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Contents

Summary

We are witnessing rapid changes in the transport landscape that have resulted in a gap between the quality of data available and what is needed from stakeholders. Therefore, this pre-study aims to increase the knowledge about bicycle flow by, together with stakeholders and the industry, identify and define: (i) data needs for better planning; (ii) data collection activities; and (iii) research and cooperation possibilities. To answer these questions a series of digital interviews and e-mail questionnaires were conducted with relevant stakeholders and industry actors.

The results show that to better plan for bicycling, stakeholders need more detailed bicycling data, meaning that they need to know the type of bicycle, bicyclists' socio-demographics, and route choice. Ideally, stakeholders need to know how the bicycling flow/exposure is changing over time, which means they need to follow the percentage share of each type of bicycle (e.g., e-scooters, e-bikes, cargo-bikes), the percentage share of different bicyclists' groups (e.g., age, gender), and which links/streets are used the most.

The bicycle flow-counting industry is trying to cope with and adapt to the rapid changes in the transport landscape and can today mainly classify e-scooters with 3D cameras, with a good degree of accuracy. Other types of bicycles are more challenging to classify, as many different branches exists, and new models are being introduced almost every year. Bicyclists' socio-demographics variables are disregarded, with GDPR as a great concern or barrier to deal with. The car industry, however, focuses on detecting bicyclists in time at crosswalks/crossings and on right-turn maneuvers, with challenges in detecting bicyclists at adverse weather conditions, e.g., darkness, twilight. Furthermore, there is also a need to vary approaching angles and detection distances, when bicyclists interact with vehicles, so the car industry can train its detection algorithms in a range of real-life scenarios.

We see a need for stakeholders (e.g., road administration, municipalities) and the bicycle flow-counting industry to establish a closer dialog to drive the technological developments in the right direction. For example, a data priority list from stakeholders may guide and incentivize the industry to develop new products or services, that are urgently needed by the market.

TITLE

Open data for Bicycle Classification for better planning and simulation, and for better Detection from motorized vehicles (OpenBike-CD)

1. Background

Gonzalez et al., (2019) found that CO_2 emissions of passenger cars in EU-13 countries (including Sweden) were increasing in the last decades (1990-2015), being on average 20%. The IPCC report (Masson-Delmotte et al., 2021) shows that human action is urgently needed to reduce greenhouse gas (GHG) concentrations, especially CO_2 emissions which have reached annual averages of 410 ppm. Attracting more users to bicycling is thus an important goal at the national and local governmental levels to achieve the goals of Agenda 2030[1], which is a worldwide effort of coordinated activities to ensure sustained social, economic, and environmental gains. Furthermore, increasing the bicycling modal share is important, not only to reduce CO_2 emission, but it does also have positive effects on health and physical conditions, as it is an active mode of transport (Sundfør et al., 2020). Therefore, planning to increase the bicycle modal share has multi-dimensional benefits for the environment, health, economy, and society as a whole. Planning for bicycling-friendly cities, new bicycling infrastructure, improved maintenance at bicyclist paths are key actions to attract more users to bicycling. To be able to measure the impact of such interventions and adapt/adjust planning processes, it is important to follow-up the development over time of the bicycling flow/exposure over the entire bicycling network, which must be done with a common and standardized method (Niska et al., 2010; Niska et al., 2012; Eriksson et al., 2019).

This project was initiated due to that today's micro-mobility has changed the transport landscape with new type of vehicles such as electric scooters (private or shared e-scooters), electric standing boards (e-skateboards), inline skates, hoverboards, electric unicycles, segways and electric wheelchairs, which means that traditional bicycle flow measurements cannot interpret the bicycle flow correctly. This implies that local and regional authorities lack a trustworthy dataset, which may result in an inaccurate bicycling planning and eventually lead to an increase in the accident risk (e.g., due to poor maintenance, insufficient bicycle infrastructure, etc.) and lowering the percentage share of bicycle usage (e.g., due to poor planning).

We are witnessing rapid changes in the transport landscape (micro-mobility, automation, connectivity, shared mobility), that have resulted in a gap among the quality of data available and what is needed from stakeholders. While the industry focuses on new products and services to provide more data, with the help of technology (e.g., WiFi, Bluetooth, digital cameras), and new methods such as machine learning (ML) and artificial intelligence (AI); stakeholders, in need of better data, lack the possibility to validate counting or classification

[1] https://unsdg.un.org/2030-agenda

results. (See for instance Nordin (2022), for a review of available bicycle data). Stakeholders need these quality-assured fine-grained data to plan for (i) new design standards (e.g., cycle lane widths and bicycle/e-scooter crossings), (ii) plan for bicyclists' route choices (commuter bicyclists, parking, bicycle garage), (iii) plan for bicyclists' school children and the elderly. To bridge this gap, national research institutions, such as VTI and TØI, can focus on validation procedures and certification criteria to warrant those standards are met, taking a more pro-active role facilitating and accelerating the availability of quality-assured bicycle data that the industry and stakeholders can freely use and benefit from.

2. Project set up

2.1 Purpose

This study aims to increase knowledge about bicycle flow by and, together with data detection and bicycle/vehicle industry, by investigating the status of data and to what extent existing data can be used for training algorithms (AI / ML) to distinguish (i) who is bicycling (e.g., gender, age), (ii) different type of bicycles (such as standard, electric, e-scooters, tricycles), (iii) route choice, and (iv) bicyclists' detection by motorized vehicles (e.g., right-turn maneuvers), and to identify future needs of more detailed data to be able to distinguish (i)-(iv) in the data.

2.2 Objectives

Specifically, the pre-study focuses on:

1. Well-defined data needs defined by the stakeholders, which will be the basis for industrial development of more accurate algorithms and better classification and detection.
2. Well-defined *'raw data'* that are required from the industry (i.e., bicycle and car), to be able to train and test ML algorithms, prototype and develop their equipment to the required data needs, see point 1.
3. Describe how a larger project can be set up to address the future research needs addressed in the pre-study by:
   a. Describing a test-site for evaluation of different data sources.
   b. Describing the training/test data needed to be collected on the test sites by organizing an event with volunteers.
4. Describe research opportunities based on the data that will be collected and other bicycling data, being stored in an open database/data stock exchange.
5. Describe how cooperation is possible, among Nordic countries (e.g., NorBIKE).

2.3 Project period

Three months (pre-study)

2.4 Partners

Viscando
Trafikia
RoadInfo
Scania
Volvo
TØI
SVV

3 Method and activities

Stakeholders and industry were first contacted by email and after a positive response, a discussion meeting was established to engage the actors. During the meetings a set of defined questions were asked to meet our objectives. The types of contacted actors are listed below:

- Digital meetings with national stakeholders (e.g., authorities, academia)
- Digital meetings/questionnaires with industry
- Digital meetings with NGO's

An excerpt of the questions during the meeting are presented below.

1. What raw data do you need for e.g., bicycle counting, bicycle behavior, bicycle simulation?
2. Case studies that you have or possible case studies within 3-5 years?
3. What cycle data is needed now in your case studies?
4. Which format is preferred?
5. Where can data be stored?
6. Which analyzes are desired to be performed?

See Appendix 1 and Appendix 2 for a list of organizations contacted during the project.

4 Results and Deliverables

Well-defined data needs of stakeholders which will be the basis for industrial development of more accurate algorithms and better measuring equipment.

Bicyclists are a heterogeneous group with different needs and interests and men and women have different travel patterns (Uteng et al., 2019). Therefore, regional and local authorities need fine-grained bicycle data for better planning to meet the needs of a variety of users (Henriksson, Wallsten, Ihlström, 2022). Age and gender are important sociodemographic characteristics to better plan for bicyclists, according to the interviews with municipalities and NGO's. As mentioned above, bicyclists are a heterogeneous group, which makes municipalities in the need of tailored-specific planning to meet the specific requirements of different bicyclists' groups. For example, to increase the share of children bicycling to school, municipalities may need accurate counting data of the number of children bicycling to school, so they can design school campaigns.

There is also a need from authorities to re-define what a bicycle is nowadays. Bicycling is an 'active' mode of transport, where the human body applies energy to reach and sustain a desired speed. The introduction of electrical bicycles (e-bikes) reduces partially the energy required by the rider to reach and sustain a desired speed, but e-bikes provides for faster speed, longer trips, and more trips (Fhyri and Fearnley, 2015; Cherry and Fishman, 2021). However, in recent years a 'passive' mode of mobility is changing the transport landscape. Namely, the number of electrical scooters (e-scooters) has been drastically increasing and is becoming, in some streets/links, the predominant mode of transportation. Authorities are, therefore, in need of classifying this 'new' vehicle type and characterize who these group of users are, e.g., young, students, speed, modal shift. The same applies for other bicycle types such as e-bikes, unicycles, etc.

For authorities it is crucial to follow-up the changes in the bicycling share (modal shift) to be able to fine-tune/adjust/introduce proper and timely measures to increase the bicycling share towards the goals of the Agenda 2030. It is crucial to know what kind of trips e-scooters are replacing. For example, whether e-scooters are replacing an active mode of transport, bus trips or car trips. It would be detrimental to physical condition and health, for example, if e-scooters are replacing bicycle trips or walking. Whereas, it can be seen as 'good', if car trips are replaced by e-scooters. The ultimate question is what kind of city we are planning for. Is it a car-oriented city? or is it a bicycling-friendly city? According to the interviewed stakeholders, current bicycling planning practices are mostly short-term planning, and they see a need for a more comprehensive and coherent long-term planning for bicycling, as for example, to plan for bicycle-only cities or at least for bicycle-only city centers. There is also a need from stakeholders to re-define bicycling performance indices, e.g., safety, accessibility, livability.

One of the important pillars of democracy is privacy, meaning that citizens have the right to decide whether their activities can be tracked by sensors (e.g., digital cameras, internet cookies) and be stored and processed for surveillance or commercial purposes. The General

Data Protection Regulation[2] (GDPR) is the legal framework that protect citizens against tracking or surveillance misuse by companies or governmental agencies. Therefore, collecting public data that can lead to the identification of citizens' age and gender needs the citizens' consent in advance to carry out such activities. These privacy requirements can be resolved by edge computing, which allows the use of sensitive data in alignment with GDPR requirements. In other words, sensitive data are processed at the camera level and only aggregated data is transmitted for further processing. Ideally, stakeholders would like to have at least age groups (e.g., children, young, elderly) as well as the gender classification of the bicyclist. However, as mentioned above, these attributes are subject to a great concern about misuse or reckless practices, thus being very difficult to collect.

Table 1 shows the attributes mentioned by stakeholder for better bicycling planning.

Table 1. Data needs for better bicycling planning (bicycle, bicyclist, and safety attributes).

Bicycle attributes	***Bicyclist attributes***	***Safety attributes***
Standard bicycles	Children	Helmet usage
e-bikes	Young	lighting
e-scooters	65+	Route choice
Cargo e-bikes	Gender	Rental bikes
Tricycles	pedestrians	Active/passive mode
Km-travelled	moped II	
Speed		
Travel direction		

Well-defined how 'raw data' should be for the industry (i.e., bicycle and car), to be able to train and test ML algorithms, prototype and develop their equipment to the required data needs, see point 1.

Bicycle flow-counting industry (BCI)

For machine learning (ML) algorithms to be accurate, they need to be generalizable, meaning that they have been trained on a large dataset containing most of the possible classification cases, in a balanced way (i.e., right percentages of the features). Otherwise, the ML algorithm is likely to learn from the data, meaning that it will only classify cases that the dataset contains. In general, the classification/counting industry needs correct/suitable annotated training data. Firstly, depending on the attribute being classified, it may need a very large training set if data are currently not available. Secondly, it needs variation in the training set, for example different types of bicyclist users, bicycles and lighting and weather conditions. For ML algorithms, the more variability in the training set, the better to avoid learning from the training set (biased on training set). Thirdly, depending on the

[2] https://gdpr.eu/

street/intersection configuration, the height and angle (position) of sensors need to be tested and fine-tuned for location-specific characteristics. Therefore, the process of obtaining correct/suitable training data needs a thoroughly planning and it is likely a learning-by-doing process.

Gathering correct/suitable training data needs to overcome privacy concerns, especially the gender and age categories, as explained before. Edge computing is being used to resolve GDPR issues when it comes to 3D cameras, thus only anonymized aggregated data are transmitted for further processing.

Some bicycle characteristics may need continuous training data. For example, the classification of e-bikes can be challenging due to different models and new models coming every year, which may impose a great burden in collecting correct/suitable training sets. Therefore, it is important to also investigate other attributes/features which can be combined/supplemented to successfully carry out the classification task. For instance, the speed of the bicycle can be interesting to look at to differentiate e-bikes, as they are faster on average than standard bicycles (Fishman and Cherry, 2016). Furthermore, other bicycle characteristics, such as helmet usage and bicycle lighting usage are important safety aspects to look at and technically feasible to classify and count. For example, if the percentage of helmet usage is low, municipalities may introduce a public campaign explaining the benefits of wearing a helmet.

For BCI, it is very important to find a business model to further develop products and services, since developing a data eco-system is expensive. Otherwise, there is no incentives for further developments. One obstacle here is that the BCI does not normally talk with municipalities about their data needs for better bicycling planning. This creates a chicken-egg problem between the BCI industry and municipalities. One solution is that municipalities make publicly available a *priority list* of what data they are willing to pay for, so industry can develop their product/services in the right direction.

Certification is an important step for municipalities as it gives the assurance that the bicycle counting meets at least a certain level of accuracy (minimum level 90%, in some internal documents). If certification is not in place, municipalities are left alone to trust whatever data are delivered. Nordic collaboration can ease the certification process, meaning that a certified company in Norway, can automatically be certified in Sweden or vice versa.

Table 2 shows the attributes the BCI is classifying or can classify for better bicycle planning.

Table 2. Bicycle attributes that the BCI can collect.

features	Status	Obstacles	Comments
e-scooter	in progress	3D cameras	
e-bike	Challenging	suitable data	speed
Cargo e-bike	not tested	suitable data	
gender	not tested	suitable data	GDPR
age	not tested	suitable data	GDPR
helmet	not tested	suitable data	
lighting	not tested	suitable data	

Car industry (CI)

Most bicyclists are killed while interacting with motorized vehicles at intersections (Kullgren et al., 2019, Ekström and Linder, 2017). For motorized vehicles, the most crucial aspect is the timely detection of conflicting bicyclists. Thus, autonomous, or manually driven vehicles can react accordingly, either yielding, slowing down, or applying emergency braking. Two distinct categories arise, namely, person cars and heavy vehicles.

For heavy vehicles, especially trucks, the most critical scenario is a right-turning maneuver with a bicyclist approaching from behind of the truck. Here it is important to warn the driver of the approaching bicyclist, by means of cameras or lidar. Different angles and distances need to be tested, which highlights the need of a data collection endeavor.

For passenger cars, the detection of crossing bicyclists is a serious concern, especially in darkness. The critical scenario is to test a range of angles and distances from the approaching bicyclists. For example, due to the intersection configuration, the detection angle can change, especially for detection of bicyclists at 10 m or 20 m from the conflict point. Conflicting events occurring under 300 ms are the most important to detect and react on.

In general, challenging conditions for sensors to detect bicyclists are darkness, twilight conditions, heavy rain, and blinding sunlight (Kullgren et al., 2019). Other important aspects to consider are a relevant speed for the approaching bicyclists (i.e., actual speeds of real-life interactions) and bicyclists approaching in platoons.

Table 3 exhibits the scenarios and challenges the CI are facing on collecting data on conflicting bicyclists.

Table 3. Scenarios and challenges of CI industry.

Vehicle type	Interaction	Solutions	Obstacles	Areas	Test for
Heavy vehicle	Right-turn	Mobile apps	Darkness	Urban	Angles Distances
Passenger car	Crossing	AEB	Darkness Twilight Heavy rain Blinding light	Urban	Angles Distances Relevant speed Platooning

Describe how a larger project can be set up to address the future research needs addressed in the pre-study

Description of a test-site for evaluation of different data sources and the training/test data that must be collected on the test-site by organizing an event with volunteers.

A bicyclist donate-data day (6-hours) will be planned in Oslo and Linköping in the spring 2023. VTI will arrange a bicycle test track (1 km - Motala / Mantorp), where different types of bicyclists and bicycle types will be ridden on varying bicycle route environments, such as traversing on bicycle paths and intersections. We aim for around 400 bicyclists to participate who will ride for 6 hours with different genders and age groups to bring in population variation in the trial. The data collection is expected to take place under different light conditions between 07.00 and 19.00 and, if possible, under varying weather conditions such as sunny, cloudy, and rainy day. Below is a list of the possible bicyclists and type of bicycles to start from:

• 100 regular bikes

• 100 electric scooters (e-scooter)

• 100 electric bicycles

• 50 race bikes

• 50 box bikes / cargo bikes

In addition to the bicycle vehicle type, the following distributions will be included in the trial:

• Gender distribution, i.e., 50% women, 50% men

• Balanced age distribution (<18, <65, 65+)

• Helmet use / no helmet

• Bicycle lighting / no lighting

The bicycle test track will be equipped with a number of sensors such as high-resolution traffic cameras (computer vision) that record in grayscale for higher light sensitivity and infrared sensors along the track for data collection. Different camera layouts will be tested such as camera angles and camera height which can result in the highest accuracy classification, i.e., the highest proportion of correct classification.

Describe research opportunities based on the data that will be collected and other bicycling data, being stored in an open database/data stock exchange.

It is likely that the data collected by proprietary sensors will not be shared among companies, as each participating company will develop its own product/service. However, companies are likely to share aggregated data (anonymized) to research institutions (e.g., VTI, TOI), given that data sharing agreements are in place. i.e., that the available data will not be shared further and that specific research purposes are agreed upon. Some research directions are described below:

Data fusion from different data sources (e.g., cameras, radar sensors, lidars, pneumatic tubes, WiFi signals) to increase classification accuracy. The aim is to combine all kind of information available to produce the highest possible classification accuracy of factors such as, bicycle type. It is important that data exchange agreements are in place with the research institution, so companies are warranted that aggregated data are stored safely. Furthermore, data coming from different sources and companies, gives the opportunity to develop a dedicated data eco-system for bicycling. For example, other data sources (e.g., Strada, exposure data, bike rental) can add value through processing the data to derive further analytics and applications from the combined data. This step is key to really get all the benefits from the data.

Traffic conflict studies can be carried out from trajectory data. This is another promising research direction that can give insights on the interaction between bicyclists and motorized vehicles, specially at unsignalized crosswalks.

Standardization methods are important to establish. One example is to standardize how to annotate bicycles, so companies can apply the same method, which in turn facilitates data exchange protocols. In other words, standardization allows for the same methodology to be applied across platforms, which in turns allows for smoother data exchange among stakeholders. For example, the NorSIKT project (Vaa et al., 2012) aimed to standardize the classification methodology of motorized vehicles, from data coming from pneumatic tubes, within the Nordic countries.

Describe how cooperation is possible, among Nordic countries (e.g., NorBIKE).

For local, regional, and national governmental levels, bicycle data collection is important to follow-up its changes over time in the total transport modal share. Normally, this follow-up is done within each country. However, if the data being collected are stored in a common open platform/database, comparisons can be done across countries, regions, and municipalities more easily. This can open new possibilities for policy analysis and comparison among municipalities and countries and eventually speeding up the share of *best practices* across participating countries. Additionally, this open database can be seen as a hub/exchange platform of bicycling related data, such as accidents (Strada), exposure (bicycling flows/volumes), road/street category (NBDV).

Furthermore, pilots or data collection activities can be organized in different countries (e.g., Sweden, Norway) to populate the open database described above. A project currently running in Norway where CDI can cooperate is the project STOR.

Certification is another collaboration possibility. For example, if a company is certified by Norway to carry out bicycle counts, that certification would also be valid in Sweden or vice versa. Thus, it is important to have in place standardized methods of classification, as the NorSIKT project (Vaa et al., 2012), described before.

5 Conclusions, Lessons Learnt and Next Steps

To achieve the goals in Agenda 2030, there is a need for better bicycle data to follow-up transport modal choice changes and adjust policies accordingly. Bicycling long-term planning is needed to answer the question of what type of city we aim for. We also need a re-definition of what a bicycle is, as new micro mobility vehicles are changing the transport landscape (e-bikes, e-scooters, cargo e-bikes). Finally, we also need to know who is bicycling, as bicyclists are a heterogeneous group. However, there is a gap between what data are needed and the data being provided by the industry. To bridge this gap, an open and continuous dialog is needed, so municipalities can help industry develop their products/services in the right direction and vice versa.

It is common practice that industry will not share data among possible competition actors. Research institutions (e.g., VTI, TØI, AI Sweden) can play an important role acting as a hub to store collected data from different partners. This step is a key to create data eco-systems to really get the full benefits of the collected data. For example, data fusion and ML algorithms to increase classification accuracy can boost the benefits of the collected data.

Collaboration among the Nordic countries can really add value for such a platform. Policies can be compared across countries and municipalities, which can lead to faster propagation of best practices among Nordic countries.

6 Dissemination and Publications

Final report to SAFER.

7 Acknowledgement

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Appendix 1: Contacted stakeholders.

	Organization	Contacted	Interest
Government	TrV	digital	positive
	Falkenberg	email	positive
	SVV	digital	positive
Academia	TØI	digital	positive
	RISE	digital	positive
	AI Sweden	digital	positive
	SAFER	digital	positive
NGO	SCS	digital	positive

Appendix 2: Contacted industry actors.

	Company	Contacted	Engaged
counting	Trafikia	digital	Engaged
	RoadInfo	digital	Engaged
	Dynniq	email	no
	Bumbee Labs	email	pending
sensing	Univrses	digital	no
	UniqueSec	digital	no
	XenseVision	digital	no
	Viscando	digital	Engaged
	Technolution	digital	no
	Vivacity Labs	digital	no
rental	Clear Channel	email	no
Car	Scania	digital	Engaged
	Volvo	digital	Engaged
	Autoliv	email	no