MegaBITS

MegaBITS

Interreg North Sea

Co-funded by the European Union

Recommendations on a specification for Floating Bicycle Data

Laure De Cock (imec)
Evelien Marlier (imec)
Casper Van Gheluwe (imec)

May 2024

Disclaimer:
This paper reflects only the authors' view, and the Interreg North Sea is not responsible for any use that may be made of the information it contains.

The MegaBITS project is supported by the Interreg North Sea Programme of the European Regional Development Fund of the European Union.

imec
embracing a better life

Document information

Summary					
Programme	Interreg VI North Sea	**Project short name**	MegaBITS		
Deliverable no.	D 2.3	**Deliverable name**	Recommendations on a specification for Floating Bicycle Data		
Status	Final	**Due**	M12	**Date**	30/05/2024
Author(s)	Laure De Cock (imec) – Innovation specialist urban mobility & logistics Evelien Marlier (imec) – Project manager Casper Van Gheluwe (imec) – Solution architect urban mobility & logistics				
Corresponding author	Casper Van Gheluwe (imec) – casper.vangheluwe@imec.be				
Dissemination level	PU – Public				
Document history	**Version**	**Date**	**Submitted**	**Reviewed**	**Comments**
	v1.0	06/05/2024	IMEC	Robin Kleine	/
	v2.0	24/05/2024	IMEC	Ronald Jorna	/
	V3.0	30/05/2024	IMEC	/	/

Table of contents

List of figures

List of tables

Project executive summary

As global urban mobility evolves with a growing emphasis on sustainability, cycling is increasingly recognised as an important mode of transportation. However, compared to other transport modalities, cycling innovation still lags behind. The "Mobilizing Europe's Green Ambitions through Bicycles and Intelligent Transport Systems" (MegaBITS) project, an Interreg North Sea Region initiative, aims to bridge this gap by integrating Intelligent Transport Systems (ITS) into cycling.

Running from 2023 to 2026, MegaBITS is aims to revolutionize cycling infrastructure across the North Sea Region by embedding cycling ITS into mobility governance at the local, regional, and European levels. This transformation will enhance the safety, comfort, and convenience of cyclists, bringing the digitalisation of the cycling sector to new heights and enriching the cycling experience.

MegaBITS sets ambitious targets: a 10% increase in cycling kilometres within targeted groups and an 8.8% reduction in CO_2 emissions. The project encompasses five flagship pilot initiatives spread across seven cities and regions, each exploring different ITS applications such as intelligent bike parking systems and 'green wave' traffic management systems, which optimize traffic lights to prioritize cyclists. These initiatives are tailored to uniquely advance the digitalisation of cycling in their respective contexts.

Furthermore, the project leverages data-driven insights to refine cycling infrastructure, focusing on user patterns and safety needs. A major challenge remains the lack of standardisation in cycling data across different locales, which hampers the ability to effectively gather, compare, and analyse data. Addressing this gap in standardisation is a important goal for MegaBITS, as it seeks to enhance coherence and efficiency in cycling data usage across Europe.

Deliverable executive summary

The ongoing 'Mobilizing Europe's Green Ambitions through Bicycles and Intelligent Transport Systems' (MegaBITS) project has identified several critical challenges and opportunities in harnessing Floating Bicycle Data (FBD) for enhancing bicycle mobility across the Europe. Despite its potential, FBD is currently underutilised due to a myriad of governmental, operational, technical, and standardisation hurdles. The project partners identified the need to inventory these challenges and potential solutions, to help the pilot regions apply FBD sources more effectively during and after the MegaBITS project.

This document therefore presents the findings from a set of comprehensive interviews conducted with experts across various domains such as academia, industry, standardisation bodies, and data providers. This analysis has helped to understand the current landscape of FBD, its applications, and the challenges that currently exist for its wider adoption and effectiveness.

Key issues identified include the lack of standardisation in FBD, which complicates data comparability across regions and applications, the varied data quality and its representativity which affects its utility, and the significant gap in stakeholder capabilities particularly in terms of data handling and policy application.

To address these challenges, this document outlines several recommendations aimed at improving the floating bicycle data ecosystem. It is crucial to engage stakeholders at all levels to understand and incorporate their specific needs. Developing a comprehensive set of use case descriptions, complete with FBD requirements and examples from across Europe, can serve as a valuable resource for both data providers and insight seekers. Moreover, emphasizing the unique perspectives of stakeholders within the ecosystem, particularly those who are disadvantaged, such as insight seekers and FBD suppliers, is essential. Providing these groups with resources, training, and intermediary connections will help bridge gaps and enhance their participation.

Creating a simple, inclusive and unified standard that addresses compliance and privacy concerns, while catering to the differing requirements set forth by the stakeholder groups, is vital. This standard should be developed collaboratively, involving a diverse range of stakeholders, and aligned with existing initiatives like NAPCORE's workgroup on Cycling. Learning from the car industry's experiences with floating car data can provide valuable insights to avoid common pitfalls. Beyond standardization, it is important to tackle business modeling and privacy issues concurrently to ensure the long-term sustainability and integrity of the FBD ecosystem.

By embracing these recommendations, the European cycling community, and the stakeholders and partners of the MegaBITS project can unlock the full potential of FBD, paving the way for more informed and effective cycling policymaking.

List of abbreviations and acronyms

Acronym	Meaning
AI	Artificial Intelligence
API	Application Programming Interface
CEN	Comité Européen de Normalisation (Fr.) European Committee for Standardization (En.)
CIE	Cycling Industries Europe
DATEX II	Data Exchange standard for exchanging traffic information
DMI	Dutch Metropolitan Innovations
DPO	Data Protection Officer
EC	European Commission
EU	European Union
FBD	Floating Bicycle Data
FCD	Floating Car Data
GBFS	General Bikeshare Feed Specification
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
ITS	Intelligent Traffic Systems
MDS	Mobility Data Specification
MegaBITS	Mobilizing Europe's Green Ambition for Bicycles through Intelligent Traffic Systems
NAP	National Access Point
NAPCORE	National Access Point Coordination Organisation for Europe
NDW	Nationaal Dataportaal Wegverkeer (Nl.) National Road Traffic Data Portal (En.)
NeTEx	Network Timetable Exchange
NSR	North Sea Region
SENSORIS	Sensor Interface Specifications
SIRI	Service Interface for Real-time Information
TPEG	Transport Protocol Experts Group
NIH	Not invented here

1 Introduction

Floating bicycle data (FBD) can provide valuable insights into cycling patterns, traffic flow, and traffic safety, but few policymakers use it today. This became evident in the Mobilizing Europe's Green Ambitions through Bicycles and Intelligent Transport Systems (MegaBITS) project, where several regions expressed interest in utilizing FBD but had many questions regarding its implementation. Informal discussions within the project consortium and the advisory board, indicated that data inconsistency was a significant concern, as different smartphone applications and hardware devices collect data in varied formats, making it difficult to aggregate and analyse data uniformly across systems, let alone across cities. Furthermore, the lack of standardisation between data formats and systems was identified as a barrier to seamless integration and transferable solutions, limiting the ability of cities and organizations to create comprehensive analyses or solutions, and to learn from each other. Inconsistent data quality and representativity, including inaccuracies and gaps, were also found to hamper the usefulness of FBD, leading to ineffective cycling policymaking.

Unlike floating car data (FCD), which is more established and has clearer standards, floating bike data lacks uniformity. The diverse range of bike-sharing companies, Global Positioning System (GPS) devices, and mobility tracking applications further complicates the data collection and integration process. Additionally, bicycles tend to move in different patterns from cars, including on dedicated bike lanes or through pedestrian zones, making it more difficult to compare data sets directly. The data requirements (i.e. preciseness, required representativity, sampling frequency, etc.) for FBD can also vary significantly depending on the use case. The lack of a comprehensive framework for integrating bicycle data into existing traffic management systems, along with a subpar understanding what quality is needed for what purposes, pose another challenge for city administrations, preventing them from creating unified mobility strategies.

Given these challenges, *imec* conducted this study to address the issues and better integrate floating bike data into urban mobility strategies. This research seeks to unlock the full potential of floating bike data, helping cities gain a clearer understanding of cycling patterns, infrastructure needs, and mobility trends, ultimately contributing to more sustainable, efficient, and liveable environments for residents. The results of the study will also be used by NAPCORE's cycling ambassadors to aid the definition a new European floating bicycle data standard, further facilitating the integration and utilization of this valuable data in sustainable urban mobility efforts. The recommendations will also support the MegaBITS project in developing a strategy for the role of FBD in ITS and assist the pilot sites in refining their use of floating bicycle data for policymaking support.

Section 2 of this document will detail the research methodology, including the expert selection process, interview structure, and analysis approach. Section 3 presents a stakeholder mapping and a comprehensive overview of the results regarding data sharing, challenges, opportunities, and standardization potential. Finally, Section 4 provides recommendations and next steps to further integrate FBD into data-driven policymaking.

2 Methodology

To support the recommendations on potential standards or specifications for Floating Bicycle Data insights and viewpoints were acquired through a series of structured interviews with 15 experts across various relevant subdomains, including academia, the bicycle industry, standardisation experts, data and application providers, and potential data intermediaries to perform this qualitative research.

2.1 Selection process

A selection process was implemented to identify experts possessing extensive knowledge and experience in the domains pertinent to bicycle data collection, processing, and application. The selection criteria aimed to encompass a diverse range of expertise to ensure a comprehensive understanding of the multiple aspects involved in standardising FBD.

First, all partners of the MegaBITS project consortium, as well as external experts from leading organisations in the European mobility world, were asked to nominate persons they felt were interesting potential "experts" or "data suppliers" that should be considered for further interviewing. This led to a longlist of 36 potential parties to interview. To preserve the anonymity of the experts, their names and organisations have been redacted in this report, and their responses have been aggregated into several stakeholder groups. One important remark is that potential data consumers, such as city officials or other public authorities, were left out of this list on purpose, as there was a parallel investigation, conducted by researchers of *Chalmers University of Technology* in Gothenburg, a fellow partner in MegaBITS, on how consumers perceive the potential value and opportunities that FBD can bring[1].

From this longlist, 18 potential interviewees were invited to participate, keeping in mind that there would be a good balance between the different stakeholder groups. Each of these participants was sent an e-mail invitation to participate by *imec* or by one of the other MegaBITS partners with closer ties to that potential interviewee.

Finally, 15 out of the 18 potential interviewees responded positively and booked an interview timeslot between late January and late March of 2024. Three others did not respond to the invitation. Once a timeslot was booked, a follow-up e-mail was sent with an informed consent form (see Annex 5.2) that provided further details on the data collection and anonymisation, and an optional approval to record the interview for later analysis. Table 1 offers an overview of the invited and confirmed interviewees, divided into eight stakeholder categories that are further defined below.

[1] The results of this investigation will be published, once it is ready, on the MegaBITS website. That report will also integrate insights from this deliverable.

Table 1 - Anonymised overview of selected interviewees

Stakeholder group	No. invitations	No. interviewed
Academics	3	1
Apps for cycling intelligence	2	2
Bicycle manufacturers	2	2
Bicycle logistics operators	1	1
Data intermediaries	2	2
Hardware for cycling intelligence	3	2
Route planner providers	1	1
Standardisation organisations	4	4
TOTAL	**18**	**15**

- **Academics:** Individuals from research and educational institutions who can contribute their knowledge and experience in cycling ITS and the use of floating bicycle data.
- **Apps for cycling intelligence:** Organisations that have developed mobile applications that can track cyclists during their trips.
- **Bicycle manufacturers:** Organisations or divisions that design, produce and/or sell bicycles.
- **Bicycle logistics operators:** Organisations that provide logistics services (i.e. cargo deliveries) via bicycles.
- **Data intermediaries:** Organisations that can act as support or go-between in the collection, processing, analysis, or distribution of floating bicycle data.
- **Hardware for cycling intelligence:** Organisations that produce and/or sell physical devices or components that can, as a primary or secondary function, assist in gathering cycling data, such as sensors or trackers.
- **Route planner providers:** Services that offer route planning solutions that can also track cyclists as they perform their trips.
- **Standardisation organisations:** Entities that establish and promote standards to ensure compatibility and interoperability amongst different products and services in a certain domain, not limited to cycling.

2.2 Interview structure

A detailed topic guide was prepared to maintain consistency across the interviews while allowing sufficient flexibility for in-depth discussions. This guide directed the interviews towards critical areas, including data collection methodologies, data quality issues, standardization challenges, and the potential applications of FBD. The questions within

the guide were a mix of open-ended and specific queries, created to elicit detailed insights while maintaining focus on the project's overarching goals.

The interviews followed the structure that is detailed below. Each of these segments was timed to approximately 10 minutes, but occasionally certain sections took more or less time depending on the specific expertise of the interviewee and their prior knowledge on floating bicycle data. This approach to the organisation of semi-structured interviews by use of a topic guide is supported by literature[2]. Table 2 offers a selection of the questions that were posed in each interview segment. The full topic guide, including the lists of questions that were prepared for each segment, is available in Annex 5.1.

1. **Introduction:** Brief introduction of the interviewers, the MegaBITS projects, what the research entails and why we are looking for input from the interviewee. Get more insight into the expertise of the interviewee, their role within their organisation and the organisation's involvement with FBD.
2. **Current practices:** Exploring how FBD is currently being defined, utilised, collected, shared, and managed by the interviewee and their organisation.
3. **Challenges and needs:** Identifying and understanding the challenges, limitations and needs in the interviewee's current use and management of floating bicycle data.
4. **Opportunities:** Discussing potential solutions and opportunities for the improvement of the interoperability of floating bicycle data.
5. **Innovation confrontation**: Presenting standardisation of the FBD data feeds as a hypothetical solution to gather feedback and insights from the interviewees.
6. **Wrap up**: Concluding the interview with an opportunity for the interviewees to offer additional insights or takeaways that were not yet discussed.

Table 2 - Selection of questions for each interview segment

Interview segment	Example question
Introduction	Can you briefly describe your organisation's **involvement** with floating bike data, and your role within these projects?
Current practices	What is, according to you(r organization), the **definition** of floating bike data?
	How do you ensure or check the **quality** and accuracy of the floating bike data in your data processing pipeline?
	How do you measure and reach the desired level of **representativity** (i.e. sample size of number of tracked/included cyclists vs. the actual population)

[2] Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *Co-design*, *4*(1), 5-18.
Bernard, H. R. (2006). Research Methods in Antropology: Qualitative and Quantitative Approaches, pp. 230.
Merriam, S. B. (2009). Qualitative Research: A Guide to Design and Implementation, pp. 109.

Challenges and needs	From your experience, what are the most significant **challenges** you face in the interoperability of floating bike data? And why?
	Which **stakeholders** are typically involved or disadvantaged because of the challenges that you have just identified? (i.e. city planners, bike-sharing companies, study agencies, DPOs, …)
Opportunities	Based on the challenges you've identified, what would an ideal **solution** or improvement look like, in a perfect world?
Innovation confrontation	How do you think that **standardisation** of floating bike data could address the challenges you have mentioned earlier?
	Are there any specific **requirements** that this standard must comply to?
	Do you think there are any **existing other standards** in the mobility domain that we should look towards for inspiration?

2.3 Interview process

Each interview was conducted on an individual basis and was scheduled to last approximately one hour. The structured format ensured that each session efficiently gathered relevant and substantial information from the experts. For each interview, one *imec* researcher was tasked with asking the questions while the other took notes. In case the interviewee gave consent, their responses were also recorded, to supplement our own notes in case certain responses were incompletely noted down. The first interview took place on January 24, and the last one was completed on March 25, 2024.

2.4 Analysis

The responses gathered from the interviews were transcribed, coded, and categorized to extract clear statements, themes, or keywords. In the first step, the similarities, and differences between the statements of various stakeholder groups were analysed, resulting in a stakeholder mapping. Next, the prevalence of several statements was determined by counting their occurrences. This prevalence gives an indication of the amount of thought a certain topic, practice, or challenge receives. The combination of coding and counting is often used as a systematic approach for qualitative research[3]. The results of the analysis are presented in section 3, while our recommendations and key takeaways are described in section 4.

[3] Elliott, V. (2018). Thinking about the coding process in qualitative data analysis. *The qualitative report*, *23*(11), 2850-2861.

3 Results

The results of the analysis of the answers provided by the interviewees are detailed in this chapter. The significant findings and insights are meant to serve as a resource for further development and decision-making processes within the MegaBITS project and other standardisation bodies and initiatives, such as NAPCORE. It offers an overview of the relevant stakeholders and looks at their current practices on handling FBD, at the challenges they experience and opportunities they see. Finally, it also goes deeper into their opinion on what role standardisation could play to increase the maturity of the floating bicycle data ecosystem.

3.1 Stakeholder mapping

Figure 1 illustrates the position of the different stakeholders on the FBD processing pipeline from providing FBD to seeking insights.

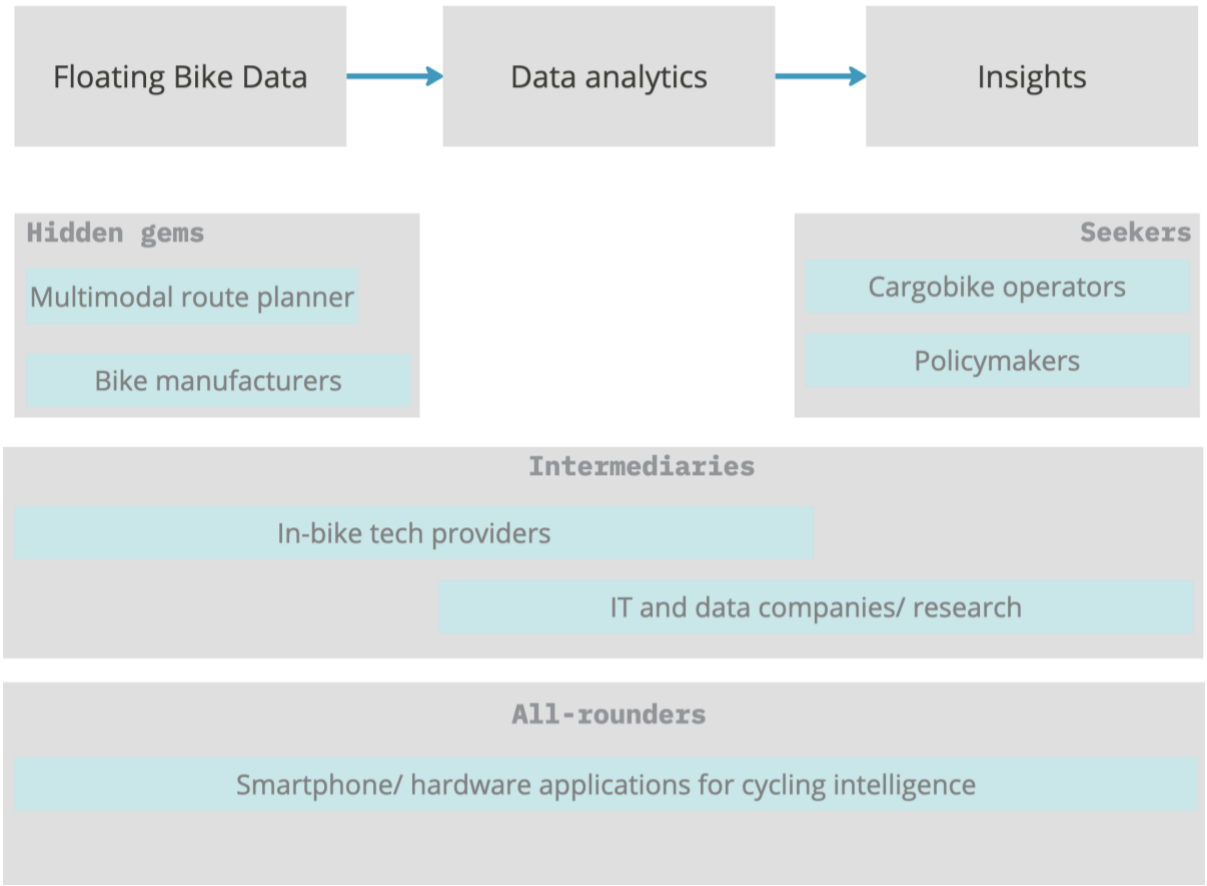

Figure 1 - Stakeholder mapping of the FBD ecosystem

Four stakeholder groups have been defined:

- **Seekers** understand the potential value of FBD to enhance their policymaking, operations, or practices, but they often lack the capabilities to collect or analyse the data themselves.
- **Hidden gems** have access to FBD and (could) collect it, yet they fail to utilise this data effectively, primarily due to the absence of a clear business model or specific demand from their customers, leaving valuable potential insights untapped. Some of them do not have in-house knowledge for successfully transitioning from raw data to policymaking insights and employ external consultancy companies to do this step.
- **Intermediaries** play a bridging role; they not only collect and generate FBD but also focus on turning this data into actionable insights, through collaboration with the other stakeholders.
- **All-rounders** have successfully developed a self-sustaining model. They gather FBD through their smartphone applications or hardware add-ons and directly provide their customers with valuable analytics through comprehensive dashboards. Some of them even process data and execute Artificial Intelligence (AI) algorithms directly on the sensing devices, to minimize backend processing loads and security and privacy concerns. In brief, All-rounders not only gather and provide raw data, but also refine it to provide actionable knowledge.

The position of stakeholders on the processing pipeline determines what their current practices are (section 3.2), which challenges they face (section 3.3), and in which solutions they believe (section 3.4). Moreover, the gap between FBD providers and insight seekers is reflected in their definition of FBD.

3.2 Current practices

In this section, we investigate the current practices surrounding the use, collection, sharing, and management of FBD. As urban cycling becomes increasingly recognized for its role in sustainable mobility, the ways in which FBD is harnessed are pivotal to improving city planning and cycling infrastructure. First, it aims to assemble a common understand of what FBD entails. Then it explores the methodologies implemented by the interviewees to gather, utilise, and share data. Finally, it examines the importance of data quality and representativity.

3.2.1 Definition

As mentioned in the previous section, a significant gap was identified between the providers of FBD and the seekers of insights. This gap primarily stems from a misalignment between the nature of the data provided and the type of data required for actionable insights. FBD providers typically offer raw positioning data sourced from Global Navigation Satellite Systems (GNSS). However, insight seekers need data that has been aggregated and processed to be useful for analysis and decision-making. This discordance necessitates a framework that supports both the collection of raw data and

its transformation into valuable processed information. Table 3 offers an overview of the interviewee's opinions on the definition of FBD, and what kinds of information it entails.

Table 3 - Opinions on the definition of FBD

Definition	Relative coverage
Contains raw positioning data	High
Contains aggregated or pre-processed data products (e.g. routes, stops, speeds, O/D matrices, volumes, ...)	High
Contains functional data of the bicycle (e.g. battery status, distance travelled since last maintenance, ...)	Medium
Contains real-time data	Low
Contains data from road-side sensors	Low
Contains data on the infrastructure	Low

The interviews have highlighted six main opinions regarding the nature and scope of FBD, which need to be addressed to bridge this gap effectively. First, as mentioned, it includes raw positioning data of bikers or bicycles from GNSS, which serves as the fundamental layer of information. A significant portion of the interviewees use this as their definition of Floating Bicycle Data.

Secondly, there is a demand, specifically from *seekers*, for it to also encompass aggregated or pre-processed data products such as routes, origin-destination, number of stops, volumes, and speeds. These derived data forms are crucial for applications requiring immediate usability, such as insights for policymakers, who seldomly want to deal with extensive additional data processing on their side.

The inclusion of functional data from the bicycles themselves, such as battery status and maintenance needs, is considered interesting for operational and safety purposes. This type of data can aid in the effective management of bike fleets and individual bike health, enhancing overall service quality. Furthermore, there is some demand for FBD to be available in real-time, enabling dynamic responses to situational changes on the road, which is essential for applications such as dynamic routing and real-time traffic management.

Additionally, the integration of data from roadside sensors into FBD is seen as valuable for enriching the data pool with environmental and infrastructural context, thus allowing for more sophisticated analyses.

Finally, data concerning infrastructure, like road conditions and cycling paths, was also mentioned. This information can help in planning and improving cycling infrastructure, thereby promoting safer and more efficient cycling environments.

Combining these diverse opinions and needs in one definition of Floating Bicycle Data is challenging. The quote below offers a first attempt at a definition of FBD, that aims to address this wide range of perspectives. By incorporating a broad spectrum of data types and ensuring their timely availability, the FBD standard can significantly improve the alignment between data providers and insight seekers, ultimately fostering enhanced decision-making and more effective bicycle-related services and infrastructure development. However, it remains to be seen whether the gap between these two stakeholder groups can be bridged by a single standard.

Floating Bicycle Data encompasses various types of information that detail the movement and usage patterns of cyclists or bicycles.

3.2.2 Data sources

It is interesting to examine what the underlying data sources of common floating bicycle data are. From the interviews, it appears that these sources range from mobile applications and sensor devices, to connected bicycles and smart locks. An overview of these underlying data sources is given below.

- **Mobile applications:** Some interviewees mention that their primary source of FBD is mobile applications, which can offer varied and extensive data due to their widespread utilisation. However, some challenges exist in differentiating the different modes of transportation, which complicates data interpretation. Some of these apps are specifically tailored towards cycling, i.e. by allowing cyclists to share their route data while ensuring anonymity and privacy through aggregation. Other apps are developed for general location tracking but can be configured or filtered to focus specifically on cycling data. These apps primarily provide data from their own user base, which somewhat limits the diversity of data.
- **Connected bicycles:** These bicycles are equipped with integrated sensors and connectivity solutions, represent a growing source of FBD and were mentioned as an important source by the experts. These bicycles can provide comprehensive data not just on location, but also on various other aspects of the bicycle's status and usage, such as motor performance, battery charge and maintenance needs. The data collected from connected bicycles offers a high degree of coverage and granularity, making it particularly interesting for understanding cycling patterns. However, representativity is a key concern when using connected bicycle data, as this is still a limited fraction of all bicycles and are expensive and therefore used only by a subset of the cycling community.
- **Dedicated sensor devices:** Dedicated devices with sensors and GNSS location tracking, designed specifically for use on bicycles can also provide highly accurate locational data. These devices can be integrated directly into bicycle components, such as the wheels or handlebar, or attached elsewhere, such as on the luggage rack. These sensors can be installed on any kind of bicycles and can

provide continuous sensing capabilities such as location, but also on road surface quality or air quality.

- **Smart locks:** Several interviewees also mentioned smart locks equipped with connectivity technology as a potential contributor to FBD collection. These devices can track the location and status of bicycles and is particularly useful in shared bike schemes or bike fleets, where tracking the movement and usage of multiple bikes simultaneously is critical for operational reasons. These smart locks are designed in-house or purchased separately from external vendors.

When asked whether they have also experimented with supplementing their own data sources with external data from other suppliers, some of the interviewees responded that they have experimented with this, but that the outcomes were not satisfactory and required a lot of technical data integration work. Another reported issue was that the enrichment and fusion of different data sets demands significant efforts to align the legal and privacy requirements set by the Data Protection Officers of the participating data providers. Finally, some of the interviewees highlighted that there is often a significant difference in quality between location data gathered by mobile applications that track their users in the background, and location data gathered via dedicated sensor devices.

This brief overview of the underlying data sources for FBD reveals a diverse landscape encompassing mobile applications, connected bicycles, dedicated sensor devices, and smart locks. Each source presents unique advantages and challenges, from extensive coverage and granularity to issues of data quality and representativity. Furthermore, efforts to integrate and supplement these data sources with external datasets have encountered significant technical and legal hurdles. Consequently, any future standardisation efforts must consider these varied data characteristics and the complexities involved in data integration to enhance the utility and accessibility of floating bicycle data.

3.2.3 Data aggregation

The aggregation level of FBD is an important factor in determining the utility and applicability of the data for various stakeholders, including policymakers, data specialists, and commercial entities. This necessity to balance the richness of raw data with practical applicability highlights the need for flexible data aggregation approaches suited to diverse requirements.

FBD is primarily managed by geospatial data specialists, yet there is a significant need for its transformation into forms more usable for policymaking. This transformation typically requires separate disciplines that can tailor the raw data into digestible, actionable materials. As such, the challenge lies in determining the appropriate level of aggregation to maintain data utility while making it more easily accessible for strategic decisions. The applications and aggregation requirements that multiple interviewees highlighted are outlined below.

- **Speed and movement data**: For traffic management systems and mobility policymaking in general, there is a need to aggregate average speed data on various road segments. This type of aggregation helps in assessing traffic flow and planning accordingly. Additionally, incorporating these data into dashboards provides real-time actionable insights.
- **Heat maps**: Heat maps are generally used by policymakers to visualize data in a derivative form, showing trends and patterns in bicycle usage across different areas. These are often aggregated at higher levels to avoid identification of individual patterns and focus on broader trends.
- **Safety data**: Aggregated data concerning swerving, braking, and accident hotspots are interesting for analysing road safety and planning interventions. This data must be carefully processed to pinpoint areas of concern without compromising individual privacy.
- **Raw GNSS traces**: While raw GNSS traces provide detailed locational data, they are not directly useful for policymakers without significant pre-processing. Techniques like map matching and speed aggregation are necessary to transform this data into a usable format for policymaking.
- **Origin-destination matrices**: O/D matrices are highly valuable for traffic modelling and understanding commuting patterns. These are aggregated from individual trips to reflect the broader movement trends without revealing personal travel details.
- **Routing information**: Data on routing preferences and travel times are aggregated to understand preferred routes and potential bottlenecks in the network. This information aids in optimizing route planning and enhancing the overall cycling experience.

The level of data aggregation is naturally influenced by the intended use case. For example, while some applications might benefit from very granular, real-time data, others may require high-level summaries to inform broader policy or business decisions. This was highlighted by multiple respondents. Moreover, the balance between maintaining the utility of raw data and protecting individual privacy of the cyclists is an important consideration, requiring sophisticated aggregation techniques and the potential use of Privacy Enhancing Technologies (PET).

The aggregation level of FBD therefore needs to be carefully calibrated to serve the dual purposes of functionality and confidentiality, ensuring that data serves its intended purpose effectively while adhering to data privacy regulations. This tailored approach to data aggregation is, according to the interviewees, essential for maximizing the benefits of FBD across various applications and domains.

3.2.4 Data sharing

Based on the interviews, the data suppliers and experts were categorised into three levels of data sharing willingness and policies: no sharing of data, sharing of aggregated results, and sharing of unprocessed data. An overview of their data sharing policies is available in Table 4.

Table 4 - Floating bicycle data sharing policies

Category	Data sharing policy
Do not share	Not the data owner, and it is therefore impossible to share the data further with other organisations
Aggregated sharing	Sharing via dashboards
	Sharing via APIs or data files
	Tailored sharing to clients' demands
Full sharing	Raw data possible via usage policies
	Raw data sharing possible with universities or public authorities

The willingness of data suppliers to share FBD therefore varies significantly, as do their specific policies on how they wish to share data with consumers. While some hold their data closely due to its proprietary and legal or privacy constraints, others have adopted a more collaborative stance, and are offering to provide aggregated and anonymized data through dashboards, Application Programming Interfaces (API) or even tailored services. Some have embraced a policy of full transparency, showing willingness to share even raw data, provided that some conditions, in terms of usage policies, are met. This varied landscape underscores once again the complex landscape of data privacy, ownership, and the perceived value of floating bicycle data.

Figure 2 confirms this. As shown, the *hidden gems* indicated that they have not shared a lot (if any) floating bicycle data up until now, because they have not yet found a business model, or because they believe that the prevailing privacy regulations do not permit them to do so. It is not always clear to the *hidden gems* and *all-rounders* what they can and cannot share, as unambiguous guidelines on this topic are lacking (see also section 3.3). *Intermediaries*, on the other hand, have shared FBD occasionally on a project basis. Their offerings depend highly on the needs of the customers and on their own technical capabilities. Finally, *all-rounders'* business model is built on the use of floating bicycle data, and so they typically have developed quite advanced tools to share (aggregated) data products with their customers, often through interactive dashboards or APIs.

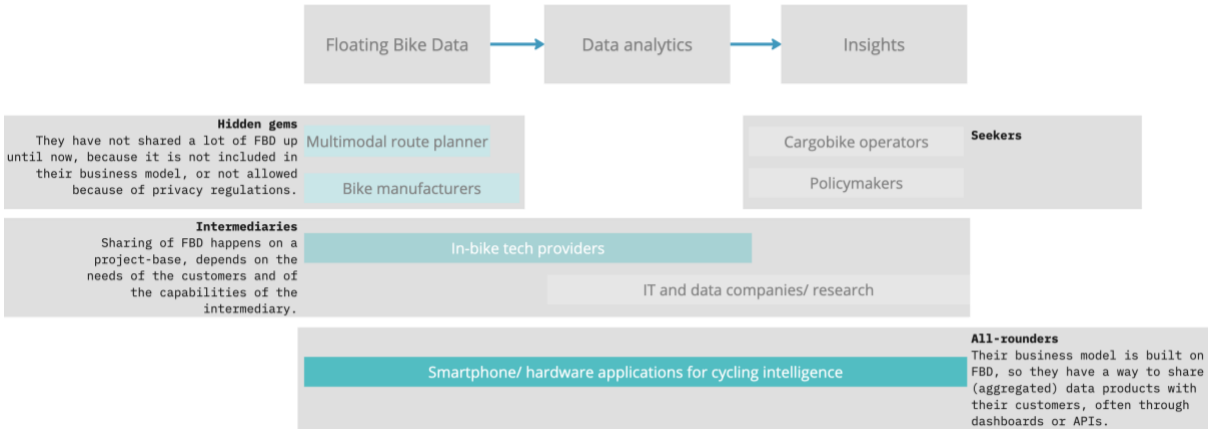

Figure 2 - State of practice in data sharing for the different stakeholder groups.

3.2.5 Data quality and representativity

This section explores the essential aspects of data quality and representativity in FBD, which are crucial concepts for its effective use in urban mobility planning and policymaking. We discuss the measures taken by the stakeholders to ensure data accuracy and consistency, and how they address challenges related to the representativeness of the data, ensuring it reflects the diversity of the cyclist population. These factors are vital for making informed decisions that affect cycling infrastructure and policy.

3.2.5.1 Data quality

The different data suppliers and experts that were interviewed, underscore the importance of robust data quality measures in the use of FBD, ensuring that the data is not only accurate but also practical for diverse applications. However, there exist widely varying visions on how to measure and deal with the data quality, with each entity adopting unique approaches to ensure the accuracy and reliability of their data:

- **External quality control**: Some entities rely on external sources for their data, implementing data cleaning processes and making necessary corrections to meet specific information needs. Others perform their quality checks or rely on methodologies that automatically correct data as needed.
- **Systematic monitoring**: There are instances where data generation is monitored according to ISO norms, focusing on addressing data gaps and ensuring correct data entry into systems. In some cases, additional different data sets are used for comparison to analyse the quality of the floating bicycle data.
- **Manufacturer responsibility**: In some cases, the responsibility for data quality is assumed to be managed by the manufacturer of the devices, such as sensors in connected bicycles, or by the upstream provider of the data.
- **Field studies**: Quality checks are performed at various stages of data aggregation, and real-world studies (such as those on road surface conditions or cyclist behaviours like swerving and braking) are used to validate data accuracy.

- **Validators & public monitoring**: A number of standardisation bodies have created data feed validators. These tools check data feeds for errors, with validators focusing on syntax and logical errors. Such validators exist for the NeTEx and GBFS standards, for example. Some standards also provide public visibility into data quality status of their implementations, to help maintain transparency.
- **Baseline comparisons**: For entities with a large user base, historical data on user behaviour and modal splits, including those from other regionally or nationally organised large scale travel surveys, can serve as a baseline for ongoing data quality checks.

A potential role for National Access Points (NAP) and NAPCORE was also highlighted by some of the interviewees. Some NAPs already check the quality of data that is submitted into their repositories (i.e. some form of validation), while others do not.

3.2.5.2 Representativity

The interviews indicate a generally low prioritization of representativeness in the collection and utilisation of floating bicycle data. While some organizations forego traditional representativeness checks in favour of interpreting results on a relative scale for greater analytical flexibility, others recognize and address biases in their data - such as the potential underrepresentation of certain groups, like youths, newcomers, and non-native residents. The level of scrutiny applied to the data varies, often influenced by the population size of the area of study, with a shared understanding that complete population coverage is not always essential for meaningful analysis and is very use case dependant.

Some respondents do some efforts to increase representativity, including targeted marketing and social media campaigns aimed at diversifying the user base to improve the representativeness of the data. It is, however, clear that more guidance is needed on this topic.

3.3 Challenges

The interviewees were also questioned on the challenges they face in terms of floating bicycle data sharing and interoperability. This will help to prioritise which issues to tackle first and to scope the future standard in such a way that it solves the most critical needs. Section 3.3.1 aims to list the challenges and needs of the floating bicycle data ecosystem, from the point of view of the interviewees. It is followed by section 3.3.2 that offers insight into which stakeholder groups are disadvantaged by the challenges. Later, section 3.4 discusses the potential solutions for these challenges and other opportunities that the respondents brought up during the interview.

3.3.1 Challenges

The challenges that are identified by the interviewed stakeholders, related to floating bicycle data in general, and its interoperability in particular, have been combined into eight categories (Table 5).

Table 5 - Significant challenges identified by the stakeholders

Challenge	Statements	Relative coverage
Unclear expectations	Ambiguity in the ask and different expectations from the *seekers*.	High
Governance & privacy	Storage, access, and the lack of legal framework are critical issues.	High
Business model	Uncertainty about who will finance initiatives to bolster FBD.	Medium
Data needs & policy relevance	Difficulty in defining the exact requirements and in data modelling, combined with concerns about the limited applications of FBD in policymaking thus far, leading to limited standardisation.	Medium
Lack of expertise	Floating bicycle data remains underutilised due to a gap in expertise within public authorities, research agencies, and data suppliers.	Medium
Technical	General technical challenges in effective data utilisation and sharing.	Medium
Data sharing	Barriers to sharing data among manufacturers and across platforms due to competitive advantages.	Low
Lack of standards	There are no unified standards for FBD data sharing and use.	Low

- **Unclear expectations:** The respondents primarily stressed that the *seekers* often do not know exactly what they need and regularly come to the data suppliers with unclear use cases. They do not always know what the strengths (and weaknesses) of floating bicycle data are, and for which use cases it is useful and for which it is not.
- **Governance & privacy:** A large portion of the interviewees noted that there is a need for robust governance to determine who may access and use this data. For example, the vetting of potential data consumers was mentioned as a time-consuming but necessary governance process to ensure that an organisation's data is used for positive purposes and not for potentially exploitative sectors like advertising or real estate. Legal frameworks and privacy regulations are also paramount, as remains an ongoing search for legally solid data sharing frameworks. Because this framework does not yet exist, data protection officers of different companies often disagree on what is and what is not possible, complicating data sharing initiatives.

- **Business model:** Several respondents, primarily from the data suppliers, recognize the inherent value in floating bicycle data. However, they indicate that there are still doubts with some potential customers whether FBD applications offer enough added value over more traditional approaches. Thus, they face significant challenges in persuading public administrations to pay for their data products. This means that the actual business model is still in doubt. The problem, they suggest, lies in the fragmentation of administrative responsibilities. Different departments focus on their specific areas - be it road safety, micro mobility, or cycling infrastructure - without a designated authority responsible for the investment in the floating bicycle data.
- **Data needs & policy relevance:** Some policymakers also expect that FBD can deliver a similar representativity as floating car data (FCD), which is, at the time of writing, a far better understood concept, with greater standardisation and several well-developed data offerings available in Europe and worldwide. While FCD and FBD are undeniably related, the use cases for them in policymaking are not all identical, and it has been mentioned that the bicycle ITS community should define its own use cases that suppliers and seekers can align on.
- **Lack of expertise:** The respondents also perceive a lack of expertise internally within potential data suppliers, but also at many policymakers and research agencies, leading to underutilization of the data. This is made worse by the increasing reliance on short-term consultancy within public administrations, which leads to continuous brain drain, and a scarcity of intuitive and suitable data processing tools.
- **Technical:** Some of the respondents in the interviews reported encountering a series of technical hurdles when dealing with floating bicycle data. These challenges encompass the full spectrum of data handling: from the initial capture of the data to the intricate processes of analysis, and finally to the sharing of insights through visualisations or dashboards. The technical barriers can manifest in various forms, such as issues with data accuracy, and complexities in applying advanced algorithms to extract meaningful information, such as map matching of the raw GNSS traces to the (cycling) road network.
- **Data sharing:** A few interviewees noted a general reluctance towards sharing data among entities, particularly when those entities stand in potential or actual competition with each other. This hesitation stems from a desire to maintain a competitive advantage by safeguarding proprietary data and analytics methods. As a result, data that could be invaluable for broader analysis, innovation, and public benefit may remain siloed within individual organizations, limiting its potential for the optimization of cycling infrastructure and safety initiatives.
- **Lack of standards:** Interestingly, the issue of lack of standardisation in the floating bicycle data ecosystem was only explicitly mentioned by a minority of the interviewees, suggesting that while it may not be a primary concern for all stakeholders, it still represents a significant challenge for those who did raise it. This observation implies that while some stakeholders are successfully working around this issue or may not see immediate impacts on their operations, there is an underlying issue that could affect broader scalability and interoperability in the

future. Addressing this concern could potentially enhance the efficiency and effectiveness of data use across different platforms and stakeholders, leading to more unified approaches and solutions in the FBD ecosystem.In summary, the challenges identified by the stakeholders underscore the complexity of utilising this novel data source effectively. Issues range from unclear expectations and insufficient governance mechanisms to the struggles in developing sustainable business models and overcoming technical barriers. Similarly, the reluctance to share data and a lack of standardisation also impede the effective integration and utilisation of FBD for policymaking purposes. These concerns collectively highlight the need for a comprehensive strategy that includes better clarity in use cases, enhanced governance and legal frameworks, and further efforts to standardise the domain.

3.3.2 Disadvantaged stakeholders

When asked who is disadvantaged by these challenges, eight respondents pointed at the *seekers*. They are the potential end-users of good insights generated from floating bicycle data, but the aforementioned challenges prevent them from getting access to it. Seekers' limited budgets also constrain them in terms of capacity to make custom integrations between their existing data platforms and the FBD suppliers and in terms of budget to procure data from multiple, potentially complementary suppliers.

The business modelling challenges also strongly affect the data suppliers themselves, as they have a hard time convincing others to pay for their sensors, tools, data, or insight platforms. Some respondents also compared the FBD to the FCD ecosystem and noted that the target market is far smaller for the former, which negatively affects the number potential business models that can applied.

Reflecting on the stakeholder mapping outlined in section 3.1, it is evident that the stakeholders at both ends of the data spectrum face the most significant disadvantages due to the prevailing challenges. Specifically, the *seekers* struggle to access the necessary insights because the *hidden gems*, those who possess valuable but as of now underutilised data, have not yet developed a sustainable business model to share this data effectively.

Lastly, three interviewees pointed out that cyclists represent a group that is inadvertently marginalised due to the scarcity of available floating bicycle data. The lack of available floating bicycle data places them at an inherent disadvantage when contrasted with motorists, who benefit from a much richer data ecosystem. For example, this scarcity of (floating) bicycle data often results in traffic signal configurations that are designed with a bias toward improving car traffic flows, while overlooking the needs of cyclists and other non-motorised vulnerable road users.

3.4 Opportunities

When asked if they saw any potential solutions to the challenges that they discussed, the interviewees offered a varied set of suggestions. These are listed here and summarized

in Table 6. It is interesting to note that, while the lack of standards was not high on the list of challenges, as was highlighted in section 3.3.1, standardisation is the most mentioned potential solution.

Table 6 - Potential opportunities identified by the stakeholders

Opportunity category	Relative coverage
Standardisation	High
Enhanced collaboration	Medium
Training and research	Medium
Centralised storage and access	Low
Legal frameworks	Low
Role for intermediaries	Low

- **Standardisation:** A large fraction of the respondents pointed at standardisation as a key catalyst to enable further development of the FBD ecosystem. It ensures that data suppliers will not have to develop converters for different formats used in different countries or by different data consumers. They specified that a number of support mechanisms should be set up to aid the stakeholders in implementing and adhering to these nascent standards, such as technical assistance, validation labs and a support desk. One interviewee put forward that data standardisation should happen at the lowest (raw) level, and that there is, according to them, no merit in standardisation at higher aggregation levels.
- **Enhanced collaboration:** Collaboration between the stakeholders is also emphasised as an important component. The consensus amongst the respondents is that organisations must converge and dismantle data silos as much as possible, to foster an ecosystem that is conducive to data sharing. The Dutch Metropolitan Innovations[4] (DMI) ecosystem was mentioned by some as a blueprint worth iterating upon. One interviewee also put forward that collaboration between stakeholders could also enable potential new business models, for example a smart sensor attached to a bike sharing fleet could enable improved insights for the cities and give them a competitive advantage over other bike sharing providers in a tender. Another interviewee felt that the main solution lays in open sharing of the data.
- **Training and research:** The respondents identified a need for improved proficiency in the utilisation and tooling for handling FBD. Tools that facilitate more straightforward publishing of data in the appropriate formats are seen as a significant asset that could be developed. One respondent also suggested to establish dedicated data teams within municipalities as a way to ensure

[4] DMI Ecosystem

sustained expertise and continuity in data management, particularly for complex data sources such as floating bicycle data.

- **Centralised storage and access:** Two respondents proposed the concept of a structured repository for raw floating bicycle data, to support research activities such as scenario modelling. This centralized approach could streamline access to valuable data. However, there is a contention that the utility of such a repository may be limited, as cycling data from one municipality may not be directly applicable or useful to another due to distinct urban layouts and cycling patterns, and the short duration of a typical cycling trip, leading to a limited number of cycling trips between different urban areas.
- **Legal frameworks:** Some interviewees suggested to work towards some sort of standardised contracts for the sharing of floating bicycle data with public authorities for certain use cases, as this would reduce the need for lengthy peer-to-peer discussions between the organisations' legal departments each time a data sharing agreement is drafted. One respondent commended the European Union for the work it is doing on building legal frameworks, and they highly anticipate further developments from that effort.
- **Role for intermediaries:** Other respondents look towards potential intermediaries, companies with high amounts of expertise in collecting, processing, and sharing of mobility data, to help other parties, both in the public and private sector, with their digitalisation efforts and with improved access to useful data-driven insights in general, and insights based on floating bicycle data in particular.

3.5 Standardisation

When asked explicitly whether standardisation could be a potential solution for the challenges that they face, the interviewees' answers were divided. We see that the stakeholders' position in the wider floating bicycle data ecosystem determines their opinion on the value of standardisation: the closer they are to pure data provisioning, the more sceptical, while professionals closer to the insight side see more merit. Table 7 gives an overview of the opinions divided by the five stakeholder groups.

Table 7 - Opinions of the stakeholder groups on the standardisation of FBD

Stakeholder group	Interest in standardisation
Seekers	High
Standardisation bodies	High
All-rounders	Medium
Intermediaries	Medium
Hidden gems	Low

The *hidden gems* are the most sceptical towards standardisation. They see the most hurdles and do not believe that standardisation will solve the challenges they are currently facing (see section 3.3.1 above). The *intermediaries* and *all-rounders* show mixed feelings. They see merit in standardisation and most believe that standardisation could be a solution, but they are unsure about the potential conversion costs involved, and whether standards will be applicable to all levels of aggregation and use cases. *Seekers*, on the other hand, are the most in favour of standardisation. They consider it to be the main solution for all their FBD-related challenges. Perhaps unsurprisingly, the interviewed standardisation bodies also show a strong preference towards the creation of a specification for floating bicycle data.

Those critical about the prospect of standardisation pointed out that they feel that standardisation can only be useful at the level of individual GNSS traces, while others noted that the accuracy of the data and privacy issues are the biggest blockers, and that a standard will not solve either of these, or that the cost to implement standards could be prohibitive for smaller data providers, leading to unwanted competitive advantages for the bigger players. Another hindrance that was mentioned is the *Not invented here* (NIH) syndrome, highlighting that it is already hard to standardise within a single country, and that it will be even harder at an EU level.

Those optimistic about the prospect of standardisation generally noted that it would be useful to have standardised data collection practices, standardised vocabularies (e.g. what is meant by *dwell time*?) and standardised use cases. They also brought up that standardisation is a proven solution for these kinds of challenges, which also existed in the early days of FCD, before it was standardised. One respondent mentioned that any standardisation should come with a dynamic ecosystem of experts that build the bridge between the providers and the seekers, as a sort of intermediary service providers.

Further in this chapter, section 3.5.1 describes the proposed requirements for a future standard for floating bicycle data, while section 3.5.2 gives an overview of other standardisation efforts in the wider mobility sector that might serve as good inspiration. Finally, section 3.5.3 lists stakeholders that the interviewees deem important to involve in the standard setting process.

3.5.1 Requirements

Four main sets of requirements were mentioned by the interviewees. The most important requirement for a new FBD standard is that all stakeholders must be able to easily implement it. These requirements are enumerated below.

- **Keep it simple:** It is deemed very important that any standard remains simple. There is no need to standardise *everything*, as this makes the implementation needlessly hard and makes the transformation from their current state of practice to the use of standards very costly for all the involved stakeholders. Furthermore, a simple base standard makes it easier to iteratively improve it. It is important to

aim for the quick wins and not to get bogged down in long discussions on details early on.

- **Governance body & ecosystem engagement:** A fair number of respondents see a need for a good governance body to ensure the long-term sustainability of the standard. They also stress the need for co-creation by all involved stakeholders for the development of the standard. The governance should also keep in mind the desires of both the producers and consumers and could involve also intermediary service providers to bridge the gap between the insight needs and the available data.
- **Compliance:** The respondents indicated that compliance with existing legal frameworks, directives, and delegated regulations from the European Union (EU) is necessary. The EU Data Act is seen as an important starting point for the definition of use cases and the optimal aggregation level of floating bicycle data that ensures sufficient privacy while also delivering adequate value for insight seekers.
- **Technical requirements:** A minimum sampling rate was identified as a key technical requirement for a successful FBD standard. If the measurement frequency is too low, several use cases are no longer possible, and the data may even not be considered floating anymore.

3.5.2 Sources of inspiration

Table 8 below lists several other standards and application domains that the interviewees feel should serve to inspire the floating bicycle data ecosystem in their future standardisation efforts.

Table 8 - Inspiration for standardisation

Category	Examples
Automotive	DATEX II
Bicycle sharing	GBFS, MDS
Public transportation	NeTEx, SIRI
Vehicle-to-infrastructure	TPEG, Sensoris
Research toolset	Bike PRINT

Although it was indicated by the respondents that the automotive ecosystem significantly differs from the cycling ecosystem, automotive standards are often mentioned as possible sources of inspiration. One respondent would ideally see the same standards adopted for FBD as those that are in use in the FCD ecosystem. DATEX II[5] was mentioned by two interviewees.

[5] DATEX II

Some interviewees pointed at the bicycle sharing world for inspiration, as the General Bikeshare Feed Specification[6] (GBFS) and Mobility Data Specification[7] (MDS) have been quite successful there. The open governance model of these standards was specifically highlighted as inspirational.

Network Timetable Exchange[8] (NeTEx) and the Service Interface for Real Time Information[9] (SIRI), two European standards for the public transport sector, as subsets of the European Committee of Transportation (CEN) Transmodel[10], were also highlighted by the respondents.

Finally Bike PRINT[11], as an innovative toolset that can form the link between research and cycling policy was mentioned by one respondent, as were the Transport Protocol Experts Group (TPEG)[12] suite of protocols and Sensoris[13] as interesting examples from the Vehicle-to-Infrastructure (V2I) world.

3.5.3 Stakeholders

When asked which stakeholders should be involved in the further development of a specification for floating bicycle data, the interviewees pointed towards a broad coalition of actors. This would include government agencies, the bicycle industry in the broadest sense, representatives from cycling app developers, citizens, European and national organisations, research organisations, and ITS professionals. Table 9 gives an overview of the identified important stakeholder groups.

Table 9 - Proposed stakeholders to involve in further standardisation efforts

Stakeholder group	Example organisations[14]	Relative coverage
European organisations	EC, NAPCORE, EIT Urban Mobility	High
Bicycle industry	CIE, bicycle manufacturers, motor manufacturers	High
Mobile application developers	Strava, GeoVelo, Komoot, …	Medium
National organisations	National Access Points (NDW)	Medium
Standardisation bodies	CEN, MobilityData, OpenMobilityFoundation	Medium

[6] GBFS: General Bikeshare Feed Specification
[7] MDS: Mobility Data Specification
[8] NeTEx: Network Timetable Exchange
[9] SIRI: Service Interface for Real Time Information
[10] Transmodel: CEN Reference Data Model for Public Transport
[11] Bike PRINT: Policy Renewal and Innovation by means of Tracking technology
[12] TPEG: Transport Protocol Experts Group
[13] SENSORIS: Sensor Interface Specification
[14] The examples of organisations provided are neither comprehensive nor presented in a specific ordering, and they do not serve to restrict the scope of potential individual entities that should be considered.

Shared bicycle providers	Dott, DonkeyRepublic, Blue-bike, Shared mobility Italy, …	Medium
Citizens	Citizen scientists, cyclists	Low
Other bicycle data providers	Ecocounter, cell phone data providers, …	Low
Public authorities	Leading cities and regional governments, road authorities	Low
Other potential stakeholders	Research institutes, the automotive industry, the bicycle logistics industry	Low

European organizations were suggested most often, with entities such as the European Commission (represented by DG MOVE and DG CNECT), NAPCORE, and EIT Urban Mobility were collectively acknowledged by respondents seven times. Second is the bicycle industry itself, where CIE (Cycling Industries Europe), various bicycle, and motor manufacturers were mentioned as potential key partners.

Mobile application developers like Strava, GeoVelo, and Komoot, along with national organizations including NAPs such as the Nationaal Dataportaal Wegverkeer (NDW), each received several mentions. Standardisation bodies such as the Comité Européen de Normalisation (CEN), MobilityData, and the OpenMobilityFoundation, were also mentioned several times, as they can share their knowhow and best practices.

These stakeholders can provide a foundation upon which specifications for floating bicycle data can be built. Nonetheless, it is also important to involve the seekers of insights in this process, such as public authorities, citizens, and research institutes to ensure that the standardised data feed serves the diverse needs of the cycling community and aligns with their requirements.

4 Recommendations and next steps

Building on the comprehensive analysis of responses collected from the interviewees, several recommendations have been formulated to guide the direction of future initiatives. These suggestions are aimed at addressing the key issues and opportunities identified during the interviews, with the intent to further the development of a healthy floating bicycle data ecosystem. These recommendations are detailed below.

- **Bridge the gap**: Address the disconnect between the different aggregation levels by engaging stakeholders across the spectrum to identify their specific needs and concerns, and tailor solutions accordingly. Future FBD standardisation efforts should clearly indicate which definition of FBD is used, as this will determine which stakeholders will be most affected.
- **Prepare a use case portfolio**: One way to bridge the aforementioned gap is to develop a well-defined set of use case descriptions, along with the floating bicycle data requirements that are necessary to successfully implement these use cases and also example implementations from across Europe. This encyclopaedia of FBD use cases can be used by insight seekers as a basis from which to write tender documents, and by providers as a way to refine their data product offerings.
- **Understand stakeholder perspectives**: Recognize that a stakeholder's position within the ecosystem shapes their willingness to share FBD, the challenges they face, and their view on potential standardisation. Invest in dissemination on the benefits of standardisation for the different stakeholder groups, but especially for the ones on the providing side of the FBD ecosystem.
- **Address disadvantaged stakeholders**: Support the most disadvantaged stakeholder groups, i.e., insight seekers, who lack offerings and clarity on use cases, and FBD suppliers, who lack clear business models. Provide resources, training, and guidance to help these groups overcome their challenges, for example to connect them with potential intermediaries who can help them.
- **Develop a simple, inclusive standard**: Adhere to the KISS principle (Keep It Simple, Stupid) for creating a standard that is open, collaborative, and accommodates the compliance and privacy concerns that currently exist. Involve a diverse range of stakeholders, including standardisation bodies, insight seekers, data providers, research institutes, and intermediaries in the standard's creation. Align this standard with the NAPCORE workgroup on Cycling and consider developing feed validators to simplify compliance testing.
- **Learn from FCD**: Recognize that FBD is significantly different from floating car data but draw on lessons learned from the car industry in the standardisation process. This can help streamline efforts and avoid pitfalls encountered in other mobility sectors.
- **Beyond standards**: Acknowledge that while standardisation is essential, challenges remain in business modelling and privacy aspects of FBD. Develop strategies to address these issues in tandem with the standardisation efforts, ensuring sustainable business models and privacy protections are integral to the ecosystem.

5 Annexes

5.1 Topic guide

1. INTRO – 10min
Introductory Text: I'm Casper Van Gheluwe, a solution architect and mobility researcher at imec, a research institute that focuses on chip- and nanotechnology, but also on innovations in AI and data technology for several application domains, including mobility and automotive technology.

We are one of the partners of the Interreg North Sea Region project "MegaBITS" that aims to implement cycling ITS technologies in five flagship regions around Europe (Copenhagen, Hamburg, Seine-Metropole, province of Overijssel, province of Antwerp). Currently, we are conducting an exploration study on floating bicycle data (FBD) as part of this project.

Thank you for agreeing to participate in this interview. Your insights and experiences are incredibly valuable to us. The purpose of today's discussion is to gather in-depth information on floating bike data, specifically on the interoperability aspects. We are interested in understanding current practices, challenges, and potential opportunities for innovation on this topic. We will use your feedback to map out the current challenges and opportunities of the interoperability of floating bike data and look towards building a standardized data model for sharing this data. This effort happens in close collaboration with NAPCORE, the European organization that coordinates and harmonizes the National Access Points for mobility data. We will never disclose your personal data. The results may also be shared with other relevant stakeholders such as NDW (Netherlands), Fietsberaad (Flanders), ...

Structure of the Interview:

- **Current practices:** Exploring how floating bike data is currently being utilized, collected, shared, and managed.
- **Challenges and needs:** Identifying and understanding the challenges, limitations, and needs in the current use and management of floating bike data.
- **Opportunities / solution concept:** Discussing potential solutions and opportunities for improvement in the interoperability of floating bike data.
- **Innovation confrontation:** Inspiration from other standardization efforts in the mobility ecosystem.
- **Wrap up:** AOB.

Check if informed consent is signed. If approved, start the recording.

Questions:

- Could you please start by introducing yourself (i.e. role in organization, expertise in bike data or standardization, ...)
- Can you briefly describe your organization's involvement with floating bike data, and your role within these projects?

2.1 CURRENT PRACTICES – 10min
Focus Area: Exploring how floating bike data is currently being utilized, collected, shared, and managed.

Questions:

- What is, according to you(r organization), the **definition** of floating bike data?
    - Origin/destination matrices to/from zones for bicycle use based on traces.
    - Speed/volume of cyclists per road segment.
    - Raw GNSS traces of cyclists.

    - Extra properties (i.e. comfort, experienced safety, type of travel) of cyclists per road segment, or others.
- What is the typical **aggregation** level of floating bike data that you work with? (speed maps, volumes per segment, raw GNSS traces, etc.)
- What are the data **sources** for your floating bike data and how were they collected (if relevant)?
- What kinds of **processing**/aggregation/analysis do you perform yourself on this FBD?
- How do you ensure or check the **quality** and accuracy of the floating bike data in your data processing pipeline?
    - How do you measure and reach the desired level of **representativity** (i.e. sample size of number of tracked/included cyclists vs. the actual population)
- How do you currently **share** floating bike data with other organizations?
    - What kinds of floating bike data is that? (i.e. O/D, volumes per segment, speed/volume maps, full GPS traces, speeds per segment, travel times to/from zones, ...)
    - Are there any specific formats or methods that you are using for this?
    - Can you perhaps share a sample of this data after the interview?

2.2 CHALLENGES AND NEEDS - 10min
Focus Area: Identifying and understanding the challenges, limitations, and needs in the current use and management of floating bike data.

Questions:
- From your experience, what aspects of the interoperability of floating bike data currently **work well**? And why?
- From your experience, what are the most significant **challenges** you face in the interoperability of floating bike data? And why?
    - *Explanation:* Are there specific needs or requirements in your field that are currently not being met by existing floating bike data sharing solutions?
    - How would you **prioritize** these issues?
- Which **stakeholders** are typically involved or disadvantaged because of the challenges that you have just identified? (i.e. city planners, bike-sharing companies, study agencies, DPOs, ...)

2.3 OPPORTUNITIES / SOLUTION CONCEPT – 10min
Focus Area: Discussing potential solutions and opportunities for improvement in the interoperability of floating bike data.

Questions:
- Based on the challenges you've identified, what would an ideal **solution** or improvement look like, in a perfect world?
    - ~~(If no clear answer) would you be willing to compare multiple versions of a potential FBD standard to see which one fits your use cases/needs/expectations most?~~
- Are there any **emerging technologies** or methodologies that you believe could revolutionize the interoperability of floating bike data in the next 3-5 years?
- In your opinion, who are the key **stakeholders** that should be involved in developing and implementing solutions for the interoperability of floating bike data?

2.4 INNOVATION CONFRONTATION – 10min
Focus Area: Presenting a hypothetical solution or innovation to gather feedback and insights.

Questions:
- How do you think that **standardization** of floating bike data could address the challenges you have mentioned earlier?
- Are there any specific **requirements** that this standard must comply to?
    - Any specific properties that *must* be present in your view? (i.e. volumes, average speed, max speed, travel times, ...)

- Do you see yourself or your organization **using** this type of solution, and under which conditions?
- Do you think there are any **existing other standards** in the mobility domain that we should look towards for inspiration? (DATEX-II FCD, MDS, TOMP, GTFS, NeTEx, …)
    - Does a pan-European standard with profiles per member state (~ NeTEx) make sense to you for this case, or rather a single strong standard?
- In your opinion, who are the key **stakeholders** or organizations that should be involved in developing such a standard for floating bike data?

3. WRAP UP – 5min
Focus Area: Concluding the interview with an opportunity for additional insights and summarizing key takeaways.
Questions:

- Is there any aspect of floating bike data interoperability that we haven't discussed that you think is crucial for our understanding?
- What is the most important take-away we should remember from this interview?
- Do you want to add anything to this interview? Remarks, feedback, suggestions?

That's all. Thank you very much for all your effort and time!

5.2 Informed consent form

Interviewee consent form

Thank you for participating in the interview we conduct as part of the Interreg North Sea Region initiative: **MegaBITS** (Mobilizing Europe's Green Ambitions through Bicycles and Intelligent Transport Systems). Together with our partners (See Annex 1) we work in close collaboration to create a data space for bicycle ITS data based on the input from stakeholders and potential interested parties. As part of this project, we are also looking at the current state of Floating Bicycle Data (FBD) in the wider ecosystem and inventorying the opportunities for possible standardization of how this FBD can be shared between parties.

Data collection and purposes
For the study, we interview different experts. To be able to organize these interviews we will collect and process your name, email address and company. The interview results will be used:

- to generate a report for the project MegaBITS,
- to form an overview of the current state of the art and state of practice of Floating Bicycle Data in academia, government agencies, non-governmental organizations, and private companies.
- for research about data and publications including presentations at conferences,
- to inspire further work on Floating Bicycle Data standardization.

The report will be published on the MegaBITS website and will be shared with project stakeholders. Individual contributions of interview subjects will be anonymized. Optional recordings of the interviews will never be shared and are only used to aid with the initial analysis to supplement the notes that we take.

Responsibility and control
The MegaBITS partners (See Annex 1) are jointly responsible for this processing activity. All questions related to this activity or to the project can be directed either to the coordinator of the initiative, the Dutch province of Overijssel (to be found though the MegaBITS website) or to your first point of contact (below).

Access, rectification, and erasure
You have the right to access your data, rectify them, or have them erased. If you wish to do so, please contact your first point of contact (below).

Duration of the data collection
The information collected during this study will be kept for no longer than the duration of the project which ends on March 31st, 2026. Interview recordings will be kept no longer than strictly necessary to supplement our notes, and in any case no later than April 30th, 2024.

Any other questions, remarks, or complaints
I am your first point of contact (casper.vangheluwe@imec.be). If you wish to file a complaint about how we handle your data, you can contact the imec Privacy Office at: *imec vzw, Kapeldreef 75, 3001 Leuven,* privacy@imec.be or the Belgian Data Protection Authority at: Gegevensbeschermingsautoriteit *(GBA), Drukpersstraat 35, 1000 Brussel, +32 2 274 48 00,* contact@apd-gba.be.

☐ I agree to take part in the interview.

☐ *(Optional)* I agree that my interview is recorded to supplement the notes taken.

☐ I agree to the use of my anonymized contributions for a public report of the MegaBITS project.

Signed by (name) on (date)