Gearing up for Smart Cycling

Towards a sustainable mobility system in Europe

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List of abbreviations

ADS	Automated Driving Systems
AEB	Autonomous Emergency Braking
BSIS	Blind Spot Information System
BGI	Blue Green Infrastructure, i.e. individual parcels of natural space and features that when connected, deliver quality of life and environmental benefits for communities
BIM	Building Information Model
BITS	Bicycles and Intelligent Transport Systems (Interreg North Sea Region project)
C2C-CC	Car 2 Car Communication Consortium
CDS	Cycle Data Space (part of the Mobility Data Space)
CCAM	Cooperative, Connected and Automated Mobility
CEF	Connecting Europe Facility
C-ITS	Cooperative Intelligent Transport Systems
C-Roads	European Platform about Cooperative Intelligent Transport Systems (C-ITS)
DfRS	Data for Road Safety
EC	European Commission
ECF	European Cyclists' Federation
EMDS	European Mobility Data Space
ETSI	European Telecommunications Standards Institute
EU	European Union
Eurocities	Network of European Cities
FBD	Floating Bike Data
GSR	General Safety Regulation
HMI	Human Machine Interface is the part of a machine with which humans interact and in which they can intervene.
ICT	Information and Communications Technology
IoT	Internet of Things
ISO	International Organisation for Standardisation
iTLC	Intelligent Traffic Light Controller
ITS	Intelligent Transport Systems: ITS are systems in which information and communication technologies are used in road transport, including its infrastructure, vehicles and users, as well as in traffic and mobility management and for interfaces with other modes of transport.
KPI	Key performance indicator

MegaBITS	Mobilizing Europe's Green Ambitions through Bicycles and Intelligent Transport Systems (Interreg North Sea project)
MERIDIAN	CEF co-funded European ITS implementation Corridor
MMTIS	Multimodal Traveller information
MOIS	Moving Off Information System
NAPCORE	National Access Point Coordination Organisation for Europe, co-funded by EC
NRA	National Road Authority. NRA is often used in Europe. This document uses the term “road operator” that also includes NRAs.
POLIS	Cities and Regions for Transport Innovation
RTTI	Real-Time Traffic Information
Smart Cycling	The application of ITS and/or C-ITS in the cycling domain
SME	Small and Medium Sized Enterprise
SRTI	Safety-Related Traffic Information
SSMS	Sustainable and Smart Mobility Strategy
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
V2X	Vehicle to everything

1 Executive summary

Introduction

This report describes how Smart Cycling can contribute to sustainable mobility solutions in Europe and identifies actions needed to fully exploit the potential of Smart Cycling in Europe.

Smart Cycling refers to intelligent and cooperative systems (ITS and C-ITS), digital applications and digital services that make cycling safer and improve the cycling experience on the basis of cycling-relevant data, communication technologies and products and services based on these.

Cycling has seen significant development and is increasingly viewed as a key component of a sustainable mobility system. This evolution is driven by several factors:

- **Technological Advancements**: The development of electric bikes and bike sharing systems has extended the range and capabilities of cyclists, making cycling more accessible, practical and smart. This also increased the cycling market.
- **Health and Climate Benefits**: Cycling contributes to physical fitness, even using electric bikes, and is a CO_2-neutral mobility option, which is crucial in addressing the climate crisis.
- **Improved Infrastructure**: Upgrades in cycling infrastructure have enhanced safety and usability, in combination with a strengthened awareness of urban development and liveability that is moving towards shorter distances (e.g., the '15 Minute City').
- **Policy Support and Political Momentum:** Increasing recognition of cycling's benefits has led to stronger policy frameworks and political commitment at local, national, and EU levels. Many cities are now embedding cycling into their mobility strategies and climate plans.

In addition, technological developments in the field of ITS and C-ITS provide new opportunities for cycling:

- **Smartphones and Connectivity**: Smartphones (and wearables) have the potential to transform cycling into a smart, connected mode of transport.
- **Digital Infrastructure Enhancements**: Integration of cameras, sensors, and Cooperative Intelligent Transport Systems (C-ITS) into road infrastructure has the potential to improve safety and usability. And this is highly important since the perceived safety in road traffic is seen as an important reason for not using a bicycle.

Process followed by the Smart Cycling Task Force

This report was written by a joint Smart Cycling Task Force initiated by the Interreg North Sea co-funded project MegaBITS and the CEF co-funded project MERIDIAN, including representatives from Austria, Belgium/Flanders, Germany, the Netherlands and Slovenia. For data standardisation matters, the Task Force cooperated with the cycling ambassadors of the NAPCORE project, whereas C-ITS input was received from the C-Roads Platform. The process included:

1. **Inventory of Use Cases**: Identifying potential use cases for Smart Cycling and mapping them onto the Bicycle Pyramid, which defines cycling needs.

2. **Collection of Best Practices**: Gathering nearly 25 new best practices from different regions in Europe and adding them to the now in total 90 Smart Cycling products and services in the BITS Directory.
3. **Stakeholder Analysis**: Understanding the roles and perspectives of various groups involved in Smart Cycling.
4. **Identification and analysis of gaps and obstacles**: Addressing challenges for the take-up and implementation of Smart Cycling, e.g., in the field of data availability, standardisation, knowledge, legislation and privacy.
5. **Formulating recommendations**: Formulating recommendations addressing various stakeholders, such as the European Commission, regional and local authorities, industry and the research sector to overcome the obstacles identified earlier in the process.

Various sessions have been held with MegaBITS partners from Denmark, Sweden, Germany, The Netherlands Belgium and France, based on their experiences with implementing Smart Cycling solutions in the BITS and MegaBITS project, and with external stakeholders from MERIDIAN and MegaBITS. These sessions were held to collect use cases, identify and discuss obstacles and to formulate recommendations for the road map for Smart Cycling.

Gaps and obstacles for Smart Cycling

Based on the input collected during various workshops with MegaBITS and MERIDIAN stakeholders, a series of gaps and obstacles for the implementation of Smart Cycling were identified and analysed. This has resulted in the following list (in random order) of key topics that need to be addressed:

- **Road safety**: Improving cyclists' safety through (C-)ITS services and addressing gaps in safety data.
- **Data Availability and Quality**: Ensuring the availability and representativeness of cycling data, improving data quality, whilst addressing privacy concerns.
- **Legal and Regulatory Framework**: Aligning new technologies with existing laws and regulations.
- **Financing and Economic Sustainability**: Addressing funding challenges and the economic value of cycling data.
- **Digital enhancement of infrastructure**: Integration of intelligent systems into existing infrastructure.
- **Awareness and Acceptance**: Building awareness and acceptance among policymakers, the general public, and the cycling industry, offer opportunities for participation and address behavioural change.
- **Knowledge**: Sharing knowledge and expertise between stakeholders in the Smart Cycling domain.

Road map for Smart Cycling in Europe

Based on the analysis of the obstacles for Smart Cycling, and with input from MegaBITS and MERIDIAN partners, the Smart Cycling Task Force has formulated a list of recommendations to stimulate the take-up of Smart Cycling in Europe. Ultimately, these recommendations resulted in the following four key actions, forming the basis of the Road Map for Smart Cycling in Europe:

1. **Improve Safety and Attractiveness through Smart Cycling policy**: Integrate Smart Cycling into active mobility and smart mobility policies at all government levels. Make Smart Cycling a mandatory part of Sustainable Urban Mobility Plans (SUMPs) and climate-neutral city programs.
2. **Foster Innovation and Digitalisation**: Allocate dedicated budgets for research, development, pilots, and deployment of Smart Cycling solutions. Develop guidelines for safe product/service design (Human Machine Interface).
3. **Enable Smart Cycling Services**: Collect and standardise cycling data, making it findable and accessible via National Access Points and the European Mobility Data Space. Address data quality and privacy issues.
4. **Raise Awareness and Create a Collaborative Ecosystem**: Establish a European Smart Cycling organisation or platform to drive research, innovation, deployment, and knowledge sharing. Organise high-level dialogues to boost the uptake of Smart Cycling.

By implementing these recommendations, the Smart Cycling Task Force aims to make cycling smarter, and thus to make cycling a more attractive mode of transport, leading to a modal shift from cars to environmentally friendly modes of transport.

Reader's guidance

The key strategic section of this report can be found in chapter 7, which provides the reader with a 5-page Road Map for Smart Cycling in Europe: A Call to Action. This chapter provides a high-level overview of the work of the Task Force and the key actions to be taken.

The reader with more time can find much more detailed information, starting with an introduction in chapter 2 and an analysis of the potential of Smart Cycling in chapter 3. The state of the art of Smart Cycling is presented in chapter 4, which contains an extensive overview of use cases for Smart Cycling, collection of best practices, an outlook of C-ITS for Smart Cycling and an elaboration of various other topics. Chapter 5 provides a detailed overview of the obstacles for Smart Cycling, and chapter 6 provides an extensive list of recommendations linked to the obstacles mentioned in chapter 5. Finally, chapter 7 presents the "Road Map for Smart Cycling: A Call to Action" in Europe.

2 Introduction

A multimodal mobility system, including cycling, offers numerous societal and economic benefits. First of all, the following societal benefit can be mentioned:

Improved Public Health:

- Reduced Pollution: By encouraging the use of public transportation, cycling, and walking, multimodal systems can significantly reduce air and noise pollution, leading to better respiratory health and overall well-being.
- Increased Physical Activity: Active modes of transport like cycling and walking promote physical activity, helping to combat obesity and related health issues.

Enhanced Accessibility:

- Inclusive Mobility: Multimodal systems provide more transportation options, making it easier for people of all ages and abilities to travel, including those with disabilities.
- Reduced Congestion: By offering alternatives to private car use, multimodal systems can alleviate traffic congestion, making travel more efficient and less stressful.

Safety Improvements:

- Safer Streets: Well-designed multimodal infrastructure, such as bike lanes and pedestrian paths, can reduce the risk of accidents and improve safety for all road users.

Environmental Sustainability:

- Lower Carbon Emissions: By reducing the reliance on private vehicles, multimodal systems contribute to lower greenhouse gas emissions, helping to mitigate climate change.

Community Engagement:

- Social Interaction: Public spaces designed for multimodal transport can foster community interaction and social cohesion.

In addition, a multimodal system offers the following economic benefits:

Economic Growth:

- Job Creation: Investment in multimodal infrastructure can create jobs in construction, maintenance, and operation of new transport systems.
- Business Opportunities: Improved accessibility can stimulate local economies by attracting businesses and increasing consumer spending.

Cost Savings:

- Reduced Healthcare Costs: By improving public health, multimodal systems can lead to lower healthcare costs associated with pollution-related illnesses and traffic accidents.
- Lower Infrastructure Costs: Efficient use of existing infrastructure and reduced need for road expansions can save public funds.

Increased Property Values:

- Real Estate: Areas with good multimodal connectivity often see an increase in property values, benefiting homeowners and investors.

Tourism Boost:

- Attractiveness: Cities with robust multimodal systems can attract more tourists, contributing to the local economy through spending on accommodation, dining, and attractions.

Efficient Use of Resources:

- Optimised Transport: Multimodal systems can optimise the use of transport resources, reducing waste and improving the overall efficiency of the mobility network.

Integrating various modes of transportation, including cycling, will create more liveable, sustainable, and economically vibrant communities.

The time for Smart Cycling is now!

As an important element of multimodal transport cycling has recently seen a strong development all over Europe and is more and more considered one of the main angles to achieve a sustainable mobility system. To understand this evolution, a number of technological leaps, trends and societal changes in cycling can be noticed:

- The electric bike has been developed and matured such that in more and more countries it already constitutes the bulk of bicycle sales. In other countries there is still a high potential to increase the sale of e-bikes. This type of bicycle extends the range of cycling in distance as well as in mastering ascents and in carrying loads. Consequently, the offer in the (cargo) bike market increased, new use for cycling can be served and buyers come from all social groups and ages. New models can effectively serve as a viable alternative to cars, as they feature load capacities that go beyond just the rider, both in terms of the number of passengers and the amount of cargo they can carry.
- Personal health and prevention of common degenerative diseases is a growing concern for many citizens. Cycling provides an easy option to contribute to physical and mental fitness, which is a main factor.
- The climate crisis will continue to increase the incentive to use CO_2 neutral mobility, of which cycling is the most evident option.
- Policy Support and Political Momentum: Increasing recognition of cycling's benefits has led to stronger policy frameworks and political commitment at local, national, and EU levels. Many cities are now embedding cycling into their mobility strategies and climate plans.
- The image of cycling is improving, with an increasing number of people seeing it as a viable and attractive option for themselves. At the same time, it is still an affordable means of transport.
- The upgrade of cycling infrastructure in many and prominent urban areas but also rural settings has improved real safety as well as perceived safety.
- Densification in cities to counteract land-intensive development enables short distances for active forms of mobility.
- The Blue and Green Infrastructure (BGI) experience of nature, seasons and landscape has grown in importance to many people.

In addition, technological developments in the field of ITS and C-ITS provide new opportunities for cycling:

- With the uptake of e-bikes and speed-pedelecs an increasing number of bikes are connected. And if the bike itself is not connected, the rider can be connected through his/her smartphone or wearables. This offers enormous opportunities to provide cyclists with all kinds of information during their trip.
- Road infrastructure will be more digitally enhanced, for example with cameras, sensors and C-ITS units, to improve road safety and the efficient use and maintenance of the infrastructure.

The current strong interest of society in cycling in combination with the new technological developments offered by e-bikes and smart infrastructure will drive the development of Smart Cycling and open up a market for Smart Cycling applications. Even formerly high-tech solutions have come to be realistic for use in cycling. Examples are artificial intelligence, but also in the infrastructure (V2I communication like C-ITS) is also no longer restricted to motorised vehicles and could contribute to preventing dangerous encounters with bikes as well. European legislation has paved the way to a large international market for such applications

Need for sustainable transport

The EU is aiming towards a greener society, with the ultimate EU target of at least 55% greenhouse gas reduction by 2030 and climate neutrality by 2050 (*European Green Deal, 2019*). For transport, this implies a 90% reduction in the sector's emissions by 2050 (*Sustainable and Smart Mobility Strategy, 2020*). One of the three key pillars of action is: *Make sustainable alternatives widely available in a multimodal transport system.* By making cycling more attractive (safer, faster, easier, more reliable, better experience), this will contribute to a modal shift from car to bike, thus contributing to sustainable (urban) mobility and transition to a CO_2 neutral economy.

CO_2 emission per km per conventional bike is 21gr compared to 271gr per passenger km by car[1], equivalent to a 92% reduction. Noise and pollution are practically zero and cycling is good for physical and mental health. For cycling to become a real alternative for car use, cycling must become safer, faster, more reliable and easier to use. Both as a stand-alone mode, and in combination with other modes (bus, tram, train, metro).

Need for Smart Cycling

Traditionally, cycling policy at all levels (local, regional, national, European) consists of one or more of the following measures: (1) building cycling infrastructure, (2) building bike parking facilities, (3) cycling education and (4) cycling promotion and incentives. With the rise of smartphones and e-bikes, in combination with an ever-increasing smarter road infrastructure and digital applications, now time has come to introduce (5) Smart Cycling. Not as a goal in itself, but as a tool to make cycling safer, faster more reliable, easy to use and a good experience. This will lead to a higher appreciation of cycling as a mode of transport and thus leading to a modal shift towards cycling.

Need for cycling data

There are different types of cycling data, and each of them can be used for different purposes. Cycling infrastructure data and cycle use data (counting) can be used for infrastructure planning. Cycling infrastructure data can also be used for routing and navigation apps. Data on quality of the infrastructure can be used for maintenance planning. Bike parking data can be used to analyse the need for extended bike parking facilities. And floating bike data can be used to analyse speed and delays on the main cycle routes.

[1] https://www.cyclinguk.org/article/how-much-carbon-can-you-save-cycling-work

Today, cycling infrastructure is generally only rudimentarily digitised. Taking into account the increasing accuracy of modern sensors and navigation systems, infrastructure data can now be used in a much more comprehensive way, including use cases like micro-navigation, barrier avoidance, signalling, worksite guidance, detailed accessibility modelling or road surface management. Therefore, establishing a harmonised approach for describing the digitisation of infrastructure is an important goal, such that data becomes available in a standardised format. This not only applies to infrastructure data, but in fact for all sorts of cycling data (counting, parking, floating bike data, …).

Data about car traffic is already collected and has been used for decades. For cycling the picture is quite different: in some countries data has been collected for many years, whereas in other countries is has only just started. Since every ITS system for cycling will also be able to produce cycling data, a wide-spread implementation of ITS for cycling also more data about cycling will become available, such as bicycle counting, availability of bike hires and shared bikes, floating bike data, statistics on safety, etc. This is perfectly in line with the Delegated Regulations on RTTI and MMTIS, where already cycling data is mentioned as specific data types (e.g., cycling infrastructure, bike rental, shared bikes, bike parking facilities, …). These cycling data can then be published via the NAPs.

It is important to highlight how new technologies make it possible to quickly track and monitor which routes cyclists use, and which ones they avoid. A careful analysis of the different patterns of use within the transport network can support the modification or creation of cycling infrastructure that better meets cyclists' needs, or even just help establish surrounding conditions that encourage cycling. This can be achieved even with limited but well-targeted investments.

The Smart Cycling applications and cycling data will be a ‘digital layer’ on top of the physical bike infrastructure (such as bike lanes and bike parking facilities). In some cases, ITS for cycling can offer solutions where there is no space or budget for physical infrastructure, e.g., in urban areas, but this requires a careful analysis of costs and benefits. The combination of cycling data and Smart Cycling applications can be used to make cycling a more attractive mode of transport.

Need for cross project coordination

The joint Smart Cycling Task Force, initiated by the Interreg North Sea co-funded project MegaBITS and the CEF co-funded project MERIDIAN, includes representatives from Austria, Belgium/Flanders, Germany, the Netherlands and Slovenia. For data standardisation it cooperates with the cycling ambassadors of the NAPCORE project, whereas in relation to C-ITS meetings have been held with the C-Roads Platform. This should be seen only as a starting point for a wider cooperation between all stakeholders in the Smart Cycling domain.

Need for a European Smart Cycling Road Map

The key outcome of the work of the Smart Cycling Task Force of MegaBITS and MERIDIAN is the Smart Cycling Road Map. The Smart Cycling Road Map in chapter 7 aims to stimulate actions of the political decision makers, the road operators and other actors in order to tackle the obstacles that are still blocking the wider uptake of Smart Cycling solutions and the Smart Cycling data collection and usage. These recommendations should create the framework conditions for a wider take-up of Smart Cycling in cities and regions. Thus, making cycling a more attractive mode of transport, leading to a modal shift from the car to environmentally friendly modes of transport.

3 The potential of Smart Cycling

Both Intelligent Transport Systems (ITS) and Cooperative Intelligent Transport Systems (C-ITS) have the potential to improve road safety, reduce traffic-related emissions and optimise traffic flow. In the road transport sector, many projects have already demonstrated bidirectional communication between road users and the infrastructure as well as between road users. There are numerous ongoing (C)-ITS deployment actions across the Member States, not only on motorways but also in cities and urban areas. To increase the road safety of cyclists, it is now time to apply the (C-)ITS technology to cycling.

As road traffic is a complex, distributed system with a large number of road users and means of transport. Communication between vehicle manufacturers, mobility service providers and transport infrastructure operators must be standardised. The standardisation and specification of (C)-ITS is being driven forward for motorised traffic. However, the requirements of cyclists, the bicycle industry and service providers for bicycle applications have not yet been incorporated into the well-established processes.

This was recognised by the main stakeholders for ITS/C-ITS in 2024, so that efforts were made by various stakeholders, but above all in European-funded projects, to determine the current status of (C)-ITS in the bicycle sector, to identify the requirements of the stakeholders and existing gaps in the various areas and to formulate recommendations for all stakeholders but especially for political decision-makers.

Nevertheless, cycling is not a one-design-for-all activity. From traditional bicycles to cargo bikes, e-bikes, and even e-scooters that share bike paths, different types of vehicles have varying requirements. Reliable data of different cycling types could help policymakers developing tailored solutions, such as separate lanes for speed pedelecs or improved infrastructure for cargo bikes. If politicians succeed in supporting cycling user groups, both the personal benefits and the societal benefit of using a bicycle may more clearly outweigh the benefits of using a car and become a stronger complement to public transport. This means fuelling the modal shift but also counteracting congestion - also on public transport.

Mobility is becoming increasingly digitalised and the networking of information will play a decisive role in the future. For cycling to be considered as a valuable mode of transport also in the future, it is necessary that also the cycling domain becomes digitalised, both with respect to applications and data. With this strategy, we want to drive Smart Cycling forward and utilise its enormous opportunities for road safety, modal shift and health.

3.1 Adding Smart Cycling to the cycling policy tool

Smart Cycling refers to intelligent and cooperative systems (ITS and C-ITS), digital applications and digital services that make cycling safer and improve the cycling experience on the basis of cycling-relevant data, communication technologies and products and services based on these. Smart Cycling comprises both the smart solutions and the collection and use of cycling data. In the context of the smart city, it mainly refers to the interaction between infrastructure and bicycle. In the context of smart mobility, the bicycle is part of a combination of transport modes.

Cycling is part of a multimodal transport system. By combining and optimising all modes (walking, cycling, motorised traffic and public transport) a sustainable mobility system can be reached. Smart Cycling should not be a goal in itself. It's a tool.

Smart Cycling is an effective and cost-efficient addition to the policy toolkit to promote cycling and increase safety for cyclists. Traditionally, policies to stimulate cycling at all levels (local, regional, national, European) consists of one or more of the following measures:

- Building cycling infrastructure (bike lanes, bike paths, bike bridges, etc., both for commuting and recreational purposes)
- Building bike parking facilities (at multimodal hubs such as railway stations and bus stations, in neighbourhoods, near shopping areas, etc.)
- Education (e.g., at primary schools, adult returners especially with E-Bikes, immigrants, elderly)
- Promotion and incentives (tax schemes to buy a bicycle, bike-to-work campaigns, safety campaigns, etc.)
- Penalisation (city fees and city taxes for - emission based - motorised private transport)
- Proximity of destinations (designing cities so that people live near enough to everyday destinations to make walking and cycling realistic choices)
- Restricting other modes (e.g., lowering speeds and reducing volumes by network interventions to make roads safer and cycling a more competitive option)

It can be noted that Intelligent Transport Systems are not mentioned explicitly as a traditional policy measure to stimulate cycling. Nevertheless, various commercial ITS products and services for cycling and a range of pilot implementations has shown that Smart Cycling can have a remarkably positive effect on cycling, and that ITS certainly deserves a place in the cycling toolkit, in addition to the 'traditional' measures (e.g., cycle infrastructure, parking facilities, education and promotion as well as penalisation).

The **Bicycle Pyramid**[2], a tool for cycling policy, is derived from Maslov's Pyramid, and defines a series of 'cycling needs' that need to be fulfilled in order for people to start cycling (first three levels) or to increase the amount of cycling (last three levels). This is shown in figure 3.1.

Figure 3.1: Six levels of the Bicycle Pyramid

[2] Durven, kunnen en willen fietsen! De klantwensenpiramide voor reizigers toegepast op het fietsbeleid. Mark van Hagen, Nederlandse Spoorwegen Bas Govers, Goudappel Coffeng BV. Link: https://www.cvs-congres.nl/e2/site/cvs/custom/site/upload/file/cvs_2019/sessie_b/b3/cvs_17_durven_kunnen_en_willen_fietsen_de_klantwensenpiramide_voor_reizigers_toegepast_op_het_fietsbeleid_1_2019.pdf

The link between the data enriched policy instruments and the impacts (from the bicycle pyramid) is shown in figure 3.2.

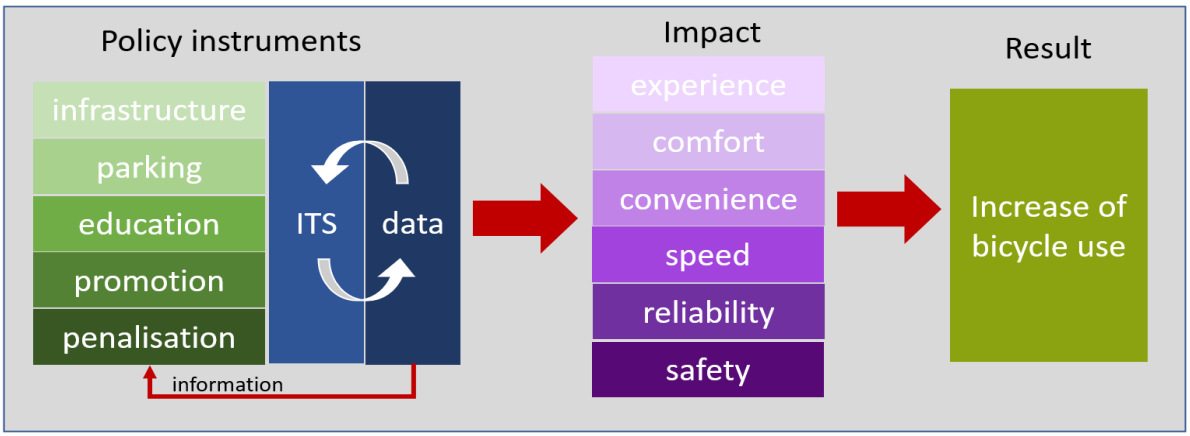

Figure 3.2: ITS and data as part of cycling policy toolkit

The figure above shows that Smart Cycling (consisting of both ITS applications and cycling data) has an impact on safety, reliability, speed, convenience, comfort and experience of cycling, and this will lead directly or indirectly to an increase of bicycle use. To explain the role of Smart Cycling in achieving impact on bicycle use, the following examples of best practices of Smart Cycling applications are given:

- **Safety**: In Utrecht (NL), cyclists were informed through a Variable Message Sign about very busy bike traffic and stimulated to reduce their speed. In Aarhus (DK), cyclists received extended green time at a traffic light when they approached with a too high speed (downhill).
- **Speed**: In among others the Dutch cities Enschede, 's Hertogenbosch and Utrecht, cyclists get faster green at traffic lights when they use a specific app. And bike couriers in Zwolle (NL) got even higher priority, but only outside peak hours.
- **Convenience/comfort**: Students in Zwolle (NL) got access to bike sharing, thus reducing the pressure on the public transport system at peak hours. In Bruges (BE) cyclists received information about available parking places in an underground parking facility through LED screens.
- **Experience**: Both in Oldenburg (DE) and province of Overijssel (NL), citizens were incentivised to cycle to work through an app. The more they cycle, the higher the reward. In Aarhus travel times for cyclists were shown on Variable Message Signs, to show both cyclists and motorised traffic that cycling could be a good alternative.

An additional benefit of using Smart Cycling applications is that they often generate valuable data (counts, speed, delay, trajectories etc.), that can be used in at least two of the following ways:

- As direct feedback to the cyclist, for example via an app or VMS (speed advice, nearest available bike parking, priority at traffic light, etc.)
- To gain new insights resulting in data-driven and evidence based cycling policies and planning.

Cycling data is underrepresented in the overall traffic and transport data, with most data available and collected focused on motorised traffic. Smart Cycling applications offer the possibility to generate more cycling related data. Thus, Smart Cycling can become the digital layer for cycling and bring cycling data to an equal status with motorised traffic data.

3.2 Smart Cycling as a contributor to EC policy for smart, sustainable and safe transport in Europe

Currently however, Smart Cycling is not a structural part of the European Smart Mobility Strategy. If we look at smart mobility in relation to road transport, it is almost purely focused on individual car traffic (especially CCAM) and MaaS. With respect to CCAM, cycling is mentioned only in the context of so-called 'vulnerable road user', and in MaaS cycling is only mentioned in the context of shared bicycle schemes. While the cycling industry is following both of these opportunities closely (with the European cycling trade association CONEBI participating in the CCAM partnership, and Cycling Industries Europe developing MaaS for cycling via its bike share members), now it is time to comprehensively include Smart Cycling as a fully-fledged component of the Smart Mobility Strategy. Both as a self-standing mode of transport and as an important part of the multimodal transport system (to and from the bus and railway stations).

Smart Cycling can play a significant role in achieving many EC policy objectives mentioned in various European policy documents, ranging from the *Green Deal* to the *Mobility Transition Pathway*, and from the *Sustainable and Smart Mobility Strategy* to the *Shaping of Europe's Digital Future*:

- Smart Cycling can help achieve the goals of the *Green Deal*, since Smart Cycling will make cycling more attractive (safer, faster, more reliable, more convenient, more comfortable, and a better experience) by applying (C)-ITS. Expanding and integrating innovative (C)-ITS applications for cycling contributes to making cycling a viable alternative to other, less sustainable and healthy means of transport.
- Cyclist are so-called Vulnerable Road Users and in the context of the *EU Road Safety Policy Framework 2021-2030 – Next steps towards "Vision Zero"* they need special attention. Not only should CCAM take into account the VRUs, but bicycles and bicycle infrastructure can also be made safer, e.g., through ISA for speed-pedelecs, ISA for cars, safe intersections using ITS and connected bikes (without making the cyclists obliged to be connected for a safe trip).
- In the *Sustainable and Smart Mobility Strategy* (SSMS), digitalisation is one of the flagship implementation strategies "making connected and automated multimodal mobility a reality: The EU needs to take full advantage of smart digital solutions and intelligent transport systems (ITS)." This calls for a boost in the uptake of zero-emission urban mobility, especially by addressing the large target group of commuters in cities and metropolitan areas. Smart Cycling provides such a boost by making cycling more attractive through the use of innovative ITS applications for cycling.
- Creating mobility data spaces to facilitate data sharing, and thus to support future data-driven innovation is a key component of *Shaping Europe's Digital Future*. Cycling data constitutes an important component of Smart Cycling and thus combining the various initiatives in the field of data spaces (MegaBITS, deployEMDS, FIWARE, EU Dataspace, GAia-X, etc), initiatives in the field of standardisation and specification (e.g. NAPCORE, C-Roads) and initiatives in the field of demonstration leading to a European road map for Smart Cycling use cases (e.g. MegaBITS, MERIDIAN, national projects, e.g. Mobilidata, Talking Traffic) can lead to a European road map for Smart Cycling, thus providing a valuable contribution to shaping this Digital Future.
- The *Urban Mobility Framework*, as part of the Efficient and Green Mobility Package, requires cities identified as urban nodes to create and adopt concrete Sustainable Urban Mobility Plans (SUMPs) that foresee an increase in the city's modal share of active transport modes such as cycling. ITS is one of the

tools identified to achieve this modal change, apart from (among others) more cycling infrastructure, bike parking facilities, education, promotion & incentives and integrated multimodal transport.

- The *revised ITS Directive 2023/2661 (*November 2023) is mainly focused on motorised traffic. However, it also states with respect to active mobility: "This Directive should ensure that ITS applications in the field of road transport enable seamless integration with other modes of transport, such as rail or active mobility, thus facilitating a shift to those modes whenever possible, to improve efficiency and accessibility". So, although cycling is not mentioned explicitly, seamless integration with other modes of transport is aimed for. In addition, Delegated Regulation (EU) 2024/490 amending DG (EU) 2017/1926 regarding the provision of EU-wide multimodal travel information services includes Level of services for static, historic and observed travel and traffic data and dynamic travel and traffic data, including cycling.
- The *European Declaration on Cycling* (C/2024/2377) recognises cycling as one of the most sustainable, accessible and inclusive, low-cost and healthy forms of transport. The Declaration should serve as a strategic compass for existing and future policies and initiatives related to cycling. Chapter VIII describes the need 'to improve the collection of data on cycling'. Cycling data needs to be collected in the same way across the EU to ensure effective monitoring of progress on implementation of the principles and commitments included in this Declaration.
- The opportunity for smart mobility to generate new and improved business efficiencies is also extensively referenced in the *Mobility Transition Pathway (MTP)* published by DG Grow in February 2024, including the cycling sector. Specifically, the MTP says "The integration of data from different areas and businesses could, for example, help leverage the value of aggregated data, while improving products and generating business opportunities to the entire ecosystem." "The stakeholders recalled that electrification, new sustainable modes of transport, increased connectivity and an increased role of software and data sharing are all shaping how businesses and consumers will operate and behave in the future." Action points for stakeholders including the EU Commission include "Develop and share best practices on new business opportunities and efficiencies brought by the European mobility and industrial manufacturing data spaces ". The cycling sector is not scaled or funded to take advantage of these opportunities which provide a competitive disadvantage to the sector compared to automotive and public transport.
- In the *Mission Letter of Ursula von der Leyen, president of the EC, to Apostolos Tzitzikostas*, Commissioner-designate for Sustainable Transport and Tourism (September 2024), she states the need to "ensure that digitalisation continues to help modernise the transport system, including the deployment of Intelligent Transport Systems and Smart Mobility solutions" and ""Work has to be done on a Sustainable Transport Investment Plan outlining a strategic approach to scale-up and prioritise investments in transport decarbonisation solutions". In addition, the Commissioner "will follow up on the European Declaration on Cycling and publish a first progress report by the end of 2025". Smart Cycling should be part of this smart and sustainable mobility system. Cycle data must be of the same quality as car data, but also the development of different kinds of (C)-ITS solutions (e.g., safety and speed) for cyclists will be needed.

From the above policy documents, it becomes clear that Smart Cycling and Cycling Data should be treated the same as motorised traffic.

4 State of play of Smart Cycling

In this chapter, we will first provide an inventory of use cases of Smart Cycling and map these on the Bicycle Pyramid used in the MegaBITS project (see explanation in 3.1). Next, we will present 24 best practices from North Rhein-Westphalia, Baden-Württemberg, other parts of Germany, Austria, The Netherlands and Flanders that have been added to the BITS Directory. This is followed by a mapping of these best practices with the use cases. Finally, we provide a brief analysis of this market overview.

4.1 Use cases and the bicycle pyramid

In two sessions, in MegaBITS and in the MERIDAN Smart Cycling Taskforce, an inventory has been made of the (potential) use cases for Smart Cycling. As a result, a total of 11 use cases has been identified, where each use case has multiple technical (C-)ITS solutions. In the next step, these use cases have been matched with the six levels of the bicycle pyramid as applied in the BITS and MegaBITS project and explained in section 3.1.

The Bicycle Pyramid defines a series of 'cycling needs' that need to be fulfilled in order for people to start cycling (first three levels) or to increase the amount of cycling (last three levels):

1. Safety and Security
2. Reliability
3. Speed
4. Convenience
5. Comfort
6. Experience

As mentioned in section 3.1, traditional cycling policy often aims at physical measures (e.g. infrastructure and parking). But a Smart Cycling Strategy in addition uses the power of Intelligent Transport Systems (ITS) to address the Bicycle Pyramid's needs. For example: route guidance using a 'safe bike route' will increase the safety of the cyclist and smart bicycle parking facilities will make finding a parking place in a large bicycle parking more convenient.

The result of this analysis is shown in the table below.

Table 4.1: Use cases versus level of the bicycle pyramid

Level of pyramid→ **Use case ↓**	**Safety/ security[3]**	**Reliability**	**Speed**	**Convenience**	**Comfort**	**Experience**	**Comment**
Secure bike parking and avoiding bicycle theft, e.g., provision of smart and secure bike parking, information about bike parking (VMS/app), orphan bike management, smart locks with geofencing, tracking devices to recover stolen bikes	X	X		X		X	

[3] Although 'safety' and 'security' are not the same, we have chosen to put them in the same column, because they are somehow related.

Level of pyramid→ Use case ↓	Safety/ security[3)]	Reliability	Speed	Convenience	Comfort	Experience	Comment
Facilitate bike sharing and bike share parking, using apps for bike share locations and bike share parking (e.g., geolocation), unlocking bikes, paying for bikes		X		X			
Route planning for cyclists e.g., shortest route, safest route, beautiful route, calm routes, healthy routes, for multimodal passenger trips (MaaS, multimodal route planning including cycling), for cycle logistics/cargo bikes	X	X	X	X	X	X	Different user groups have different requirements
Give cyclists the right route guidance near intersections. As C-ITS application this requires intersection topology (good data on the layout of intersection) and guidance at Intelligent Traffic Light Controller iTLC level. A more simple (not interactive) form could be a guidance light at the traffic light.	X		X		X	X	
Information provision to cyclists, e.g., providing road works information, pre-trip, on trip, surface conditions, winter maintenance, alternative routing, incident warnings. Special attention for HMI.	X	X	X		X	X	Some information is available (e.g., routes, surface type, winter maintenance routes), others not yet (e.g., surface conditions, road works for cycling)
Incentivising/rewarding cyclist e.g., cycling to work, health monitoring, cycling to school, by local/regional authorities. Possibly link to health insurance, tax reduction schemes.						X	
Improved traffic management for cyclists, e.g., faster green at traffic lights, green waves, rain sensors at traffic lights, with groups through green light, priority green for bike couriers	X		X		X	X	
Speed advise for cyclists, e.g. GLOSA at traffic lights, but can also be in school zones and mixed pedestrian/cyclist areas (geofencing), in peak hours depending on amount of traffic/cyclists. Special attention for HMI.	X		X		X		Speed advice for traffic lights exists. Geofencing is just starting, especially focus on speed-pedelecs.
Increase safety of cyclists through ITS and C-ITS: • ITS: black spot warning, safe bike crossings, smart solutions (AI based solutions) to measure (un)safety of intersection, smart lighting, … • C-ITS: predict accidents, detection and warning of dangerous intersections/situations (e.g., potential collisions, not enough distance	X		X		X	X	C-ITS currently is mostly focussed on car drivers, in which cyclists are considered as vulnerable road user. Warnings for cyclists are possible via haptic,

Level of pyramid→ Use case ↓	Safety/ security[3)]	Reliability	Speed	Convenience	Comfort	Experience	Comment
between car and cyclist when overtaking), bicycle as part of CCAM (Connected Cooperative Automated Mobility), e-Call for cyclists, speed management (geofencing) of fat bikes and speed pedelecs, prevent dooring through C-ITS. Special attention for HMI and on fail-safe design.							acoustic and visual systems.
Use bicycle as a sensor and as a source for data collection: all kinds of sensors that can be connected to cycling, e.g., sniffer bike, stress sensors, pavement measurements, hard braking, swerving, e-call	X	X	X	X	X	X	Only indirect link to bicycle pyramid: the bicycle data can be used for better policy making, data-driven traffic planning, optimisation of cycling infrastructure, more comfort for cyclists, integration into traffic guidance systems, etc.
Provision of mobility data according to EC delegated regulations 2022/670 (RTTI) and revision of the 2017/926 (MMTIS) using (C-)ITS solutions for cyclists: counting cyclists, speed/delay, available free bike parking places, number of shared bikes	X	X	X		X		Only indirect link to bicycle pyramid: the cycling data can be used for better policy making (cycle lane planning, cycle facility planning), performance indicators, investment needs.

It can be concluded that all levels of the pyramid are covered by at least four use cases. The levels with the highest number of use cases are 'safety/security' (nine use cases) and 'speed', 'comfort' and 'experience' (eight use cases). 'Reliability' and 'convenience' are populated with respectively six and four use cases.

However, not all use cases mentioned by MegaBITS /MERIDIAN Smart Cycling Taskforce are already on the market:

- Information provision to cyclists is existing, but not for all information types, and only in the most advanced cities/regions. Some information is available (e.g., routes, surface type, winter maintenance routes), while other information is rarely or not (yet) available for cyclists (e.g., surface conditions, road works for cycling).
- Speed advice for traffic lights exists. But geofencing is just starting, especially focusing on speed-pedelecs.
- C-ITS currently is mostly focussed on car drivers in which cyclists are considered as vulnerable road user. The idea is to make cyclists digitally 'visible' for car drivers through V2V communication. C-ITS

applications for cyclists not including a car are rare[4] or not yet existing, e.g., warning for dangerous situations, such as sharp curves, railroad crossings, etc.

Furthermore, it can be noted that the two use cases on data collection only indirectly link to the bicycle pyramid: the data can be used for better policy making, and this can then contribute to the various levels of the bicycle pyramid.

4.2 Collection of best practices

Since the start of the BITS project in 2019, the project partners started to collect best practices of Smart Cycling. So far, 80+ best practices have been collected, and these can be found in the BITS Directory. The Smart Cycling Taskforce of Meridian offered a good opportunity to expand the BITS Directory with new best practices from other regions in Europe. As a result, 24 additional best practices have been added to the BITS Directory from North Rhein-Westphalia, Baden-Württemberg, other parts of Germany, Austria, The Netherlands and Flanders.

Table 4.2: Best practices of Smart Cycling

Smart Cycling solutions	*Short description*	*More information*
Information Portal covering information on cycling infrastructure including routing	Navigation support / Cyclists information	www.radwanderland.de
Radroutenplaner Deutschland - Navigation service nationwide based on regional subsystems	Navigation support / Cyclists information	www.radroutenplaner-deutschland.de
Radroutenplaner BW - Information on cycling routes incl. routing	Navigation support / Cyclists information	www.radroutenplaner-bw.de
Website with mobility data - incl. cycling data. Also published according to INSPIRE guidelines.	Open Data	https://www.mobidata-bw.de/dataset/radnetz-bw https://www.geoportal-bw.de/geonetwork/srv/ger/catalog.search#/metadata/ffed9bf6-a6ec-4d3b-b047-55d3d01d9712
Information Portal und Cycling Data "hub" for Planners and Government. Current main Focus are cycling networks (RadNETZ BW), local networks and infrastructure data.	Cycling Data portal (Infrastructure)	www.radvis-bw.de

[4] https://zagdaily.com/featured/bosch-redefines-v2x-to-digitally-connect-e-bikes/

Smart Cycling solutions	*Short description*	*More information*
Information Portal incl. certain Cycling Data from RadVIS (mentioned above) for Public. Incl. WFS/WMS-Services for individual use.	Open Data / Cyclist Information	radroutenplaner-bw.de/radvis
Dutch Metropolitan Cycling Innovation - project of Dutch Ministry of Transport and Water Management on bicycle data innovation.	Development of standards and interfaces, showing opportunities of data to improve cycling policy. Cooperation of public and private parties focussing on 4 types of data: 1) data from smart traffic lights, 2) floating bike data, 3) bike parking data, 4) counting data and data fusion.	https://dmi-ecosysteem.nl/en/about-the-dmi-ecosystem/
Province Zuid-Holland improves cycling accessibility through digital twin	Argaleo: digital twin and dashboards	https://www.argaleo.com/ https://www.argaleo.com/2022/03/06/provincie-zuid-holland-verbetert-fietsbereikbaarheid-met-digital-twin/
Dexter platform: one platform for bicycle counting data in NL	open platform for bike counting data	https://dexter.ndw.nu/opendata/bicycle
Veloviewer	Dashboard for counting data from traffic lights (V-Log) in The Hague (NL). Expandable to waiting times, red light negation, bike parking information	https://www.fietsberaad.nl/CROWFietsberaad/media/Kennis/Bestanden/Paper-De-VeloViewer.pdf?ext=.pdf
Shared mobility dashboard	Dashboard showing all shared mobility vehicles in the Netherlands	https://dashboarddeelmobiliteit.nl/
Bike Quality Application	With the Bike Quality service, Salzburg Research has created an application for digitally recording and analysing the surface quality of bicycle infrastructure.	https://www.salzburgresearch.at/en/2020/bike-quality-bicycle-infrastructure-under-the-microscope/
Overtaking manoeuvre analysis	Overtaking manoeuvres are analysed and their risk assessed based on positions, distances, and velocities of cars. To this end, LiDAR scanners on a smart bicycle followed by automatic detection and tracking of vehicles are used.	https://www.salzburgresearch.at/projekt/radbest/
Cycling traffic counts in Salzburg	The City and Province of Salzburg operate over 20 permanent counting stations for cyclists, particularly in the urban area of Salzburg. The figures can be viewed online.	Magistrat Salzburg (eco-counter.com)
Holoscene Bike	Multi-sensor bike (developed by Boreal Bikes): a research bike equipped with the latest technology for connectivity (C-ITS), edge computing and HMI. The bike is equipped with sensors comparable to those of the latest generation autonomous vehicle.	https://www.borealbikes.com/

Smart Cycling solutions	*Short description*	*More information*
senseBox Münster, Germany	The core of every senseBox is the easy-to-program senseBox mini-computer to which various sensors are connected. Sensors can be connected to collect relevant data for cyclists (e.g., particles, quality of infrastructure, etc.). It is demonstrated in the ATRAI Bikes project.	https://sensebox.de/en/ https://atrai.bike/en
Bike route planner	Digital bike route planner based on the Austrian Multimodal Journey Planer (VAO), accessible via different web clients and different apps, e.g. "Radlkarte Salzburg"	https://verkehrsauskunft.salzburg.gv.at/
Leezenflow Münster (dynamic traffic sign)	To calculate the colour gradient, the system combines the traffic light forecast data with the average speed of bicycle traffic at the respective locations, which was first collected in bicycle projects in the city of Münster. Leezenflow is free software (Open Source).	http://leezenflow.de
Radwelle Oberhausen (dynamic traffic sign)	The bicycle wave reduces waiting times for cyclists at traffic lights. Anyone approaching a traffic light is detected at an early stage either by a thermal imaging camera or by an induction loop and a corresponding programme is initialised to quickly switch to green. The waiting time at the traffic lights is considerably reduced and convenience is increased as there is no need to press a button at the lights.	https://www.swarco.com/de/stories/radwelle-fuer-oberhausen-deutschland https://www.oberhausen.de/de/index/rathaus/verwaltung/stadtplanung-bauen-mobilitat-umwelt/mobilitat/verkehrsplanung-undsignalwesen/radwelle.php
Stadtradeln (Gamification-App to promote cycling among adults)	Stadtradeln is a competition in which the aim is to cycle as many everyday journeys as possible in a climate-friendly way for 21 days	https://www.stadtradeln.de/home
Schulradeln (Gamification-App to promote cycling among children)	Pupils collect their cycled kilometres individually or as a class for the school team and can win something	https://www.stadtradeln.de/schulradeln
Traffic Pilot Düsseldorf (An app shows the correct speed for the green wave)	On the bike, the traffic pilot ensures a relaxed and calmer riding experience, which makes cycling more pleasant and attractive. Mobile phone app that can also be used when using the bike, but was not developed for this purpose.	https://www.duesseldorf.de/verkehrsmanagement/mobilitaet-neu-denken/traffic-pilot https://www.duesseldorf.de/verkehrsmanagement/projekte/abgeschlossene-projekte/komod-next
Woehr Bikesafe	Round tower für Bike-Parking, up to 128 places.	https://woehr.de/en/bikesafe.html
Radroutenplaner NRW	Cycling route planner for North Rhine-Westphalia	https://www.radroutenplaner.nrw.de/

Smart Cycling solutions	*Short description*	*More information*
Radverkehrsnetz NRW	Information about the cycle path network in North Rhine-Westphalia with details.	https://www.radroutenplaner.nrw.de/rrp_radnetz.asp

All of the best practices in the table above have been/will be entered into the BITS directory[5], managed by Cycling Industries Europe (CIE). The BITS directory currently contains 80+ products and service as well as best practices of Smart Cycling, and this number is continuously growing. The BITS directory focuses on Smart Cycling applications that are relevant for local and regional authorities, and which they can influence, e.g., through implementation of the Smart Cycling applications or by providing good quality data. The BITS directory does not include ITS applications that are fully under the control of the automotive sector, such as smart dooring systems, AEB when detecting a bike, etc.

From the new best practices added to the BITS Directory, the following can be observed:

- Most of the German examples are focused on digitisation of the cycling infrastructure, e.g., getting a digital overview of the existing cycling infrastructure
- In Austria and The Netherlands, they are also looking at digital solutions for the cyclists, such as smart traffic lights, improving road safety with (C)-ITS, providing bike parking guidance, etc.

This might be related to the fact that in Austria and the Netherlands there are national reference geographic databases for road/transport infrastructure (including cycling), in Germany it's still rather fragmented. Good network data is a prerequisite for any advanced solutions.

The best practices should reflect both types of Smart Cycling:

- The data/information layer, as a kind of basic digital infrastructure
- The (C)-ITS systems/services that directly influence the behaviour of the cyclists.

It should be noted that BITS Directory only shows Best Practices and products that are directly relevant for cities and regions. But ITS systems and services driven by the automotive industry could be relevant for formulating actions directed to the EC.

4.3 Mapping best practices with the use cases

In this section, the inventory of use cases from section 4.1 is mapped with the best practices from section 4.2. The table below shows that most best practices fall in the categories 'Provision of mobility data according to EC delegated regulations on RTTI and MMTIS' and 'Route planning for cyclists and for multimodal trips.

Table 4.3: Mapping of best practices with collected use cases

Use case	**Frequency**
Provision of mobility data according to EC delegated regulations on RTTI and MMTIS	8
Route planning for cyclists and for multimodal trips	6
Use bicycle as a sensor	3

[5] The BITS directory welcomes new contributions in field of Smart Cycling products, services and best practices. New contributions can be uploaded via the webform on the BITS directory.

Use case	Frequency
Incentivising/rewarding cyclist	2
Speed advise for cyclists	2
Avoiding bicycle theft	1
Information provision to cyclists (road works, pre-trip, on trip, surface conditions, etc.)	1
Facilitate bike sharing and bike share parking	1
Improved traffic management for cyclists	1
Give cyclists the right route guidance near intersections (e.g. choosing the right lane when turning left or right)	0
Increase safety of cyclists through ITS and C-ITS	0

Two categories are not covered, e.g., 'Give cyclists the right route guidance near intersections' and 'Increase safety of cyclists through ITS and C-ITS'. This does not mean that they don't exist. It only means that they are not mentioned during this analysis.

This analysis to a certain extent shows the focus of the parties implementing Smart Cycling. However, it must be noted that this also depends on the parties involved in the Smart Cycling taskforce. If more commercial parties have participated, the list of best practices would most likely show a different distribution across the various use cases.

Safety of cyclists through C-ITS: A critical view from ECF

From the cyclist's point of view there are some reservations with respect to V2V type of safety technology. Technology that connects the car/driver and the cyclist/bicycle and either warns or brakes one of the vehicles.

- Often the problem for cyclists and pedestrians is not so much a lack of awareness on the part of drivers, rather it is negligence from bad, risk-taking drivers. So, warning systems that can be voluntarily downloaded could appeal more to those drivers who are already looking out for cyclists and are interested in being safe on the road. They would not really be the ones that need to be attracted. Although of course it can also be useful for conscientious drivers as well, perhaps a useful tool especially in the rural context, or on twisty roads with very limited vision at corners it could be very useful to know when a cyclist is nearby.
- From the perspective of cycling advocates, there is the moral dilemma of requiring cyclists, the "victims", to tool up and make sure they are responsible for not allowing motorised vehicles to hit them. It should be the motor vehicle driver bringing the vehicle onto the road that should shoulder the responsibility for avoiding the crash.
- V2V Warning systems would be very difficult to implement in areas of high exposure, e.g., where there are lots of cyclists and/or vehicles. The vehicle would be braking or beeping constantly to signal cyclists are near and would be turned off by the driver eventually.
- It could give a false sense of security. Drivers and cyclists may start to assume that they are safe which could lead to increased risky behaviour, or lack of concentration. After a few positive encounters where the technology may have worked well, the driver may assume the system is doing the job of looking out for cyclists and assuming they are safe. Leading to more risky driving. Same for the cyclist, leading to riskier cycling behaviour.
- It could be perceived as taking the responsibility away from the vehicle manufacturer to put proper safety measures in their vehicles. Speed limiters that would not allow their cars to go over the speed limit are available and work,

they are also an option in the General Safety Regulations ISA options – manufacturers and regulators should focus on these.

- Likewise making sure that vehicle to cyclist/pedestrian Autonomous Emergency Braking (AEB) and the Moving Off Information System (MOIS)/Blind Spot Information System (BSIS) for trucks work perfectly should be the focus. The General Safety Rules (GSR) AEB for cyclists and pedestrians should be supported, and also the MOIS and BSIS for trucks and buses. But these are qualitatively different systems, often for specific crash scenarios, albeit still with some of the problems concerning false sense of security.
- Does this sort of tech essentially kick the problem down the road to those that don't have the application? If it is on an app then kids, elderly people and those unwilling to pay for the app will be excluded. If it is on the bike then all those unequipped or unwilling to pay the extra 50 euros for the tech on the bike will be excluded. And this is even before considering pedestrians. There must be better ways to ensure safety.
- For this technic to be put on bikes rather than apps. What about all those thousands (millions?) of old bikes still rolling around the EU, the bicycle fleet gets turned over much slower than the car motor vehicle fleet. And should cyclists really have to pay an extra 40-50 euros to have this tech on their bikes. It is said that all are equal on the road and all should have equal responsibility on the roads to be/stay safe. It is an enticing concept but unfortunately not true. We are fundamentally unequal on the roads, with cyclists and pedestrians bring negligible power and mass onto the roads, but being susceptible to small amounts of power and mass. This requires motor vehicle/drivers to shoulder more responsibility.
- Liability – if this tech becomes widespread then it could be a way of reducing driver liability and increasing liability for cyclists. In some countries cyclists are being challenged in court when applying for damages after a crash with a car if they were not wearing a helmet.

4.4 Smart Cycling stakeholders

Intelligent Transport Systems (ITS) and Cooperative Intelligent Transport Systems (C-ITS) are pivotal in enhancing cycling safety, providing information about cycling infrastructure and to find the best individual route from A to B. A comprehensive stakeholder analysis involves understanding the roles and perspectives of various groups:

1. Political decision-makers: Government officials and policymakers establish the regulatory and funding frameworks that facilitate the implementation of ITS and C-ITS initiatives, influencing the pace and direction of technological integration in cycling infrastructure. Politicians at European, national, regional and municipal level set the framework conditions for the promotion of cycling and the implementation of ITS solutions. Through legal requirements, financial support programmes and strategic planning, such as a National Cycling Plan, they have a significant influence on the development and implementation of ITS in cycling.

Nevertheless, when multiple political decision makers oversee the digitalisation of mobility, several challenges for Smart Cycling can arise:

a. Fragmented Policy Development: Each ministry may have distinct priorities, leading to policies that are not harmonised. This fragmentation can result in overlapping initiatives and fundings or even worse, gaps in addressing critical issues.
b. Coordination Difficulties: Without a centralised coordinating body, aligning efforts across ministries becomes challenging. This lack of coordination can hinder the development of integrated digital mobility solutions.

c. Resource Allocation Inefficiencies: Disparate budgeting and resource allocation can lead to inefficiencies, with some areas potentially underfunded while others receive redundant investments.
d. Inconsistent Standards: Different ministries might establish varying standards for digital systems, complicating interoperability and data sharing across platforms.
e. Slower Decision-Making: The need for consensus among multiple ministries can delay decision-making processes, slowing the implementation of digital mobility initiatives.
f. Accountability Challenges: With shared responsibilities, pinpointing accountability becomes difficult, potentially leading to a lack of ownership and reduced effectiveness in policy execution.

How much more complicated is it when not only different policy bodies of all European Member States but also the European Commission are working on the digitalisation of the mobility system?

2. Road Operators: Entities responsible for road (cycling) infrastructure, including government agencies and municipal planners, play a crucial role in implementing ITS and C-ITS technologies. Their commitment to incorporating Smart Cycling provisions into road designs is essential. However, challenges like limited funding, lack of experience and political support can hinder these efforts. On the other hand, they can act as launching customers, thus stimulating the implementation of Smart Cycling solutions.

3. Cycling organisations: This group includes cycling advocacy organisations, community groups, and individual cyclists who advocate for safer and more efficient cycling conditions. Their input is vital in shaping ITS solutions that meet the actual needs of the cycling community. They advocate for safer and attractive cycling conditions and are instrumental in promoting the adoption of ITS solutions that enhance safety and convenience. Their active participation ensures that the needs of cyclists are taken into account when new technologies are introduced.

4. Cycling Industry: Manufacturers and retailers of bicycles and related accessories are increasingly integrating smart technologies into their products. The global bicycle market is projected to grow significantly, driven by innovations such as connected bicycles equipped with GPS/GNSS tracking and performance monitoring features. Furthermore, electric bicycles continue to boom, fuelling the use of ITS services.

5. Technology Providers: These stakeholders supply the necessary hardware and software solutions for ITS and C-ITS systems and services. Their innovations enable real-time data collection and communication, enhancing safety and efficiency for cyclists. It includes bicycle-based, infrastructure based and other forms of ITS and C-ITS solutions.

6. Research Institutions: Academic and research bodies analyse (among others) cycling behaviours, safety and infrastructure needs, providing data-driven insights that inform the development and deployment of ITS solutions. Their findings are key for the development of ITS solutions tailored for cyclists. For instance, research[6] has identified barriers to cycling investment, such as funding shortages and leadership gaps, which can be addressed through targeted ITS initiatives.

7. The cyclists play a pivotal role in the development of Intelligent Transport Systems (ITS) for cycling, both as contributors to system design and as beneficiaries of enhanced safety and convenience. Cyclists' behaviours and needs are integral to shaping effective ITS solutions. For instance, the BITS project (Bicycles and ITS) aimed to integrate a 'digital layer' into cycling, benefiting both cyclists and local authorities. This initiative aimed at encouraging more people to cycle by leveraging digital technologies.

The integration of ITS in cycling, such as connected cycling systems, relies on citizen adoption. Cyclists contribute to policy discussions on smart cities and the Internet of Things (IoT), influencing how cycling is

[6] Barriers to investing in cycling: stakeholders views from England, Aldred, Watson, Lovelace, Woodcock. https://pubmed.ncbi.nlm.nih.gov/31582879/

integrated into these frameworks. Analysis of European Commission's 2013 Urban Mobility Package reveals the importance of public discourse in shaping sustainable urban mobility policies that prioritise cycling. The annex to this package defines SUMPs as plans that "build on existing planning practices and take due consideration of integration, participation, and evaluation principles."

In summary, cyclists' engagement is fundamental to the development and implementation of ITS for cycling, both through their direct involvement in system design and as key users whose safety and experiences are enhanced by these technologies. Their active participation ensures that these systems are user-centric, sustainable, and effectively integrated into the broader urban mobility landscape. Their role as consumers is also pivotal: Ultimately, only ITS solutions that are convenient, safe, cost-efficient and provide real added value will be adopted by cyclists on a large scale.

Only the cooperation of all stakeholders enables the targeted roll-out of Smart Cycling services. Effective collaboration among these stakeholders is vital for the successful implementation of ITS and C-ITS in cycling. By addressing challenges and leveraging technological advancements, a safer and more efficient cycling environment can be achieved.

4.5 Data, data privacy and security

The market for bicycle traffic data in Europe is developing continuously, although the availability and quality of data varies from region to region. In countries such as the Netherlands and Denmark, where the cycling mode share is particularly high, extensive data is available. In the Netherlands, for example, 61% of the population aged 15 and over regularly cycle. In other European countries, the proportion of regular cyclists is lower, which often goes hand in hand with a less developed cycling infrastructure and correspondingly limited data availability. In Cyprus, for example, the proportion of regular cyclists is only 0.6%[7].

Overall, efforts are being made in Europe to improve the collection of cycling data in order to support the planning and promotion of cycling. The market for cycling data is rather small and business cases, apart from application for sports like Strava and Komoot, are rare. Although big players like Google are actively looking for more cycling relevant data by the authorities.

In Europe, cycling data is provided by a combination of organisations, including governmental bodies, non-profit organisations, and private companies. Despite these fragmented efforts, there is no single comprehensive source for cycling data across Europe. The availability and quality of data vary by region, often depending on local infrastructure and data collection initiatives. Collaborative projects and standardised data collection methods are ongoing to address these disparities and improve the overall quality and accessibility of cycling data in Europe.

With this in mind, the newly extended European co-funding project NAPCORE will focus on the provision of harmonised, high-quality cycling data at the NAPs. The NAPs in Europe should also provide data on for example bike parking facilities, shared bikes, bike infrastructure, etc. but a report of NAPCORE[8] shows that this is only done to a very limited extent.

The integration of smart technologies into bicycles, offers numerous advantages such as improved navigation, fitness tracking and theft protection. However, this networking also could bring challenges in the area of data security, although it heavily depends on the data categories (safety-relevant data are less prone to security challenges than personal data).

[7] https://www.destatis.de/Europa/DE/Thema/Verkehr/Fahrrad.html?templateQueryString=Fahrradfahrende+in+den+Niederlanden
[8] https://www.napcore.eu/documents/M3.5_4th_report_NAP_data_availability.pdf

Data security challenges in Smart Cycling:

- Data transmission: Smart Cycling gadgets often communicate with smartphones or cloud services via wireless connections. Without sufficient encryption, this data can be intercepted and misused during transmission.
- Data processing and storage: Collected data, such as location information or personal fitness data, is often stored in the cloud. Inadequately secured servers (e.g., not placed in Europe or in places with similar data protection laws) can be a target for cyberattacks, which can lead to data leaks.
- User control: It is essential that users retain control over their data, including the ability to view, export or delete it.

4.6 Standardisation

Standardisation is essential for road operators in the context of digital twins and operating environment, ensuring seamless data exchange, interoperability, and efficient management of complex infrastructure. The absence of standardised data formats, protocols, and interfaces poses technical challenges that hinder the full potential of digital systems. By introducing common standards for data management, integration protocols and terminology, road operators can overcome these challenges and reap the benefits of improved data quality, compatibility and cost reduction. Standardisation also fosters collaboration among stakeholders, simplifies the integration of smart services into existing systems, and paves the way for a data-centric network of interconnected smart services that generates mutual value. Overall, standardisation is crucial for the successful deployment and utilisation of smart mobility in the road sector, enabling road operators to optimise operations, enhance safety, and make informed decisions based on accurate and reliable data.

It needs to be noted that Smart Cycling is just one part of a bigger digital mapping of the mobility system (e.g., digital twin, electronic traffic regulations, Building Information Model (BIM)). Connectivity between the domains is important and therefore standardisation efforts need to be connected.

For cycling standardised data on for example bicycle traffic counting, infrastructure, regulation, recommendations, rerouting or roadworks information should be following similar standards as for other transport modes, e.g., DATEX II and TN-ITS. NAPCORE is currently producing recommendations on cycling data standards in four main fields: counting, infrastructure, parking, and real-time data. However, at this time bicycle data standards are not available yet at European level in suitable form for all use cases and for cycling which is embedded in local networks and settings and accurate information may be hard to come by. There are concerns that DATEX II is complex and quite demanding regarding its structure and development. For the many small companies in the cycling industry this might be a problem to solve.

Nevertheless, the relevant DATEX II profiles need to be elaborated such that cycling will be covered. This is true in particular for the new DATEX II v.3 where a comprehensive description of all regulation is intended.

Describing the cycling network in a very detailed way is a cooperative task, where many actors are involved. Open Street Map is a community-based application which can provide the basic map data (see also section 4.8.). However, since OpenStreetMap is not an official dataset, it will not be the right data source for legally binding regulations.

4.7 C-ITS for cycling[9]

According to a study[10] conducted in 2023, the combination of driver assistance systems with C-ITS, the accident-avoidance potential for vehicle collisions can be increased from 50% to 88%. In recent years, the equipment of motor vehicles and other road users with communication technology has improved significantly. This trend is expected to continue in the coming years. Although development has fallen short of optimistic expectations, there are currently almost two million motor vehicles on European roads with C-ITS direct communication. While C-ITS has already enabled significant safety gains for motor vehicles, cycling has so far only benefited indirectly. By equipping cyclists with suitable technology or "smart up" the infrastructure, further major safety gains can be expected. C-ITS applications for cyclists are scarcely found, with only a few exceptions. In this section, we explore where C-ITS is already applied for cyclists, where opportunities exist, but also which challenges still need to be overcome.

What is C-ITS?

The interaction between vehicles and between vehicles and infrastructure is the domain of Cooperative Intelligent Transport Systems (C-ITS), enabling road users and traffic managers to exchange and use information in a trusted ecosystem (C-ITS Trust Domain[11]) to coordinate their actions. Participation in the C-ITS Trust Domain obliges you to comply with and use the standardised C-ITS protocols and message formats as well as the harmonised C-ITS services. This collaborative element - made possible by digital connectivity between vehicles (V2V – Vehicle to Vehicle) and between vehicles and transport infrastructure (V2I – Vehicle to Infrastructure) - is expected to significantly improve road safety, efficiency, and driving comfort by helping drivers make the right decisions, adapt to traffic conditions and nudge for a certain desired behaviour. A standardised PKI (Public Key Infrastructure) system ensures that transport users and infrastructure operators can trust that the information received is authentic, unaltered and comes from a trustworthy source. A standardised European framework ensures that the same high security standards apply throughout Europe. With a standardised PKI system, C-ITS components from different manufacturers can communicate seamlessly with each other. This is important, for example, for the integration of new technologies and for the expansion of the system without encountering compatibility problems. A centralised PKI system also makes it easier to manage and maintain the security infrastructure. There is the European C-ITS Security Credential Management System (EU CCMS) available, which can be used and also contracted.

The (potential) benefits of C-ITS for cyclists can be found mainly in improved road safety, time savings, comfort and experience. Examples include connectivity with nearby vehicles and warnings for hazardous situations, traffic lights turning green earlier, or easier access to (guarded) bicycle parking facilities.

[9] This section is based on an article published by Ronald Jorna (MOVECO advies) and Veronique Rietman (Mobycon) in Verkeerskunde (March 2025).

[10] Feifel, Harald & Erdem, Bettina & Menzel, Marc & Gee, Robert. (2023): Reducing Fatalities in Road Crashes In Japan, Germany and USA With V2X Enhanced ADAS.

[11] The C-ITS Trust Domain refers to a system in which all involved entities (C-ITS stations) adhere to the same security guidelines and standards and can therefore trust each other. It is used to implement security models in the complex and distributed C-ITS system. It provides the basis for access restrictions, network security and simplified management of user rights.

Existing C-ITS Applications for Cyclists

The most well-known C-ITS-like application[12] for cyclists is probably the "Schwung" app, which allows cyclists to get a green light earlier at traffic lights. This so-called 'Traffic Light Prioritisation' is already applied in various cities in the Netherlands and Flanders, where it was developed within the Mobilidata program and is currently being brought to end-users. In Zwolle, as part of the BITS project, bike couriers were given priority at several traffic lights using this app. Other applications at intelligent traffic lights (iVRIs) include 'Signal Phase and Timing Information' and 'Green Light Optimal Speed Advisory' (GLOSA), where cyclists receive information on the optimal speed to cycle through green lights. MegaBITS partner Hanseatic City of Hamburg uses this at several traffic lights. These C-ITS applications reduce cyclists' waiting times, saving travel time and increasing comfort. They can also help reduce red-light violations.

Other existing C-ITS-like applications for cyclists include 'Floating Bike Data Collection' and 'Event Data Collection'. Various cycling apps track cyclists (position, speed, direction), such as Strava and Komoot, as well as Google Maps and most bike-sharing systems. Additionally, C-ITS-like applications can collect additional data, such as Snuffelfiets (air quality) and See.Sense (route choices, speed, acceleration, deceleration, road surface quality). These types of data can be very useful for (infrastructure) planning purposes,

Future C-ITS Applications for Cyclists?

The C-Roads Platform recently released a new version of C-ITS service and use case definitions, providing a clear overview of all C-ITS use cases[13], mainly aimed at motor vehicle traffic. An analysis shows which use cases could be relevant for cyclists.

Most potential applications relate to road safety. Last year, CONEBI dedicated a white paper to this topic. Various applications could warn cyclists of dangers, such as hazardous weather conditions, obstacles on the road, emergency vehicles, or railway crossings. These warnings can prevent accidents.

Additionally, some use cases can increase convenience. Information on road closures enables cyclists to choose alternative routes in time. Apps, like for motorists, could provide cyclists with information about available parking facilities.

The next table contains a more in-depth analysis of possible C-ITS applications for cyclists. This is based on an existing list of C-ITS use cases for motor vehicles from C-Roads. Most of the listed potential applications for cyclist are not yet realised.

Table 4.4: Potential C-ITS applications for cyclists

Use Case car	Possible applications for bikes	Advantages
Hazardous Location Notification		
Weather Condition Warning (HLN – WCW)	Warnings for slipperiness, warnings for extreme wind, warnings for approaching bad weather (rain, lightning).	

[12] According to C-ROADS, a service may only be called C-ITS when it complies to the C-ROADS specifications. Consequently, it is ensured that all traffic participants adhering to the specifications are able to participate in standardised C-ITS services. Therefore, here we call it 'C-ITS like applications': they have the same objective, but technically speaking cannot be called C-ITS applications.

[13] C-ITS Service and Use Case Definitions, Version 2.2.1. C-Roads Platform, Working Group 2 Technical Aspects, Taskforce 2 Service Harmonisation (December 2024).

Use Case car	Possible applications for bikes	Advantages
Temporarily slippery road (HLN – TSR)	Warnings for slipperiness due to frost, wet leaves, gravel on the road, etc.	HLN messages are aimed at preventing accidents. Warnings can be given location-specifically.
Animal or person on the road (HLN – APR)	Warnings for a large animal on the road/cycle path.	
Obstacle on the road (HLN – OR)	Warnings for an obstacle on the road, such as a fallen tree, cargo, illegally parked car, ...	
Emergency or Prioritised Vehicle Approaching (HLN – EPVA)	Warnings for a vehicle with flashing lights.	
Railway Level Crossing (HLN – RLX)	Warnings for a railway crossing.	
Unsecured Blockage of a Road (HLN – UBR)	Warnings for subsided cycle paths, loose manhole covers, stones on the cycle path, flooding, etc.	
Public Transport Vehicle Crossing (HLN – PTVC)	Warnings for intersections with trams, bus lanes, etc.	
Public Transport Vehicle at a Stop (HLN – PTVS)	Warnings for public transport stops (and disembarking passengers).	
Road Closure (RWW – RC)	Relevant for cyclists, e.g., a bridge that is out of service, or a road that is completely blocked, also for cyclists.	Provides the opportunity to choose another route. Moreover, safer for cyclists and road workers.
Road Works – Mobile (RWW – RM)	The same as for cars, to warn cyclists of roadworks, such as mowing, sweeping, line marking, etc.	Safer for cyclists and road workers.
In-Vehicle Signage		
Traffic Signs (IVS – TS)	For example, prohibited for cyclists.	Messages can be given exactly at the location where they apply, in the language of the cyclist, can be repeated, and can cover a larger area than just physical DRIPS.
Free Text (IVS – FT)	Instructions for cyclists at festivals, in the city centre, regarding e.g., parking, prohibited for cyclists between 09:00-18:00, etc.	
Smart Routing (IVS – SR)	Detours for cyclists, e.g., bridge out of service, crowded cycle path, ...	
Probe Vehicle Data		
Vehicle Data Collection (PVD – VDC)	Cyclist automatically transmits information about position, speed, direction, etc.	Information about waiting times, speed differences, road surface quality, etc. can be used by policymakers for better cycling policies.
Event Data Collection (PVD – EDC)	Cyclist automatically transmits information about acceleration/deceleration, lights on/off, road surface quality, particulate matter, etc.	
Signalised intersections		
Signal Phase and Timing Information (SI – SPTI)	Cyclist can adjust speed to pass through green more easily.	If cyclists pass through green faster, there is less waiting at traffic lights.
Green Light Optimal Speed Advisory (SI – GLOSA)	Cyclist receives advice on the correct speed to pass through green.	

Use Case car	Possible applications for bikes	Advantages
Traffic Light Prioritisation (SI – TLP)	Prioritising cyclists in general or only bicycle couriers over other traffic.	
Imminent Signal Violation Warning (SI – ISVW)	Warning for 'cycling through red' based on speed and distance to the traffic light.	Could be possible for cyclists, but the question is whether cyclists would pay attention to this...
Points of Interest		
Parking Availability (POI-PA)	For example: cyclist receives information about available parking facilities or parking bans for shared bikes when approaching the city centre.	Convenience for the cyclist.
Collective Perception		
Collective Perception on Urban/Interurban Intersections (CP-UI)	This use case is aimed at warning motorists about vulnerable road users but could in principle also be used to warn cyclists about cars or trucks.	This can increase road safety for cyclists.

Challenges for C-ITS Applications for Cyclists

Before C-ITS is widely implemented in the cycling domain, several challenges must be tackled:

- Standardisation and interoperability: If you want to receive warnings, they must work everywhere, not just in your own city or country. Currently, if you want to cycle through Hanseatic cities such as Antwerp, Zwolle, and Hamburg (all three partners in MegaBITS), you need a different Traffic Light Prioritisation app for each city. From today's local perspective, it doesn't seem to be a big problem, for safety-critical applications, standardisation is essential. Standardisation is also crucial for manufacturers, who can achieve cost benefits and expand their market. The C-Roads Platform is working on establishing C-ITS specifications and plans to give more attention to urban C-ITS applications, such as public transport and cycling, but this is still in its early stages.
- Human Machine Interface: Besides standardisation, C-ITS for cyclists presents an additional problem compared to cars. How can information be conveyed safely to the cyclist? Some applications, like Green Light Prioritisation, work in the background, so the smartphone can stay in your pocket. However, for information on bicycle parking or road closures, a display is almost unavoidable, although acoustic signals and vibrations in handlebars or signals via helmets or other wearables are being explored as possible options for a safe Human Machine Interfaces (HMI). Alternatively, information might be displayed in public space, e.g., through Variable Message Signs (VMS).
- Critical Mass: C-ITS services benefit from mass adoption. The more users, the greater the benefits, such as improved road safety and convenience. This requires not only sufficient connected bikes, vehicles, and infrastructure but also user acceptance. Trust, safety, data protection compliance and privacy are crucial. If the Smart Cycling community wants to engage in C-ITS standardisation, it needs a member group representing the cycling (service) industry like the Car-2-Car consortium or the road operators in C-ROADS. This would bring the cycling-relevant use cases into the standardisation process. Additionally, relevant data, such as road closures and asphalt conditions, must be available. Without this data, the added value of C-ITS remains limited.

Finally, the question arises whether cyclists even want this. With the rise of e-bikes and speed pedelecs, the value of bicycles increases, and bikes will increasingly be connected, as shown by brands like Boreal Bikes and

Cowboy. Safety is important, but part of cycling enjoyment comes from the feeling of freedom. Not everyone wants to be connected all the time or travel as fast as possible.

It can be concluded that C-ITS can improve road safety and convenience for cyclists. There are already some applications, such as smart traffic lights and route information, but broader implementation still requires standards, a user-friendly and safe human-machine interface, clear added value for cyclists and a critical mass of users. Cyclists value freedom, which could influence the acceptance of C-ITS. The future will reveal to what extent C-ITS for cyclists will become a reality.

4.8 Safety improvement by Smart Cycling

Cyclists in transport fall under what is known as Vulnerable Road Users (VRUs), who are, by definition, the most exposed to road risks and especially to the severe consequences of an accident. Currently, more than 50% of urban accidents involve at least one VRU[14]. It must be emphasised that safety for cyclists is most important. Nevertheless, this report deals with safety improvements only through ITS and C-ITS applications. Many chapters of this report are addressing safety related issues.

Increasing connectivity and digitalisation in the transport sector has led to increased interest in the development and implementation of intelligent transport systems (ITS) in recent years. This can also be seen by the establishment of the ´Coalition For Cyclist Safety[15] ´. The safety of cyclists in urban areas in particular has been the focus of numerous research projects and industry initiatives. The improvement of road safety through the use of communication technologies on the bicycle itself has become important, as the steady increase in cycling traffic is also accompanied by an increasing number of often serious accidents. Therefore, there is an urgent need to reduce the number and severity of road accidents involving cyclists.[16] Identification of dangerous spots is also to be considered to improve safety in multi-modal nodes. Hence, it is important to consider, not only, the numbers of accidents, but also to evaluate the near-misses which are very often ignored. Solutions exist to monitor this invisible part of accidentology. It is better to quantify these near-misses levels to prevent future potential accidents.

4.9 Open Street Map a tool for Smart Cycling

Navigating one's way over road network often requires detailed pre-trip knowledge. In addition, different types of cyclists (recreational, commuters, families, travellers, sports people etc.) might prefer different routes. Navigation services or other Smart Cycling applications - public or commercial - can help, but they again often require comprehensive, accurate and up-to-date information about network elements and their properties. Roadworks or temporary restrictions add another dimension for providing information by the network operator. From a different angle, a high-quality coverage of cycling network data allows to model traffic, accessibility, unsafe spots and consequences of land-use changes. Consequently, usage of cycling network data comprises typical use-cases:

1. Universal Routing applications like Google Maps, Komoot, etc.
2. Nation-wide or region-wide routing applications and information services. The latter can be linked to cover entire Member States (like Radroutenplaner Deutschland)
3. Specific routing advice to public transport, touristic points of interest, schools etc.

[14] https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/road-safety-eu-fatalities-2021-remain-well-below-pre-pandemic-level-2022-03-28_en
[15] https://www.coalitionforcyclistsafety.org/
[16] BASt / Final report of project 82.0808, 2024

4. Setting up cycling schemes
5. Setting up traffic models and accessibility models
6. Systems to support maintenance of the cycling network, including signposting
7. SUMPs (Strategic Urban Mobility Plans).

In principle, cycling networks are part of the INSPIRE (2007/2/EG) datasets, however these are focused on land survey aspects and are, up to now, insufficient for Smart Cycling use cases at hand. The ITS directive (2010/40/EU) and its delegated regulation cover all roads, including dedicated cycling infrastructure. The revised version of the MMTIS delegated regulation (EU 2024/490) does contain requirements on data entities for cycling, but no definitions of these data entities. Administrative infrastructure data (including sign posting, barriers, temporary restrictions etc.) concerning cycling networks is often scattered over many public bodies (national authorities, regional authorities, municipalities) and usually no single authority is easily able to create a full and detailed representation. Moreover, sources for existing data are not very well known to the general public and sometimes even to the experts. Cycling infrastructure is in the responsibility of infrastructure operators and therefore they are in charge to provide a digital representation of their infrastructure.

Although road operators usually provide their mobility data via the national access point, the parallel transformation and transfer of cycling-related information to OSM can significantly increase the availability of relevant information for cyclists and cycling services. Cooperation between public authorities on one side and peer communities on the other pose special challenges for communication. Open Street Map covers the entire public space, is easily accessible and used by very many service providers. Technically diverse tools exist to input, maintain, extract or use data and such tools are still permanently developed. Its shortcomings are the changing level of accuracy caused by lacking volunteer contributors for some places and the limits of data sources. The paucity of strict rules in terms of necessary or possible network attribute is boon and bane: it allows a flexible approach but requires extra effort to integrate comprehensive datasets

First of all, public authorities should provide cycling data at the NAPs. The ITS directive, the delegated regulations and the NAPs are the legally binding framework of the European Commission for mobility data. This also applies to cycling data. In addition, public authorities should be opening up the data for OpenStreetMap, taking into account the following points:

- Look for ways to communicate on the right level, avoiding hierarchies and non-technical aspects
- For your own dataset, look for ways to publishing them OSM-friendly
- Address the issues of licensing and make sure your applications fit them. There are ways to use contents of OSM Data without duplicating all obligations
- Promote OSM tools towards urban data sources
- Develop tools to support the technical reference process.

4.10 Summary: Analysis and observations of the market overview

The market overview shows that there is a wide range of best practices, fulfilling a variety of use cases and levels of the bicycle pyramid. The type and number of Smart Cycling applications in principle is endless, each contributing to the stimulation of cycling in its own way. There are many opportunities for Smart Cycling, but the market is still immature, and many Smart Cycling solutions are still in the pilot phase. Cities and regions are not fully aware of the potential of Smart Cycling solutions. In order to be successful, Smart Cycling applications should be cost-effective in achieving the purpose for which they have been developed: making cycling a more attractive mode of transport by making it safer, more reliable, faster, easy to use, comfortable and/or a good experience. In addition, Smart Cycling should be seen as an additional tool for policy (decision)

makers and planners, on top of more traditional cycling policy tools such as building cycling infrastructure, bike parking facilities, communication and education/training. Smart Cycling can be a tool in promoting cycling, but only if it is cost effective compared to more traditional cycling policy tools. The (potential) benefits of C-ITS for cyclists can be found mainly in improved road safety, time savings, and comfort. Examples include warnings for hazardous situations, traffic lights turning green earlier, or easier access to (guarded) bicycle parking facilities.

There is no single comprehensive source for cycling data across Europe. The availability and quality of data vary by region, often depending on local infrastructure and data collection initiatives. The integration of smart technologies into bicycles and wearables offers numerous advantages such as improved navigation, fitness tracking and theft protection, but this networking also brings challenges in the area of data security. In addition, standardisation of cycling data is considered essential, both for the public sector and the private sector. Initiatives are taken in standardisation (e.g., GBFS, Datex II, OSM), but more work is needed in this domain.

In the next chapter we will identify the obstacles for the implementation of Smart Cycling, in order then to identify the steps needed to speed up the implementation of Smart Cycling solutions.

5 Gaps and obstacles for Smart Cycling

The introduction of intelligent systems and services for cyclists aims to increase the safety and efficiency of cycling. However, various obstacles must be overcome when introducing such technologies. This inventory of gaps and bottlenecks will be the starting point for the formulation of recommendations and actions to boost the implementation of Smart Cycling in Europe, which will be part of the Road Map for Smart Cycling (chapter 7).

In two sessions, gaps and obstacles for Smart Cycling have been identified: one with MegaBITS partners, based on their experiences with implementing Smart Cycling solutions in the BITS and MegaBITS project, and another one with external stakeholders from MERIDIAN and MegaBITS. These gaps and obstacles can be grouped under five different topics:

1. Smart Cycling to improve safety of cyclist
2. Data, data protection and security
3. Legal and regulatory framework conditions
4. Integration into existing road and digital infrastructure
5. Creating awareness and acceptance for Smart Cycling

5.1 Smart Cycling to improve safety of cyclists

Bicycle safety is high on the agenda in Europe. Currently, the cyclists' share of total road deaths in Europe is 9,9%[17], with a slowly increasing trend. Quite often, it is motorised traffic, which causes safety issues for cyclists (e.g., speeding, inattention blind spot accidents, or other visibility-related events). Traditionally, cyclist safety measures focus on bike-related safety measures, infrastructure & traffic management, and motorised vehicle design & technology. C-ITS services are widely believed having a potential impact on bicycle safety as well. This may effectively be the case as a result of different behavioural changes resulting from the use of such services: improving situational awareness, safer routing, etc. In addition, many Smart Cycling applications can generate data about road safety for cyclists, which can then be used by policy makers and traffic planners to improve the safety of cyclists by developing better cycling infrastructure.

- C-ITS messages for cyclists need to focus on those elements which are relevant for cyclists. The use of a copy of motorised C-ITS services may fall short on its safety goals.
  Bicycle safety is traditionally improved by safe cycling infrastructure, vehicle design, traffic management and low-level changes. C-ITS may be a next-level solution, but implementation is not straightforward. The simple fact that the location of cyclists can be transmitted to other road users may fill in an important safety gap. However, the impact thereof is very much dependent on the penetration rate: unless a very high penetration ratio is obtained, and safety-related communication functions near-flawless, such location-information should only remain an information source that supports driver awareness. Application can give a false impression of safety, e.g., when warnings are issued to only a part of motorists or when motorists assume that warnings will cover all cyclists.
- Safety by design
  Especially the Human Machine Interface (HMI) for the cyclist requires careful consideration, see also section 4.7. If applications fail on the ride, e.g., go out of power, sensors are no longer working, or through

[17] https://www.brusselstimes.com/234202/growing-popularity-of-cycling-reflected-in-road-fatalities?

mistakes, an extra risk for the cyclist arises. Smartphone applications may cause additional safety concerns unless very well developed. The HMI depends on the sensory mode that is chosen to provide information (visual, auditory, haptic), each with advantages and disadvantages. Or alternatively, external information sources like Variable Message Signs and traffic lights can be applied. The C-ITS communication message itself is also likely to be different for cyclists compared to motorised traffic. This may require some standardisation.

- Safety related data
  In contrast to motorised vehicles, not every cycling accident results in calling the police or the ambulance. This means that there is an important gap in knowing which spots are dangerous for cyclists. This can be addressed by e.g., 3D cameras, connected sensors on the bicycle (e.g., measuring sudden decreases in speed in combination with GPS location data) or increase reporting of dangerous spots by cyclists. Many applications in this domain already exist, and these should be promoted and/or facilitated by local and regional authorities.

- Technological and connectivity gap
  The most likely future mobility scenarios identify the interaction between well-equipped vehicles and cyclists as a highly critical issue, due to a technological and connectivity gap. This mismatch risks slowing down the technological evolution of mobility. Therefore, the need to act urgently through Smart Cycling becomes evident.

5.2 Data, data protection and security

- Availability of data and representativeness of data
  A lot of cycling data is not yet available and there are many reasons for this. Where it is available, it might be difficult to access (where is it, how can it be accessed, under which conditions). Data can be made available either under an open data license or under specific (commercial) conditions. In order to make more data available, it should also be easy to input data. Combining data sources could be another way to improve availability of data. In addition, many data collection initiatives only target specific groups or areas and are limited to a specific time period.

- Data quality
  The required data quality certainly depends on the respective application. Nevertheless, the parties involved must agree on minimum requirements for data quality in a connected mobility system. The challenge is that standards and procedures for data quality assessment for cycling data are currently missing or are being neglected. Furthermore, responsible organisations are often not having the digital competencies or resources to prioritise data quality. National Access Points not always provide quality related information in their metadata. Bicycle-centred CCAM applications require reference data and basic data of sufficient quality.

- Lack of data standardisation and system interoperability (beyond harmonisation)
  To enable widespread use, intelligent systems from different providers must be compatible with each other. A lack of standards, no open interfaces or proprietary solutions can limit interoperability and reduce the benefits of the systems. Now that data collection initiatives are getting more mature, the next couple of years are crucial to develop standards among the participating Member States. Delegated regulations like 2022/670 or 2017/1926 require the provision of digitised data in standardised way from data owners. However, at this time, there is not yet a standard for the description of the cycling network.

A particular problem is the lack of comprehensive standardised European-wide cycling-network data, as it is widely available for motorised transport. All applications that use network data would greatly benefit from such a standardised data provision. Similarly, standards are needed for e.g., bicycle parking, bicycle counting and for real-time traffic information for cyclists. If this data was provided in coverage and quality comparable to car traffic related data, creating, building and selling of Smart Cycling applications could be made more profitable, faster and easier. Also, a data dictionary for cycling data is needed. NAPCORE has published a data dictionary[18] which does not cover sufficiently specifically cycling data needs. NAPCORE published as well standardised data descriptions via a metadata catalogue (mobilityDCAT-AP), common use of standards, data exchange formats and data profiles (DATEX II & TN-ITS fusion). So far, there are some national classifications, e.g., by the FR and DE bike data specifications. Similar harmonisation activities are already undertaken for Functional Road Classifications (FRCs, currently under TISA). A harmonised classification scheme for bike network elements, denoting mixed traffic roads, cycle lanes, separated bike paths etc is missing. DATEX II is often perceived as very complicated. In order to simplify the use of DATEX II standards in the cycling domain, dedicated DATEX II profiles should be developed for the various cycling use cases.

- Making data available for cyclists
  Many Smart Cycling applications are aimed at collecting data for policy makers, whereas Smart Cycling applications can also be used to provide cyclists with better information, pre-trip and during the trip. In general, the cyclists currently receive little data, mostly only about bike parking and via traffic lights (e.g., green wave). Real-time data is hardly available (road closures, winter maintenance). This is partly due to prioritisation on motorised road traffic by road authorities, the focus on information for the policy makers, digital competencies and resources.

- Availability of computational resources
  Certain applications require computations to be carried out "on-the-edge", e.g., on the bicycle itself. However, even on E-bikes, computational resources are limited. Smartphones and other wearables are a natural alternative, but are difficult to use due to differing hardware components and operating systems.

- Information is important: to the citizens, within the organisation
  In times of mis-trust of government actors, it is essential that people can see how their data is handled, and on basis of what data decisions are made. Certification of cycling data is needed.

- Data protection and security
  Intelligent systems often collect personal data, for example on the use of bicycles or traffic participation. Protecting this data from misuse and unauthorised access is essential. There may also be concerns about data being passed on to third parties or stored in centralised databases.

- Privacy protection
  ITS by definition is able to collect a lot of data. Many data collecting initiatives rely on data from individual cyclists. They should not be retraceable to individual cyclists. There have to be agreements according to the GDPR-standards. There is a need for generic anonymisation consensus for cycling data. Privacy seems to be an important reason for commercial operators not to participate in the data stream.

[18] https://github.com/NAPCORE/Data-dictionary

5.3 Legal and regulatory framework conditions

The introduction of new technologies must be in line with existing laws and regulations. Adaptations or new regulations may be necessary to create the legal framework for the use of intelligent systems.
There are several regulations and initiatives in the European Union that deal with intelligent systems to improve the safety of cyclists. A key element is Regulation (EU) 2019/2144, which became mandatory for new vehicle types on 6 July 2022 and for all newly registered vehicles on 7 July 2024. This regulation stipulates that vehicle must be equipped with various driver assistance systems, including systems that can increase the safety of cyclists.
Other important systems are the Moving Off Info System (MOIS), and the Blind Spot Info System (BSIS), which are designed to work at low speeds and which protects lorries and buses in particular from overlooking cyclists or pedestrians when turning right. Originally not included in the general safety regulations, such systems were authorised under certain conditions when the Vienna Convention on Road Traffic was amended in March 2014. Subsequently, in May 2018, the European Commission presented a draft update to the General Safety Regulation, which provided for the introduction of MOIS and BSIS for lorries and buses. This amendment was finally incorporated into Regulation (EU) 2019/2144, which requires new vehicles to be equipped with turning assistance systems from July 2024.

In addition, the EU is promoting the development of cooperative, connected and automated mobility systems (C-ITS). These systems enable vehicles to exchange information about the traffic situation in real time, which can increase the safety of all road users, including cyclists. In Germany, for example, Autobahn GmbH is rolling out the use of C-ITS, in which roadworks signs are equipped with transmitters that warn approaching vehicles.

The European Cycling Declaration also emphasises the importance of safe infrastructure and smart systems. It recommends the application of the 'safe system' approach, which includes safe speeds, safe road use and safe vehicles, supported by consistent enforcement of road traffic regulations. The aim is to improve conditions for cycling and ensure efficient investments in infrastructure.

- Legal framework lacking behind
  In many cases, the legal framework follows after the technological development, which can cause problems and uncertainty. In addition, countries in Europe have different interpretations of EU laws. Who owns merged/adjusted data that originate from public data sources?
- Financing and economic sustainability
  The development, implementation and maintenance of intelligent systems requires considerable investment. Ensuring long-term financial sustainability, whether through public funding, private investment or a viable business model, is a challenge.
- Lack of funding
  Many projects only have a budget on project evaluation basis, but not on structurally supplying data. In addition, many European and national funding programmes have no, or very few, calls for proposals on Smart Cycling. There is a lack of funding for R&D. Actors in the Smart Cycling ecosystem have to look for funding outside the traditional 'cycling bubble'. There is the need to provide funding for data provision and diffusion. When investing in cycling infrastructure, appropriate and cost-efficient smart cycling solutions should always be taken into consideration.

- Interdependence problems
  Suppliers need sufficient customers to develop a system, and authorities want solutions that are proven. Doing a pilot with ITS and cycling is one thing, but to have a follow-up strategy for the roll-out is key.
- Not clear what the costs and benefits are of ITS for cycling from a road authority perspective
  ITS is seen as something 'extra' instead of the basis of policy. In order to make the right decision, knowledge on costs per bicycle kilometre (investment, operating, maintenance) and benefits (financial, socio-economic) is essential. Costs often are for the transport department, whereas benefits go to other departments (health, environment, social, …).
- Data economy of cycling data still in its infancy
  The value of cycling data is not yet clear. Does it have value? Can you sell it? Who is willing to pay for it? There is the need to distinguish between business economic and socio-economic value of cycling data.

5.4 Integration into existing road and digital infrastructure

ITS and cycling data could help to optimise investments or target investments. The seamless integration of intelligent systems into the existing transport infrastructure requires extensive adjustments and coordination between various players, such as road operators, urban planners, transport authorities and technology providers.

A significant wave of investment is visible in cities and municipalities to digitalise traffic light systems and thus to upgrade them for C-ITS applications such as prioritising public transport and blue light services. This offers the opportunity to think along with Smart Cycling services.

- Information on the benefits of Smart Cycling systems and services must be shared quickly
- The cooperation of all Smart Cycling stakeholders must be supported quickly so that the roll-out of C-ITS in cities and municipalities does not only benefit motorised transport.

5.5 Creating awareness and acceptance for Smart Cycling

A decisive success factor for the implementation of Smart Cycling is acceptance. Without the support of the citizens, authorities and other relevant interest groups, even technically mature solutions can fail.

- Shortage on human resources/knowledge at cities/regions
  Policy makers are not data experts, they lack knowledge on how to use cycling data. Due to labour shortage and budget issues, many government actors don't have the right staff to work data-driven. This especially applies to smaller cities/towns. Cycling topics are generally underrepresented in university curricula, and it is very rare to find any teaching content on smart cycling.
- How to find the right solution/supplier if you have a question/problem?
  When choosing a supplier, one runs the risk of a vendor lock in. To avoid this, it requires standardisation and harmonisation. Also, ITS for cycling is a new domain. Many cycling policy makers at local/regional level don't know the use cases and market parties active in ITS for cycling nor do they have sufficient (C-)ITS knowledge. There is a need for a common platform or market place that shows available solutions and best practices. Avoid reinventing the wheel again.
- Innovation process/procurement
  ITS for cycling is relatively new. Procurement of ITS solutions is quite different from procurement of infrastructure. E.g., with respect to privacy, legal issues, data ownership, etc. In addition, innovative technologies require special expertise on the part of the tendering bodies, which still needs to be built

up. Nevertheless, tenders can be a very strong instrument for promoting smart cycling and innovative companies. An ecosystem is required where companies and authorities work together.

- Acceptance by the general public
  The end-users (cyclists) don't automatically adopt Smart Cycling applications. There are different reasons for this: they are not aware of the applications (e.g., cycling apps), they are reluctant to share data (privacy), they don't want to be influenced by others (e.g., ISA for speed-pedelecs), they might not see their added-value especially compared to the price of new technologies, different user groups require different solutions, HMI has to be understandable for all (inclusiveness). Cyclists have different motives to use an app than authorities (direct benefits compared to collecting cycling data). Information and transparent communication are therefore crucial.

- Acceptance by authorities
  Cycling policy makers and cycling advocates are often unfamiliar with the use of and the use cases for cycling data. In the digital age, digital cycling infrastructure should be an inevitable part of any new cycling infrastructure, as is the case with major road or public transport infrastructure. A lack of acceptance of cycling compared to motorised traffic automatically leads to lower acceptance of Smart Cycling solutions.

6 Recommendations to stimulate Smart Cycling in Europe

In the previous chapter we have seen that Smart Cycling is often missing in the toolbox of cycling policy makers. We have also concluded that there are a number of challenges that have to be addressed:

- Improving quantity, quality, availability and interoperability of cycling data
- Improving the legal and privacy framework for Smart Cycling
- Considering financial and economic aspects of Smart Cycling
- Improving expertise in Europe and knowledge sharing on Smart Cycling
- Creating awareness and acceptance processes for Smart Cycling

In this chapter we will have a closer look at the challenges and provide recommendations for action from the various stakeholders.

6.1 Improving quantity, quality and accessibility of cycling data

6.1.1 Availability and representativeness of data

Challenges

A lot of cycling data is not yet available. To complicate matters further, there are different types of bicycle data with different use cases and different types of challenges and solutions needed. Another challenge is that in the digital age, machines must be able to process data automatically in order to utilise it comprehensively. In addition, it must be determined which bicycle data should be available free of charge and which bicycle data can be available under specific (commercial) conditions. Combining data sources could be another way to improve availability of data. In addition, many data collection initiatives only target specific groups or areas and are done in a specific time.

Vision

Cycling data is published and accessible in a standardised format on a non-discriminatory basis e.g., through National Access Points and the European Mobility Data Space.

Key Recommendations

- Stimulate data owners to make their data available via the National Access Point and EMDS, both static and dynamic data, using the appropriate formats (e.g., DATEX II, OSM) and include the recommendations for cycling data mentioned in the European Cycling Declaration. Stimulation may come thorough financial incentives, but also by improving the image or the reach-out of providers
- NAPCORE partners to check whether cycling data in their NAPs is easily available to service providers and consistent with standards requirements.
- The EC should request from Member States to deliver national action plans on cycling data. Authorities should collect and provide key cycling information (bicycle infrastructure, real-time, routing relevant information, bicycle counting, cycle safety, social safety), and make it easily accessible, including metadata. Such data is already included in delegated regulations, but explanatory notes could provide even more clarity. Alternatively, the European Commission could consider to include Smart Cycling more explicitly in future revisions of the delegated regulation on RTTI and MMTIS.

- To improve representativeness, in procurement it should be part of the program of requirements to stimulate data suppliers to use more than one target group or work together with suppliers which focus on different target groups. E.g., both commuters and sport cyclists.

Further Recommendations

- Raise awareness of a Cycle Data Space (CDS), as part of the EMDS, to facilities the exchange of data. It should also allow data owners to put conditions on the use of their data (a fee, restrictions on resharing data, referencing the source, etc.). Registration at the CDS should be easy and proper metadata for cycling data should be available.
- As OpenStreetMap as currently a de-facto standard for geographical data across the world and many large companies invest substantial effort into updating data and use it for the navigational services, authorities should make sure they are publishing cycling relevant data in ways that make it possible for others to use it to enrich OSM.
- Stimulate publication of relevant data for cycling from 3rd parties, like health or environmental stakeholders to allow added value data analysis.

6.1.2 Data quality

Challenges

The ecosystem of smart cycling actors must elaborate and agree on minimum requirements for data quality for all kind of use cases in a connected mobility system. The challenge is that the lack of standards and procedures for data quality assessment for cycling data will limit the usefulness of the data.

Vision

Bicycle data of a minimum required quality is provided for all use case groups.

Key Recommendations

- Minimum requirements for data quality and quality assessment methodologies should be provided by the National Access Points and/or NAPCORE in cooperation with relevant Smart Cycling actors.
- Certification of cycling data should be available if needed/requested. This can be done through a process of 'self certification' in which data providers state that their data are compliant with certain data criteria.
- End user feedback, which often points to specific quality issues, should be easy to give and collect and should be quickly processed.

Further Recommendations

- Develop a quality criteria catalogue to pick from for each use case. A study is needed to connect use cases (groups) to related minimum data quality.
- Road authorities should check whether digital cycling network data is good enough (in terms of coverage, geographical detail, accuracy, timeliness) to serve Smart Cycling applications. This check can be done for own data or for overall data (on a regional or national level, and in all cases covering also municipal data).

6.1.3 Lack of data standardisation

Challenges

To enable widespread use, intelligent systems and applications from different providers must be compatible with each other. A lack of standards, missing open interfaces, monopolism without any possibility to access data nor realising cooperative ITS solutions or proprietary solutions can limit interoperability and reduce the benefits of the systems. Now that data collection initiatives are getting more mature, the next couple of years are crucial to develop standards among the participating nations. For interactive systems, for example in C-ITS and CCAM, it is important that systems are built based on standardised specification, for example using C-ROADS specifications. Otherwise, these systems will not cooperate properly.

Vision

Bicycle data, C-ITS and CCAM services are provided throughout Europe in the appropriate standardised formats and specifications.

Key recommendations

- Standards for cycling data (infrastructure data, counting data, parking data, real-time data) are lacking. NAPCORE has started to standardise these data. This activity needs to be continued with higher intensity. NAPCORE should integrate cycling data in their standard specifications work (where possible based on existing national standards). Since defining standards takes time, methods to link data through heuristics is important in the next years.
- In accordance with the ITS Directive regulation is needed on European level to foster cooperation between ecosystem actors and to open systems and or provide data in standardised format.
- The data dictionaries for RTTI and MMTIS as published recently on GITHUB by NAPCORE (https://github.com/NAPCORE/Data-dictionary) should be extended with more detailed information in line with the specific data needs for cycling, e.g., 'cycling network closures/diversions', 'type of cycle lane surface', 'type of cycling infrastructure'.
- DATEX II group to be tasked to provide DATEX II profiles for cycling.
- A harmonised classification scheme would enable international cycling routing services (Komoot, Strava etc) to represent the various network elements correctly.
- A wide range of stakeholders should be involved in developing future specifications for floating bicycle data. European organisations, particularly the European Commission, NAPCORE, and EIT Urban Mobility, could be crucial contributors, as well as bicycle manufacturers, bicycle motor manufacturers, ITS providers, bike sharing providers, research institutes and European and national cyclist organisations.
- Develop specifications for direct C-ITS communication use cases which involve bicycles. The specifications involve harmonised use case definitions and harmonised message profiles. They should be formulated according to the C-Road specifications and will serve as advancement of the C-Roads and C2CC (Car2Car-Communication-Consortium) in order to address the safety and comfort of cyclists.
- Standards for georeferencing methods for cycling infrastructure data should facilitate usage in existing and widely used data sources (like e.g., OSM) and should not be limited to the official road network.
- Public and private actors need to be informed about the existence of standards and how to use them.
- Research funding calls should contain references to agreed standards and state-of-the-art in Smart Cycling.

Further recommendation

- These standards should be used also as standard in a European Mobility Data Space and National Access Points.
- Make sure cycling network data is fully integrated into the DATEX II data set, following relevant use cases and clear network reference.
- Standardise the measurements, such that data can be collected that can lead to comparable information in the analyses.

6.1.4 Data user specific obstacles

Challenges

Many Smart Cycling applications are aimed at collecting data for policy makers and road operators, whereas Smart Cycling applications can also be used to provide cyclists with better information, pre-trip and during the trip. In general, the cyclists currently receive little data, mostly only about bike parking and via traffic lights (e.g., green wave). Real-time data is hardly available (current bicycle transport options on public transport, road closures, winter maintenance, …). This is partly due to the focus on information for the public authorities and partly to the difficulty in developing a safe human machine interface on the bike. E-Bikes have these interfaces (to a certain extent). However, the problem is that the systems are proprietary without open application programming interfaces. Therefore, it is difficult for third parties to develop new applications hindering the establishment of new ecosystems.

Not only aggregated, but also raw data is needed. Mapping data is extremely important, a lot of activities are visible here, but still far from being complete. Authorities should take actions on what data they need, where to get it, how to maintain it. However, besides authorities, user communities can and will play a crucial role.

Vision

The cyclists and other data user groups (cities, regions, service providers, …) receive the cycling data (e.g., real-time, infrastructure data, parking, floating bike data) they need.

Key Recommendations

- Make sure that cycling and walking data (including data relevant for vulnerable groups are included, e.g., children, elderly, disabled…) are adequately represented when developing real-time data services. For example, cycling data should be an integral part of real-time traffic management services. The cities will benefit from all modes included in the traffic management services.
- Harmonisation requirements and specifications must be included in the contract and already requested in the terms of references of the tendering documents.
- Elaborate on European guidelines for safe HMI, how (real-time) traffic and infrastructure information can be provided to cyclists in a safe way. Further research on this topic might be needed.

Further recommendation

- A study is needed to investigate if and how the public and private sector can cooperate to provide real-time traffic information for cyclists. Cyclists (and other road users) would benefit from real-time traffic information, but dedicated real-time traffic information for cyclists is rare.

- Deployments of bike parking facilities or further bike infrastructure should consider to include provision of real-time data as part of the design.
- Work is needed on how trust can be created between ecosystem partners in (C-)ITS cycling applications and how much effort is needed from each partner to connect to the digital infrastructure.
- In order to stimulate companies to collect and provide cycling data, public authorities should bundle their request for data.
- Always test solutions in real life and with diverse groups of cyclists to ensure that they are practical and deliver sufficient added value to be taken up widely (also linked to point 6.5).

6.2 Improving the legal and privacy framework for Smart Cycling

Challenges

In many cases the legal framework follows after the technological development, which can cause problems and uncertainty. In addition, countries in Europe have different interpretations of EU regulations. Who is allowed to use data under which conditions that originate from public data sources? For the data categories embraced by the ITS directive and the Delegated Regulations, there is a European legal frame. ITS are able to collect a lot of data. Many data collecting initiatives rely on data from individual cyclists. Increasingly brands are building out profiles for their customers, tracking their rides and providing them with information about preventative maintenance and customer support. All very valuable personal data that needs to be appropriately protected. They should not be retraceable to individual cyclists. There have to be agreements according to the GDPR-standards. This requires standards for privacy compliant processing of data. A lot has been solved already for vehicle data. These standards might also be used for cycling data. Other risks also include potentially unlocking or disabling of bike motors via hacking into the firmware of the battery management system.

Vision

EU and national legislations should create a solid legal framework for the collection, provision and use of cycling data in which commercial, societal and privacy aspects are properly dealt with.

Key Recommendations

- EC or a European platform to provide guidance document on the provision of cycling data which is in line with the existing regulations (e.g., ITS directive, INSPIRE regulation 2007/2, general data protection regulation).
- Contracting authorities to make sure that licences and prerequisites requested from contractors can be provided by SME (small and medium sizes enterprises) and not only by big companies.

Further Recommendations

- Same as for cars, cyber security of (C-)ITS for cycling should be on the agenda of industry and policy makers, e.g., where it concerns the risk of hacking into smart traffic lights, electronic locks, battery management systems, etc.
- Share best practices for data privacy problems and recommend which actor of the data chain is responsible.

6.3 Considering financial and economic aspects of Smart Cycling

Challenges

Many projects only have a budget on project evaluation basis, but not on structurally supplying and collecting data. In addition, many European and national funding programs have no, or very few, calls for proposals on Smart Cycling. There is a lack of funding for R&D. Actors in the Smart Cycling ecosystem have to look for funding outside the traditional 'cycling bubble'. Provide funding for data provision and diffusion. For every investment in bike infrastructure budget should be reserved for Smart Cycling solutions (including data).

Vision

Current state of the art and evaluation is known; thus, the available public funds are utilised in a targeted and effective manner.

ITS and C-ITS for cycling is specifically promoted by European, national and regional programs.

Key Recommendations

- The European Commission should actively stimulate Smart Cycling solutions by including in their Calls for proposals (Horizon Europe, CEF, Interreg, …) dedicated topics on Smart Cycling, and should provide a dedicated budget for Smart Cycling (research, pilot, implementation).
- All available public funding programs at European, national and regional level should be accompanied by a text describing the minimum technical requirements for data format, data quality, technical specifications or coordinated harmonisation elements in order to enable seamless services and solutions for Smart Cycling.
- Stimulate cycling data monitoring and provision by public funding
- All funding programs should demand to integrate Smart Cycling requirements when renewing or digitalising (intelligent) traffic lights
- Public sector should invest in acquiring and publishing cycling data. Besides investments in physical cycling infrastructure, it needs investments in digital cycling infrastructure, enabling Smart Cycling applications and connected services.

Further Recommendations

- Public and private actors should look for funding opportunities outside the traditional ‚cycling bubble', e.g., join forces with health departments, environmental departments, etc.
- Research is needed into the costs and benefits of Smart Cycling, both financial economic and socio-economic.
- The public sector should develop a strategy to temporarily increase funding for areas with a low business case. The value of cycling data is not yet clear and business cases for cycling data are currently rare. Funding should stimulate the market in absence of a business case
- The public sector should consider the socio-economic value of bicycle data. Research could elevate the value of cycling and consequently also the value of cycling data.

- Research is needed into the viability of public private partnerships for Smart Cycling and cycling data. This could include business models for sharing of cycling data to third parties.

6.4 Improving expertise in Europe and knowledge sharing on Smart Cycling

Challenges

Cycling policy makers are often neither data nor ITS experts, they lack knowledge on how to acquire, process and use cycling data. Smart Cycling requires various expertise to be combined/come together. Due to labour shortage and budget issues, many government actors don't have the right staff to work data-driven. This especially applies to smaller cities/towns. At universities, relatively little focus is placed in curricula on cycling specific topics, let alone on Smart Cycling. There is a need for a platform or marketplace that shows available solutions and best practices, to avoid reinventing the wheel again.

ITS is seen as something 'extra' instead of the basis of policy. Cost effectiveness is not seen yet. In order to make the right decision, knowledge on costs (investment, operating, maintenance) and benefits (financial, socio-economic) is essential. Cost often are for the transport department, whereas benefits go to other departments (health, environment, social, …).

There seems to be a number of EU platforms that are dealing with parts of the (smart) cycling eco-system, such as NAPCORE (data standards, National Access Points), C-Roads (C-ITS specifications), POLIS (representing cities and regions). An umbrella platform would bridge the gap between the different actors in the Smart Cycling eco-system and between the various co-funded projects. Such an overarching platform could play a role in orchestrating the various actions that are needed to foster the take-up of Smart Cycling.

Vision

An ecosystem where companies and authorities work together on Smart Cycling solutions and where all information on Smart Cycling can be found in a central location and is available without discrimination.

Key Recommendations

- Bring all European Smart Cycling actors together with participants from authorities, private parties, cycling associations, academics, research organisations. This road map could serve as a starting point to coordinate all kinds of activities, from data standardisation to pilots, from knowledge sharing to implementations, from input to EU policy to promoting sharing of cycling data. This should be done in cooperation with well-established platforms such as NAPCORE and C-ROADS and cycling organisations like CIE and ECF. Authorities responsible for funding should be informed about state of the art in cycling.
- Best practices should be shared and easy to find in order to utilise the available public funds in a targeted and effective manner. A European body / platform for Smart Cycling is needed that serves as a knowledge base for Smart Cycling in Europe. This Platform should include a database of best practices, funding opportunities, events, existing Smart Cycling solutions, such that authorities looking for solutions can find appropriate solutions and learn from best practices. The BITS directory is a good example and could be a starting point for such a database. Public and private parties should be

encouraged to share their best practices and (commercial) Smart Cycling solutions through this database.

- The platform should consider different levels of use case maturity and different levels of cycling within the EU because their realisation is subject to different timelines.
- Harmonisation platforms such as C-Roads and NAPCORE provide guidance for the implementation bodies in their specific area.

Further Recommendations

- Governments should include data-training programmes as part of their employee development programmes.
- Distinguish between research, pilots and use cases, which are ready for roll out. Each of them has different requirements. To progress quickly they need be orchestrated best.
- Evaluation results should be stimulated and shared to reach wider impact on Smart Cycling.
- The European ecosystem of Smart Cycling should be strengthened, with cooperation between authorities and market, between stakeholders, with other adjacent fields (e.g., health, recreation, sports), understanding each other's needs and priorities.

6.5 Creating awareness and acceptance processes for Smart Cycling

6.5.1 Acceptance by the general public

A decisive success factor for the implementation of Smart Cycling is public acceptance. Without adaptation by citizens and relevant interest groups, even technically mature solutions will fail. Adaptation is therefore a fundamental prerequisite for successfully introducing innovations and bringing about sustainable change in the mobility sector.

Challenges

The end-users (cyclists and other road users) don't automatically accept the Smart Cycling applications. There are different reasons for this: they are not aware of the applications (e.g., cycling apps), don't know how to use their smart phone safely (according to law) while riding the bike, to share data (privacy), they don't want to be restricted (e.g., ISA for speed-pedelecs), they enjoy the pure, low-tech feeling of cycling, they don't see the added-value, different user groups require different solutions, HMI has to be understandable for all (inclusiveness). Cyclists have different motives to use a solution than authorities (direct benefits compared to collecting cycling data).

Vision

Cyclists and other road users are well informed about the advantages of Smart Cycling applications, experiences the benefits, do not need to worry about the misuse of personal data and makes use of Smart Cycling applications.

Towards public authorities and road operators:

Key Recommendations

- Demonstrate the value for the user
- Promote successful projects in the communication to the public, act as launching customer.

- Foster Smart Cycling infrastructure (e.g., charging, bike parking and bike sharing infrastructure).
- Incentivise the use of the new technology (price reduction compared to conventional use, introductory prices, free use, special events). Give cyclists the opportunity to test and experience the technology.

Further Recommendations

- Proper public participation that ensures the involvement and support of the population through workshops, surveys or public events.
- The public sector must take appropriate measures to inform cyclists about the benefits and characteristics of Smart Cycling.
- Include Smart Cycling use cases in the overall smart mobility policy.
- Establish a solid feedback loop with end users and act upon it.
- Cyclists should be given adequate time to familiarise themselves with new technologies, focus on first use cases.
- Provide target group-oriented communication about the benefits and functionality of the technology.

Towards cycling industry:

Key Recommendations

- Provide Smart Cycling solutions for customers and demonstrate the value for the user
- Attention must be paid to user-friendliness and safe HMI, which plays a key role in acceptance.
- Service providers should protect the data security and privacy of the end users.

Further Recommendations

- Transparent communication is crucial, using targeted information campaigns and media presence to communicate the added value and functionality of the new technology.
- Develop a safe human machine interface so that cyclists can access this information while riding in a safe way. APPs nor services should compromise safety of cyclists

6.5.2 Acceptance by authorities

Challenges

In political papers and regulations, cyclists are currently only classified as vulnerable road users, which makes only sense from the perspective of motorised transport. This is firmly interwoven with the powerful automotive industry and its digital requirements, which are divided among several stakeholders. The interest of cyclists and the commercial interest of the bicycle industry, on the other hand, is less recognised by the public. There are currently no influential car manufacturers in the cycling world, but rather small and medium-sized companies, committed local authorities and a few organised cyclists. Technical solutions for services and bicycle data are subject to different requirements. Cycling policy makers are often unfamiliar with the use of and the use cases for cycling data. In the digital age, digital cycling infrastructure should be an inevitable part of any new cycling infrastructure.

Vision

EU policy prepares the ground for the awareness and visibility of Smart Cycling and actively supports the exchange of experience. The public sector recognises the Smart Cycling ecosystem with its individual characteristics, players and requirements as a prerequisite for dealing with the specific requirements of stakeholders. The bicycle is regarded as an independent mode of transport whose requirements are considered on an equal footing with motorised transport.

Key Recommendations

Towards public authorities:

- Inform citizens about the benefits of cycling and about their choices in a healthy, sustainable multimodal mobility system.
- Develop an implementation guide for public authorities with the do‘s and don‘ts for Smart Cycling applications.
- Consider cycling when implementing the EU delegated regulations on RTTI and MMTIS.
- The public sector should develop a strategy for Smart Cycling.

Towards cycling industry and stakeholder organisations like POLIS and Euro cities:

- Highlight and quantify the potential of Smart Cycling to cities and regions, to make them aware of the potential benefits of ITS for cycling with respect to improving safety, speed, convenience, etc.
- Collect and disseminate best practices of Smart Cycling.

Towards research institutes and universities or other teaching institutions:

- Include Smart Cycling in curricula, in order to educate the next generation of policy makers, public authorities or planners.
- Research about road safety aspects of Smart Cycling applications.
- Research on the social benefits of smart cycling

7 The Road Map for Smart Cycling: A Call to Action

7.1 Introduction

Smart Cycling can play a significant role in achieving the EU's goals for safe, sustainable and smart mobility, including substantial reductions in greenhouse gas emissions and promoting cycling as a key component of multimodal transport systems.

The time for Smart Cycling is now! Cycling has emerged as a pivotal component of multimodal transport systems across Europe, driven by technological advancements, health and environmental considerations, supportive policies, and infrastructure improvements and is more and more considered one of the main angles to achieve a sustainable mobility system. To understand this evolution, a number of technological leaps, trends and societal changes in cycling can be noticed:

1. E-Bikes: Expanding Reach and Accessibility

E-bikes have become mainstream, dominating bicycle sales in several European countries. They extend cycling's range and utility, making it feasible for longer distances, hilly terrains, and cargo transport. This versatility attracts a diverse user base across various age groups and social demographics.

2. Health and Climate

Cycling contributes to physical fitness, mental health and addresses the growing health concerns of the society. Furthermore, cycling is a zero-emission mobility option, it plays a vital role in combating the climate crisis.

3. Political Momentum and Infrastructure Development

Increasing recognition of cycling’s benefits has led to stronger policy frameworks and political commitment at local, national, and EU levels. Road authorities and operators are integrating cycling into mobility and climate strategies. Their investments in cycling infrastructure enhance both actual and perceived safety, encouraging more people to cycle. Urban densification supports shorter travel distances, making cycling more practical.

4. Technological Advancements: C-ITS and Connectivity

Smartphones and wearables have transformed cycling from a low-tech solution to a smart, connected mode of transport. In addition, the rise of connected e-bikes and smart devices enables real-time information sharing, improving the cycling experience. Integration of Cooperative Intelligent Transport Systems (C-ITS) has the potential to enhance road safety and infrastructure efficiency through technologies like sensors and communication units.

5. Shifting Perceptions and Market Growth

Cycling's image is improving, with more people viewing it as a viable and attractive transportation option. The market now offers diverse models, including cargo bikes, providing alternatives to car usage. In general, cycling remains an affordable mode of transport, appealing to a broad audience.

7.2 The Potential of Smart Cycling

Smart cycling refers to intelligent and cooperative systems (ITS and C-ITS), digital applications and digital services that make cycling safer and improve the cycling experience on the basis of cycling-relevant data, communication technologies and products and services based on these. Smart Cycling comprises both the smart solutions and the collection and use of cycling data. In the context of the smart city, it mainly refers to the interaction between infrastructure and bicycle. In the context of smart mobility, the bicycle is part of a combination of transport modes.

Traditionally, cycling policies focus on infrastructure, parking facilities, education, promotion and penalisation. Smart Cycling adds a digital layer to these policies, offering tools to make cycling safer and more attractive. To give some examples:

- **Safety**: Variable Message Signs informing cyclists about busy traffic, encouraging speed reduction.
- **Speed**: An app in allowing cyclists to get faster green at traffic lights.
- **Convenience**: Access to bike-sharing reduces public transport pressure during peak hour traffic.
- **Experience**: Apps for citizens giving incentives (rewards) to people cycling to work.

Smart Cycling supports various European Commission (EC) policy objectives, including the Green Deal, Sustainable and Smart Mobility Strategy, and the Mobility Transition Pathway. By making cycling more attractive through ITS, Smart Cycling can help achieve goals like reducing greenhouse gas emissions and promoting zero-emission urban mobility. To mention a few examples:

- **Green Deal**: Smart Cycling can make the usage of the infrastructure safer and more attractive. Therefore, citizens will be stimulated to shift from fossil fuelled motorised traffic to environmentally friendly cycling.
- **Road Safety**: ITS and C-ITS can enhance the safety of the growing number of cyclists on the European roads, which is more and more digitalising.
- **Digital Future**: Creating mobility data spaces to facilitate data sharing and support data-driven innovation.

Smart Cycling has the potential to make cycling more attractive as a mode of transport, significantly improve road safety, reduce emissions, and optimise traffic flow. By integrating digital solutions into cycling policies and infrastructure, Smart Cycling can contribute to a sustainable and smart mobility system in Europe.

7.3 A vision on Smart Cycling

In a world where Smart Cycling is as integral to urban mobility as smart solutions for motorised traffic, bicycle data, Intelligent Transport Systems (ITS), Cooperative ITS (C-ITS), and Connected, Cooperative, and Automated Mobility (CCAM) services are seamlessly integrated across Europe in standardised formats and specifications. This vision is underpinned by a user-centric approach that prioritises the needs and experiences of cyclists and citizens.

Collaborative Ecosystem

An ecosystem thrives where companies, cycling organisations, researchers, and authorities collaborate on Smart Cycling solutions. All information related to Smart Cycling is centralised and accessible without discrimination, ensuring that every stakeholder can contribute to and benefit from this collective knowledge.

Policy and Support

EU policy lays the groundwork for raising awareness and visibility of Smart Cycling, actively fostering the exchange of experiences and best practices. The current state-of-the-art technologies and evaluations are well-documented, enabling targeted and effective use of public funds. Smart Cycling is championed by European, national, and regional programs that adhere to uniform minimum technical requirements, recognising the unique characteristics and needs of the cycling ecosystem.

User-Centric Focus

Cyclists are well-informed about the advantages of Smart Cycling applications and experience their benefits first hand. They are assured of data privacy, with measures in place to prevent the misuse of personal data. Cyclists and other data user groups, including cities, regions, and service providers, have access to the cycling data they need—such as real-time data, infrastructure data, parking information, and floating bike data—all meeting minimum quality standards and accessible on a non-discriminatory basis through platforms like National Access Points.

Integration and Equality

Revised Delegated Regulations on Real-Time Traffic Information (RTTI) and Multimodal Travel Information Services (MMTIS) include requirements for collecting and sharing cycling data, ensuring its application in traffic management and other services. Cycling is recognised as an independent and equal mode of transport, with its requirements considered on par with motorised transport, fostering a balanced and inclusive mobility landscape.

7.4 The Smart Cycling ecosystem

The ecosystem of Smart Cycling includes political decision-makers, road operators, cycling organisations, the cycling industry, technology providers, research institutions, and cyclists themselves. Each group plays a crucial role in the development and implementation of Intelligent Transport Systems (ITS) and Cooperative Intelligent Transport Systems (C-ITS) for cycling. Effective collaboration among these stakeholders is essential for the successful rollout of Smart Cycling services.

High quality cycling data is important and there are challenges related to data privacy and security. There is the need for harmonised, high-quality cycling data across Europe, which can be facilitated by projects like NAPCORE. Data security measures such as end-to-end encryption, privacy by design, secure storage, and strong authentication are needed to protect personal data collected by Smart Cycling applications. Transparency and user education are required to build trust and ensure compliance with legal requirements like GDPR.

Standardisation is crucial for ensuring seamless data exchange, interoperability, and efficient management of cycling infrastructure. The benefits of standardisation include improved data quality, compatibility, and cost reduction. There is the need for standardised interfaces between smart systems and the need of harmonising technologies and standards within the smart system ecosystem. Standards need to be developed for cycling data, integration of cycling network data into existing standards like DATEX II, and promotion of cooperation between public authorities and peer communities.

C-ITS for Cycling offers potential benefits for cyclists, such as improved road safety, time savings, and convenience. Already applications exist like an app for traffic light prioritisation and Floating Bike Data Collection. Future applications could include (among others) warnings for hazardous conditions, traffic light

prioritisation, and real-time information on road closures and parking availability. Challenges to broader implementation include standardisation, safe human-machine interfaces, and achieving critical mass for user adoption.

Road authorities should focus on high-quality digital network data for cycling all over Europe and provide it to their NAPs. It should take into account the INSPIRE regulation as well as the ITS directive. Nevertheless, beside this Open Street Map (OSM) could be a valuable additional tool for spreading comprehensive, accurate, and up-to-date information about cycling networks because it is widely used by many cycling systems and service operators. Using OSM offers benefits for navigation, traffic modelling, and accessibility analysis. To speed up the availability of cycling data public authorities could promote OSM tools, address licensing issues, and develop tools to support the technical reference process. As additional benefit cooperation between public authorities and peer communities is essential for enhancing the availability of relevant information for cyclists.

7.5 Gaps and obstacles for Smart Cycling

Safety: Improving cyclist safety is a high priority, with C-ITS services believed to have a significant impact. However, implementation is complex and requires careful consideration of human-machine interfaces and safety-related data. Reporting of dangerous spots by cyclists, 3D cameras or on-bike sensors can help address gaps in safety data.

Data, Data Protection, and Security: A significant challenge is the availability and representativeness of cycling data. Compared to motorised traffic only relatively little data is available about cycling (counting, infrastructure, parking, etc). In addition, many data collection initiatives target specific groups or areas, leading to underrepresentation of certain demographics like schoolchildren and the elderly. Data quality is another concern, as National Access Points require quality controls that commercial platforms may not offer. Additionally, there is a lack of data standardisation and system interoperability, which limits the widespread use of intelligent systems. Privacy protection is crucial, as ITS systems collect personal data that must be safeguarded against misuse.

Legal and Regulatory Framework Conditions: The introduction of new technologies must align with existing laws and regulations, which often lag behind technological advancements in digitalisation. Different interpretations of EU laws across countries can create uncertainty. The existing legal framework is suitable but has to be adopted to integrated the perspective of Smart Cycling.

Financing and Economic Sustainability: Smart Cycling initiatives face funding challenges, as many projects lack structural funding for data provision and diffusion. European and national funding programs often have few calls for Smart Cycling proposals. There is a need for dedicated budgets for research and development, pilots, and deployment of Smart Cycling solutions. The economic value of cycling data is still unclear, and business cases for cycling data are rare.

Integration into Existing Road and Digital Infrastructure: Integrating intelligent systems into existing infrastructure requires extensive adjustments and coordination among various stakeholders. Investment in digitalising traffic light systems offers opportunities for Smart Cycling services. However, information on the benefits of Smart Cycling systems must be shared quickly to support cooperation among stakeholders.

Creating Awareness and Acceptance for Smart Cycling: There is a shortage of expertise in Europe and knowledge sharing at cities and regions, with many policymakers lacking expertise in using cycling data. Acceptance by the general public is also a challenge, as cyclists may be reluctant to share data or see the added

value of Smart Cycling applications. Transparent communication and proper public participation are essential to build trust and support for Smart Cycling initiatives.

7.6 Key actions

Cycling is healthy, sustainable, efficient and cost effective and therefore an important mode of transport in mobility policies on all levels, as described in the EU "Declaration on Cycling".

Smart Cycling is not just an added value for cycling, just as smart mobility not only is beneficial for motorised vehicles. It has the potential of making big societal impact. It makes cycling safer, faster and easier. But the concept of Smart Cycling is not yet widely acknowledged by cycling policy makers and planners at EU, national and local level. This roadmap defines four key action that are required to give Smart Cycling the same status as smart applications for motorised traffic. Not by merely copying smart mobility services for motorised traffic to cycling, but by recognising the specific characteristics and strengths of cycling.

1. **Improve safety and attractiveness of cycling by putting Smart Cycling on the policy agenda**

Smart Cycling should get a prominent part in the policy on active mobility and the policy of smart mobility at all government levels. The EC should lead by making Smart Cycling a mandatory part in SUMPs needed for urban nodes and making it part of the program for the 100 climate neutral cities. In addition, Smart Cycling should be integrated in the revision of relevant Directives and Delegated Regulations, such as the ITS Directive, and the Delegated regulations on SRTI, RTTI and MMTIS. National cycling plans should have a section on Smart Cycling and regional and local cycling plans should consider the opportunities offered by Smart Cycling solutions.

2. **Foster innovation and digitalisation of the mobility system by stimulating the development of Smart Cycling systems and services**

European and national funding schemes for smart mobility should earmark a dedicated budget for the funding of research & development, pilots and deployment of Smart Cycling solutions (both ITS and C-ITS), requesting minimum technical requirements to ensure seamless services in Europe. These solutions can be focused directly to the cyclists and/or target public authorities (indirectly benefiting cyclists). These Smart Cycling solutions might serve various purposes, such as increasing safety of cyclists, reducing congestion, increasing health, improving liveability, etc. A specific point of attention is the development of guidelines for safe product/service design (HMI) for Smart Cycling applications, which should avoid distraction of the cyclists in traffic.

3. **Enable Smart Cycling services by collecting and standardising cycling data and making cycling data accessible**

The EC should request from Member States to deliver national action plans on cycling data. Authorities should collect more and better cycling data (including floating bike data) by using different kinds of smart counting and measuring tools. These data should be made accessible, preferably free of charge, via the National Access Points and European Mobility Data Space. Common standards for various cycling data (e.g., infrastructure data, counting data, parking data, real-time data) are lacking. NAPCORE has made a start to standardise these

data and this activity needs to be continued with higher intensity. Attention should also be given to issues regarding minimum quality of data and privacy aspects of collecting and sharing cycling data.

4. **Raise awareness on Smart Cycling by sharing knowledge and create a collaborative Smart Cycling ecosystem**

The European Commission should facilitate the creation of a European Smart Cycling organisation or platform, which will function as a catalyst and driving force for research, innovation, deployment and knowledge sharing for the Smart Cycling Ecosystem in Europe, that consists of mainly small cycling and ITS companies, research institutes and universities and national, cyclist organisations and local/regional authorities. This should be done in close cooperation with other relevant platforms like for example NAPCORE (data, data standardisation) and the C-ROADS platform (C-ITS specifications). In addition, regular high-level dialogues on Smart Cycling should be organised on a political level to boost the take-up of Smart Cycling at the administrative level.