channelling them around cities and through cities, and to provide deterrents for their use and incentives to shift to more sustainable modes.

- C-ITS technologies can be used to improve Public Bike Share schemes. There does seem to be a move towards better and more efficient PBS schemes by providing an easier ticketing, journey planning and docking system being the targets. Technologies that Are currently being used by the car industry could be utilised by Public Bike Share schemes. Copenhagen goBikes are electrically assisted bikes with a power source and access to a tablet on the handlebars. Having a power source on the bike itself could bring open access to these technological developments. We could then envisage informative C-ITS to be used on bicycles, particularly those with an electric power source like pedelec bikes, could we also see the emergency safety technologies being applied to electric bikes?

- C-ITS is also improving public transport. Making Public Transport easier and more efficient would mean less cars on the road and safer roads for cyclists. It would also enable better incorporation of cycling into public transport modes as well as providing car drivers with more choices beyond everyday car use

- With regards to safety in particular Some technologies are available now and should be promoted such as;
    o For autonomous vehicles to be competent within the law and to be responsible for driving vehicles will have to drive with extreme caution and sensitivity, watching out for and being sensitive to the needs of pedestrians and walkers *will be programmed into the vehicle itself*. This could be the only way of realistically achieving Vision Zero fatalities and serious injuries to liberate the human from driving and negate all speeding and distraction. It will be impossible for passing distances to be small or to be hit by a turning vehicle. The motor vehicle will be programmed to be the most considerate driver possible. As the vehicle fleet becomes further equipped there will be a huge jump in feedback as to how to fine tune the various systems meaning the technology can only get better over time once implementation begins.
    o Before full automation technologies like Intelligent Speed Assistance, particularly with haptic feedback or directly limiting the speed of the car in relation to the set speed limit, can be a major breakthrough in road safety. This is a proven technology that has the possibility of eliminating one of the major causes of cycling fatalities it is a technology that be used to its fullest advantage now
    o Vehicle automatic sensing and braking AEB can be a major step forward to take away problems of distraction. Manly through camera and sensing technologies but also through C-ITS vehicle to infrastructure technologies working with equipped motor vehicles. Cameras can be placed at junctions which would then interact with motor vehicles equipped with C-ITS allowing emergency braking in averting collisions with cyclists and pedestrians
    o Larger vehicles like construction lorries and buses are often in moving on the same stretch of road and are a huge problem for cyclists with some cities seeing larger vehicles as the main vehicle involved in cyclist crashes and yet the least present vehicle on the roads. These disproportionately dangerous vehicles should either be kept out of cities or should be made fit for purpose for use in urban areas. As with private motor cars AEB should also be considered for mandatory use as soon as possible. Cameras and radars should be prioritised as should C-ITS technologies that work with infrastructure in order to eliminate crashes with cyclists; infrastructure provides the camera/radar and sends feedback to the vehicle through C-ITS.

- In the field of enforcement C-ITS brings a great deal of potential for allowing enforcement authorities access to vehicle data (like speed, tax, vehicle inspection certificates, etc.), and to replace the current unwieldy physical infrastructure (speed cameras for example). This comes into its own with the idea of a 'digital number plate' made possible by C-ITS technologies. Intelligent Speed Assistance, traffic charging, vehicle roadworthiness, traffic offences, tax, and traffic infringements/points system management can be much more easily coordinated within the context of a virtual number plate or virtual vehicle/driver identification. This public authorities will be able to fine tune all aspects of their enforcement and traffic procedures to complement their transport and safety management goals. This would not only have a beneficial effect on cyclist safety with greater enforcement but would also make drivers aware of the fact that their vehicle and driving activities are inextricably linked to enforcement and justice authorities creating greater awareness of the dangers of their vehicles and the vulnerabilities of those outside their vehicle. It would also benefit the driver by allowing those law abiding drivers to remain within the law with all necessary information, of driving, registration and roadworthiness, all at easy reach. Privacy and access to data and location would of course need to be a major concern to be overcome

Discussion

There are many connected vehicle/connected infrastructure technologies that could (and do) have excellent applications for cycling and walking, road safety, Public Bike Share, journey planners, warning systems, data and traffic management, urban planning/design that we need to be aware of their existence and be prepared to campaign for their applications to improve and increase cycling. What we know about is the tip of the iceberg with regards to how quickly technology is moving forward. We need to be ahead of the curve and to be prepared to ask for a fair share of the pie! Our hope is that we can incorporate (or rather co-opt) these technologies to improve cycling safety, improve the cycling experience, and bring more people onto bicycles throughout the EU.

More specifically C-ITS, another component of autonomous driving, can be a major tool in prioritising active modes in urban areas, for example if we are talking about traffic light changes to prioritise vehicles we should be thinking about which vehicle we want to prioritise to be incorporated as part of an urban wide plan to improve the transport system for all inhabitants and road users. C-ITS could be, and has been proposed, as a technology that could bring cyclists into a network of connected vehicles that know exactly where each other are and thereby eliminating the vast majority of crashes between cyclists and car drivers. There are projects currently underway (Helmond) where an equipped bicycle is tracked. However this brings another question; should we be forcing cyclists and pedestrians to be equipped with detection devices when they should be prioritised in urban areas? Is this not handing the priority back to motorised vehicles or is this the final pieces of the jigsaw to obtaining 'Vision Zero'?

How would this work for pedestrians? If we equip bicycles with Connected technologies are we just passing the risk on down to the line to the final unequipped users, the pedestrian. Or should we also equip children walking to school? Do we want to live in urban areas where we have to

remember keys, wallet, phone and protective C-ITS device to stop cars running into us? The moral obligation for VRUs especially pedestrians to have to wear or carry devices around with them obviously has some moral problems concerning forcing the victims of crashes with large powerful vehicles to be responsible for the collision rather than shifting the responsibility to those in the vehicle. In urban areas the pyramid of rights priorities pedestrians at the top, then cyclist, public transport, private motor vehicle. Should we be forcing VRUs to wear specific items of clothing? Probably in reality sensing technologies will work hand in hand with C-ITS when it comes to the technologies in a final autonomous vehicle and perhaps this is where for cyclists connecting with infrastructure is the key, infrastructure that is able to sense non-equipped users like cyclists and pedestrians and then feeding this back to C-ITS equipped vehicles bringing bicycles and pedestrians into the network by proxy would be easier than the moving car sensing other smaller moving objects. And of course this sort of debate brings us back to the fact that we know how to make cyclists and pedestrians safe in urban areas, reduce speed, shifting cars away, and separate infrastructure. Why over engineer the solution to a known problem.

On autonomous driving we should be using the autonomous vehicle debate to argue for those technologies such as Intelligent Speed Assistance and pedestrian/cycling Emergency AEB that are essential technologies for automated driving and are either currently, or nearly, deployable. We should try to ride the wave of autonomous vehicle fervour to make vehicles as safe as possible now, particularly with regards to updating the General Safety Regulations and Pedestrian Protection type approval legislation that will be due next year. And of course given the complexities of urban transport it is possible that the technology will never be fully developed for full autonomous driving in urban areas and autonomous driving will only be available for motorway and urban use. If the technology does get stuck here should we be campaigning for funding or regulation to have full autonomy available in urban areas?

This road to autonomous driving is fraught with possible dangers. With some cars having more 'autonomy' than others will mean different driving techniques, unpredictable vehicle movements. Will eye to eye contact be reduced? It doesn't matter how good AEB is if a car places itself too far within the braking distance or danger zone, the cyclist/pedestrian will still be hit no matter how good the reactions. This will be true for semi-autonomous and fully autonomous vehicles. How will these vehicles deal with risk perception, slowing where children are cycling, or where parked cars obscures what is happening on the pavements. Risk compensation issues of motorists assuming the vehicle will stop or pedestrians assuming vehicles will stop at crossings. Semi-autonomous vehicles will have many distraction issues, while fully autonomous vehicles will have risk perception issues. But having said all this it has to be said that driverless cars will have to have positive effect on the safety on our roads. Having safety built into the vehicle itself will be a major and qualitative jump in road safety and will mean that vision zero could be a realistic possibility.

The technology in and of itself cannot be good or bad rather it is the policies surrounding them and how they are used that will be good or bad, it is important that it is used in the right way. That means cycling advocates have to be aware from the start to make sure we are as knowledgeable as possible and not be ignorant of the growth of these technologies, that we understand how it is working and to make sure that policy makers make good decisions based on sustainable transport solutions. The Smart city agenda has been criticised for assuming more technology is the answer without actually looking at what or for whom the technology is for. Cities are trying to turn

themselves into more human cities by putting people not vehicles at the centre. If we have technologies that address social problems through the prism of the technology rather than the people that live there when we end up with vehicle prioritisation, platooning of vehicles, and increasing congestion even though improving traffic efficiencies.

During the 20th Century in many countries across the EU motorised transport took the lead over cycling, walking and public transport in our urban areas. Cycling and walking were given at best a supporting role when it came to infrastructure development. Now in the 21st Century cities are now providing cyclists with good infrastructure, funding and space. However this century has also provided us with new types of infrastructures; C-ITS, ITS, Smart Cities, Internet of Things are buzzwords but with real technologies behind them that will be making huge changes in our urban transport environments. Our fear is that this new type of 'infrastructure' will again be considered with motorised transport in mind, and cycling side-lined. Motorised vehicle technologies will be making demands on infrastructure and public authorities will have to make decisions as to where to spend their money and on whom.

Cities are under pressure and we need to find a way of putting people first in urban transport and planning. New technology can be part of the solution but what we need is long-term, imaginative policy development that incorporates the benefits of technology. We need to see genuine social needs like congestion busting; moving cars out of the cities; cycling/pedestrian safety features; urban planning; energy conservation. Before we support money being spent on expensive technological advanced infrastructure it needs to support the trends towards liveable, human cities and not move us back towards the old urban planning of the twentieth century where we create thoroughfares for motorised transport