Technical Specification

Transport and Main Roads Specifications
MRTS215 Active Transport Counter / Classifier (ATCC)

March 2025

Queensland Government

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1 Introduction

This Technical Specification applies to the design, supply, installation, testing and commissioning, performance, documentation, training, and maintenance requirements for temporary and permanent Active Transport Counters and Classifiers (ATCC). Manual counting is out of scope and not included in this Technical Specification.

An ATCC is an electronic device capable of automatically detecting, counting and/or classifying individual active transport events. The device shall provide detailed event-by-event detection report. An ATCC can be a dedicated device for counting a specific event type, namely, pedestrians, bicycles, or scooters, only, or it can be a device capable of counting and classifying detected events involving bicycles, scooters, pedestrians, and undetermined categories.

Data collected by an active transport counter shall reside locally within the device until it is interrogated to transfer data to a Transport and Main Roads database.

This Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications*, MRTS50 *Specific Quality System Requirements* and other Technical Specifications as appropriate.

This Technical Specification forms part of the Transport and Main Roads Specifications Manual.

2 Definitions of terms

The terms defined in MRTS01 *Introduction to Technical Specifications* and MRTS201 *General Equipment Requirements* apply to this Technical Specification. Additional terminology relevant to this Technical Specification is defined in Table 2 below.

Table 2 – Definitions of terms

Term	Definition
Active transport	Active transport is any mode of travel that relies on human powered mobility. In the context of this Technical Specification, it refers to movement activity undertaken on cycling track and footpath and includes passive modes such as electric scooters.
ATCC	Active Transport Counter / Classifier – A device or system used for counting and/or classifying non-motor vehicle traffic including bicycle, pedestrian, and scooter traffic.
FTP	File Transfer Protocol.
Headend	A centralised control unit where data generated by field equipment are gathered, processed, and packaged for distribution.
IPPs	Information Privacy Principles. Refer to the *Information Privacy Act 2009* for details.
Qualified Technical Person	As defined in Part 1 Section 7 of the *Electrical Safety Regulation 2013.*
ROAR	Road Operations Asset Register.
Separated path	An active transport path which is divided into separate sections, one of which is designated for the exclusive use of cyclists (including scooter riders) and the other for the exclusive use of pedestrians.

Term	Definition
Shared path	An active transport path where pedestrians, cyclists and scooters share the same path space.
Video Analytics (VA)	In the context of this document, VA refers to the automated analysis of video feeds using Computer Vision to classify transportation modes such as bicycles, pedestrians, scooters, and other objects of interest.

3 Referenced documents

The requirements of the referenced documents listed in Table 3 below apply to this Technical Specification. Where there are inconsistencies between this Technical Specification and the referenced documents, the requirements specified in this Technical Specification shall take precedence.

Table 3 – Referenced documents

Reference	Title
-	*Information Privacy Act 2009*
MRTS01	*Introduction to Technical Specifications*
MRTS50	*Specific Quality System Requirements*
MRTS201	*General Equipment Requirements*
MRTS226	*Telecommunications Field Cabinets*
MRTS263	*Standalone Solar (PV) Power Systems*
QTDF	*Queensland Traffic Data Format*
SD1916	*ITS – Axle based Vehicle Classifier Sensor Installation Details*
SD1928	*ITS – Bicycle counter*
SD1929	*ITS – Bicycle and pedestrian counter*
SD1930	*ITS – Video analytics active transport classifier*
TRUM Volume 4 Part 5	*Transport Road and Use Management* Manual (TRUM), Volume 4 Part 5: *Configuration and Placement of Traffic Sensors*
-	*Electrical Safety Regulation 2013*

4 Quality system requirements

4.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points, Witness Points and Milestones applicable to this Technical Specification are summarised in Table 4.1.

Table 4.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
9.1	1. Selection of Source of Power 2. Power budget calculations by qualified technical person		
10.1	3. Confirmation of telecommunications network connection prior to procurement		
11.2		1. Approval of final location and site conditions	Approval of final location and site conditions
12.1	4. Record of tests		
12.2	5. Review of records of test		
12.3		2. Demonstration of successful connection to telecommunications network and failure recovery	Demonstration of successful connection to telecommunications network and failure recovery
13	6. Documentation		
16			Handover

5 Functional requirements

5.1 General

An ATCC as defined in this Technical Specification is an electronic device capable of automatically detecting, counting, and classifying individual active transport event.

The active transport events covered under this Technical Specification include:

- Pedestrian
- Bicycle
- Scooter, and
- Undetermined (which is any active transport event not belonging to any of the above 3 types).

The ATCC device shall provide timestamped event-by-event detection details report.

The ATCC shall be capable of operating on cycle path, footpath, roadway, or other location where active transport is permitted, carrying the expected peak volume of active transport events per day for the target site, with individual speeds between 1 km/h and 50 km/h. It shall be capable of differentiating travelling directions on path where lane discipline is not always observed.

The ATCC can be used solely for counting or for counting and classifying specific event types, such as pedestrian, bicycle, or scooter or Undetermined types.

Data collected by an ATCC shall reside locally within the device until it is interrogated to transfer data to the headend in Transport and Main Roads data centre.

The above is standard departmental practice for data collection. However, data may reside in another accessible location subject to approval by the Principal.

The ATCC shall be deployed in accordance with the requirements of TRUM Volume 4 Part 5.

5.2 Sensor technologies

Table 5.2 lists the sensor technologies currently in use. Technology that can achieve the same performance requirements or better may be considered for trial.

All sensor technologies shall comply with the relevant Transport and Main Roads standards, including Standard Drawings, and be approved by the Principal.

Table 5.2 – Sensor technologies

Site type	Permanent	Temporary
Bicycle and scooter	Piezo-Piezo	Twin pneumatic tubes
Pedestrian	Passive infrared sensor	Passive infrared sensor
Bicycle, scooter, and pedestrian	Video analytics camera	Video analytics camera

Refer to Standard Drawings 1928, 1929 and 1930 for details of each sensor configuration on site.

Piezoelectric sensors used on site shall adopt the installation methodology as shown in SD1916 *ITS – Axle based Vehicle Classifier Sensor Installation Details*.

Pneumatic tubes can only be used in temporary sites.

Further details on the configuration and placement of all traffic sensors described in this Technical Specification can be found in TRUM Volume 4 Part 5.

5.3 Internal clock

The ATCC shall be provided with an internal clock in accordance with Technical Specification MRTS201 *General Equipment Requirements*. The internal clock shall automatically synchronise with a time server specified by the Principal. The internal clock shall not drift at a rate greater than ± 1 sec per week without synchronising with the time server.

5.4 Internal memory

The ATCC shall store data in industrial grade non-volatile solid-state memory.

There shall be enough internal memory to store collected traffic data for a period of 90 days or minimum one million detection records on a circular buffer so that the oldest data is overwritten when memory is full.

5.5 Image security and privacy

Where the ATCC involves imaging technology, such as Video Analytics (VA), the images shall meet privacy requirements as covered by the 11 Information Privacy Principles (IPPs) defined in the *Information Privacy Act 2009*.

The ATCC shall have privacy settings configured to make individuals and places unidentifiable. These include but not limited to the restriction of image resolution, and masking out irrelevant areas within camera's field of view. Images with personal contents shall only be processed locally within the device and must be deleted after use.

5.6 Data collection accuracy

The ATCC, depending on the types of active transport events, shall deliver the accuracy levels as shown in Table 5.6. Appendix A provides further details about the calculation of these metrics.

Table 5.6 – Accuracy and tolerance

Active transport event type (by direction)	Permanent site	Temporary site
Count accuracy metrics (bicycle, scooter, pedestrian and undetermined) *		
• Count accuracy (%)	≥ 90%	≥ 90%
• Type M error (%)	≤ 10%	≤ 10%
• Type F error (%)	≤ 10%	≤ 10%
Classification **		
• Micro F1 score	≥ 0.85	≥ 0.85
• Macro F1 score	≥ 0.85	≥ 0.85
Wheelbase accuracy (optional)	± 10%	± 10%
Timestamp	± 1000 msec offset from time server	± 1000 msec offset from time server

* Refer to Appendix A for metrics associated with count accuracy

** Applicable to active transport classifier only – refer to Appendix A

5.7 Data resolution and format

Data from the ATCC shall be recorded in the resolutions as shown in Table 5.7 or higher.

Table 5.7 – Data resolution

Parameters	Resolution requirements
Count	1 unit
Speed	1 km/h
Wheelbase	0.01 m
Timestamp	1 msec

It is preferred that the reported data be in accordance with the format specified in *Queensland Traffic Data Format* (QTDF). However, an alternate data format may be used, subject to approval by the Principal. Time stamping of data shall be in Australian Eastern Standard Time (AEST) all year round, that is, daylight savings time is not applicable.

5.8 Data types

An ATCC shall be capable of reporting individual event data for any combination of the following:

- Bicycle event
- Scooter event

- Pedestrian event, and
- Undetermined type event

It is preferred that the data format comply with current QTDF version.

This clause shall be read in conjunction with current QTDF version.

Where it is not possible for the ATCC to report data in accordance with the QTDF, the Contractor shall provide an alternate data format agreed by the Principal.

6 Equipment

6.1 General

The equipment requirements defined in MRTS201 *General Equipment Requirements* apply to ATCC equipment provided under this Technical Specification. Additional requirements for equipment provided under this Technical Specification are described below.

6.2 Components

The ATCC shall consist of the following components:

a) sensors and sensor cables

b) all associated electronics to process sensor data and log detection information

c) configuration and diagnostics software

d) an IP67 rated enclosure on mounting structure, and

e) power supply and associated infrastructure and accessories to make an operational system.

The type of sensors and cables used shall be in accordance with Standard Drawings 1928, 1929, and 1930.

7 Operational requirements

7.1 General

The operational requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification. Additional operational requirements for ATCC equipment provided under this Technical Specification are described below.

Permanent sites shall be capable of continuous operation in varying weather conditions.

Temporary sites shall be capable of continuous operation in varying weather condition throughout the intended duration of their use.

The ATCC shall continue to detect and store data for all relevant traffic while transferring data or being accessed for real time view or software upgrade.

7.2 Environmental conditions

The environmental requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification. Additional requirements are defined below.

The enclosure that houses ATCC equipment shall comply with MRTS226 *Telecommunications Field Cabinets*.

If the device is not installed within a Transport and Main Roads approved enclosure, it shall be protected by a UV stabilised rugged case with a lockable lid. The case shall have an Ingress Protection rating of IP65 or better.

The components of the ATCC shall have an operating temperature range between -10°C and 60°C.

8 Control system

A control system shall be provided as part of the ATCC.

The relevant requirements of the control system defined in MRTS201 *General Equipment Requirements* apply to this Technical Specification. As a minimum, the control system of the ATCC shall perform the following functions:

- facilitates interrogation of the device
- communication, configuration, and setup of the device
- data transfer
- monitoring of the device's status
- software / firmware upgrades, and
- diagnostics and fault logging.

8.1 Operating system

The ATCC control system shall operate on a laptop computer running the Principal approved operating system current at the time of use. Any software provided by the Contractor shall be capable of operating on all such operating systems.

> Microsoft Windows® 7 Professional, Microsoft Windows® 10 and Ubuntu® are a few examples of systems currently used.

8.2 Software

The software provided by the Contractor shall enable both local and remote configuration of the ATCC system. It must feature an intuitive, user-friendly interface for configuring sensor settings, viewing real-time data, and generating reports. Remote access should be supported to allow authorised users to configure, monitor, and manage ATCC settings and data from any location. A user management system with role-based permissions shall control access to various functions, with user authentication required for configuration, monitoring, and data access. Data storage and transmission must be encrypted to prevent unauthorised access, and the software should comply with data privacy and security regulations, particularly for systems utilising VA sensors that may capture personal data.

8.2.1 System parameters configuration

The software shall be capable of configuring essential sensor parameters, which may vary depending on the sensor type used. At a minimum, it should allow adjustments for:

- sensor sensitivity
- detection range and angle (depression and azimuth) to optimize the field of view
- frame rate
- model updates (for improved classification accuracy)
- calibration, including multi-sensor calibration when multiple sensors are employed, and
- the software should also include tools for troubleshooting common issues related to sensor data and configuration.

8.3 Hardware

The ATCC control system shall be equipped with hardware, such as indicators, preferably LED, to show power, connectivity, and other operational parameters such as traffic activations. The hardware shall also provide a mechanism to visually identify faults whenever there is a failure of sensors or the control system.

8.4 Communications

The communications module of the ATCC control system shall include the applications listed in Clauses 8.4.1 to 8.4.3 of this Technical Specification.

8.4.1 Real-time view

The real-time view application must support online monitoring of traffic. The view shall depict the key reported parameters after each active transport event is detected at the site. It is desirable that the real time view provides the users an option to select an individual active transport event type(s) and direction(s) of travel to display.

8.4.2 Data transfer

The control system must support the secure transfer of data files from the ATCC to the remote headend in Transport and Main Roads data centre. The communications module shall only respond to data transfer request from the headend; the communications module must not initiate data transfer.

8.4.3 Firmware upgrade

The control system must support both local and remote firmware upgrade. Provision of firmware rollback mechanism is preferable.

9 Electrical

9.1 Source of power

The ATCC shall be powered by an ELV direct current (DC) power supply of 6 Vdc, 12 Vdc, 24 Vdc or 48 Vdc.

Power sources for an ATCC site can be mains, solar or battery with suitable converters, to suit individual site condition and the purpose of the installation. Though Transport and Main Roads' preference is in the order of mains, solar and battery, most active transport counting sites are unlikely to have mains supply, and therefore depend on solar power. The selection of source of power must be approved by the Principal. **Hold Point 1**

Permanent sites powered by solar system shall conform to the relevant clauses of MRTS263 *Standalone Solar (PV) Power Systems*. In addition, 3 days' autonomy shall be achieved. The Contractor is required to submit to the Principal their power budget calculation and assumptions prepared and verified by qualified technical persons. **Hold Point 2**

Temporary sites powered by battery shall have enough energy reserve to sustain a continuous operation for a minimum of 7 days without needing to change battery.

10 Telecommunication requirements

10.1 General

The telecommunications requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

Additional telecommunications requirements for equipment provided under this Technical Specification are specified below.

The ATCC shall support remote connectivity via the Principal's telecommunications network which comprises Transport and Main Roads owned cables and leased virtual private network. The device shall implement a secure access control system (for example, username and password) acceptable to the Principal and have session management or a similar method to protect the system, the configuration parameters, and stored data against unauthorised access. In addition, the ATCC shall have a time out mechanism to automatically close the session due to inactivity.

During the design stage, the Contractor shall determine with the Principal a suitable connection of the field equipment to the Principal's telecommunications network as described in MRTS201 *General Equipment Requirements*. The telecommunications network connection must be confirmed by the Principal prior to procurement. **Hold Point 3**

10.2 Network interface and protocols

10.2.1 Ethernet standard

The ATCC, when offered by the supplier as a networked device, shall be implemented with industry-standard Ethernet (IEEE 802.3).

The ATCC shall implement 100BASE-TX and 1000BASE-T.

The physical interconnections shall be RJ45.

10.2.2 TCP/IP protocol suite

The ATCC, when offered by the supplier as a networked device, shall implement industry-standard TCP/IP.

The ATCC shall implement IPv4. Port number shall be user configurable.

A list of implemented protocols within the TCP/IP suite shall be provided to the Principal. Full protocol implementations are desirable. Deviations / omissions from the respective protocol standard(s) shall be brought to the attention of the Principal in writing.

10.2.3 Application protocols

The ATCC shall be capable of implementing any of the following:

- Industry-standard File Transfer Protocol – FTP (RFC959 and RFC1123)
- Secure File Transfer Protocol (SFTP), and
- Secured Hypertext Transfer Protocol (HTTPS).

> FTP, SFTP and HTTPS are preferred where active transport data resides locally within the device and is interrogated by the Transport and Main Roads database. Where the device is not required to be directly interrogated by the Transport and Main Roads database, an alternative protocol may be used subject to approval by the Principal.

The ATCC shall implement industry-standard Internet Control Message Protocol version 4 (ICMPv4).

10.3 Maintenance communications port

It shall be possible to control and interrogate the ATCC locally at site from a laptop computer via an industry-standard serial communications port. Acceptable industry standards are EIA/RS-232, EIA/RS-422 and USB. Any other communication ports / protocols, for example Wi-Fi and Bluetooth, are subject to Principal's approval.

11 Installation requirements

The installation requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

The installation of the ATCC equipment shall be as per the manufacturer's recommendations.

The installation of piezo sensors and video analytics camera for ATCC shall be in accordance with TRUM Volume 4 Part 5 and the associated Standard Drawings.

11.1 General

The Contractor must provide full-time on-site supervision during system installation, testing and commissioning.

11.2 Site selection

For the system to perform properly, the chosen site location must provide a suitable environment for the system's sensors and instruments to operate. In addition, constructability and maintainability are extremely important considerations.

Further site selection criteria and processes are detailed in TRUM Volume 4 Part 5.

The final location and site conditions must be approved by the Principal. **Witness Point 1** **Milestone**

12 Testing and commissioning

The testing and commissioning requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

Additional testing and commissioning requirements for equipment provided under this Technical Specification are specified below.

12.1 Factory acceptance test

Prior to installation of the ATCC, the Contractor must provide a manufacturer-supplied certificate showing that each supplied sensor has been factory tested.

Additionally, the Contractor must visually inspect the sensor for damage, and perform relevant tests to the Principal's satisfaction, including checking critical electrical characteristics against the manufacturer's specification. The record of the tests will be used as a benchmark for installation acceptance test. **Hold Point 4**

12.2 Installation acceptance test

After installation but before connecting the sensors to the system, the Contractor shall perform the same tests on the sensors as being done in factory acceptance testing. The records of the tests shall be provided to the Principal in a format determined by the Principal. For sensors that fail the test, the cause of failure and a proposal to rectify must be discussed with the Principal before progressing any further. **Hold Point 5**

12.3 Commissioning test

The equipment shall be commissioned by integrating the operation, monitoring and control with other equipment and/or systems as appropriate. This shall include initialising performance parameters to suit the site-specific function of operation. The commissioning test shall prove the correct operation, monitoring and control to meet the requirements of the Contract. Additionally, where sites are connected to the Principal's telecommunications network, the Contractor must demonstrate that the system can reconnect successfully upon restarting in the event of a power failure or recovering from telecommunications network failure. **Witness Point 2** **Milestone**

13 Documentation

The documentation requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

Once the number of each ATCC asset type being installed is known, this shall be communicated to the Principal at the first opportunity. This is required to ensure assets are recorded in ROAR and have appropriate asset IDs and site IDs.

In addition, the operations manuals and the maintenance manuals must detail all assets, including the ATCC unit, sensors, and software. The manuals must include, as a minimum, the following items:

- technical specifications
- design characteristics

- general operation theory
- function of all controls
- signal responses and acceptable thresholds
- list of component parts with stock numbers
- manufacturers' certificates
- documentation for the control system including software installation, configuration and usage
- documentation for all protocols used for communications with the counter / classifier
- documentation for all data formats used by the ATCC
- test reports, and
- As Constructed drawings. **Hold Point 6**

14 Training

The training requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

15 Maintenance

The maintenance requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification.

16 Handover

The handover requirements defined in MRTS201 *General Equipment Requirements* apply to work performed under this Technical Specification. **Milestone**

17 Compliance evaluation form

The compliance evaluation form for this Technical Specification is published on the Intelligent Transport Systems and Electrical Approved Products and Suppliers webpage.

Appendix A: Accuracy metrics calculation

Table A(a) and Table A(b) depict 2 performance test templates to record test result to evaluate traffic count accuracy and classification accuracy respectively over a continuous test period. The length of the period shall enable sufficient representative data samples to be captured.

Table A(a) – Test template to evaluate count accuracy

	Reported volume	Missed detections	**Row total**
Actual volume	***C***	***M***	***A***
False detections	***F***		***F***
Column total	***R***	***M***	

Calculations of count accuracy metric shall be based on test results recorded on Table A(a) test template, where:

- C are events where the actual events that have been reported
- M are the missed detections
- F are the false detections that the corresponding actual events do not exist
- R = C + F, are the total reported volume, and
- A = C + M, are the total actual events.

This table can be used for specific type of counter, like bicycle, scooter, pedestrian. The table can also be used for the evaluation of the count accuracy of a classifier by combining all targeted types.

Table A(b) – Test template to evaluate classification accuracy

Actual / Predicted	Predicted as Bicycle	Predicted as Scooter	Predicted as Pedestrian	Predicted as Undetermined type	**Actuals total (Support)**
Actual Bicycle	B_B	B_S	B_P	B_U	$\boldsymbol{B_T}$
Actual Scooter	S_B	S_S	S_P	S_U	$\boldsymbol{S_T}$
Actual Pedestrian	P_B	P_S	P_P	P_U	$\boldsymbol{P_T}$
Actual Undetermined type	U_B	U_S	U_P	U_U	$\boldsymbol{U_T}$
Predictions total	$\boldsymbol{R_B}$	$\boldsymbol{R_S}$	$\boldsymbol{R_P}$	$\boldsymbol{R_U}$	

Calculations of classification accuracy metrics shall be based on test results recorded on Table A(b) test template, where:

- B denotes bicycles, S-scooters, P-pedestrians and U for Undetermined
- Each cell follows the format $ACTUAL_{PREDICTED}$ – where the base letter denotes the actual event and the subscript denotes the prediction of the event
- B_B, S_S, P_P, U_U are events where the actuals and predicted match and therefore these are events that have been correctly classified (predicted)
- Where base letters and subscripts do not match, this denotes an event that have been erroneously classified, for example, B_S, S_P P_U, U_B

- B_T, S_T, P_T, U_T are total actual events for the counts of bicycles, scooters, pedestrians and Undetermined category respectively (also known as Support) excluding the missed detections, and
- R_B, R_S, R_P, R_U are total predicted events for the counts of bicycles, scooters, pedestrians and Undetermined category respectively excluding the false detections.

A1 Count accuracy metrics

Count accuracy metrics include Count accuracy (%), Type M error (%), and Type F error (%) as shown in the following equations.

Count accuracy (%) measures the difference between the reported and the actuals, taking into consideration the errors of missed detections and false detections.

Count accuracy (%) is defined as the reported actual events, divided by the sum of the total number of the reported actual events, the missed detections, and the false detections. Refer to Table A(a).

Type M error (%) and Type F error (%) measure the level of missed detections and false detections respectively.

$$Count\ accuracy\ (\%) = \frac{C}{C + M + F}$$

$$Type\ M\ error\ (\%) = \frac{M}{A}$$

$$Type\ F\ error\ (\%) = \frac{F}{R}$$

Count accuracy metrics of classifier can be calculated by combining all classifiable classes.

A2 Classification accuracy

Classification accuracy metrics apply to classifier only. It measures how accurate an ATCC can classify active transport events. The accuracy performance can be assessed by 2 key metrics, namely, Micro F1 score and Macro F1 score.

Note that Count accuracy metrics of an ATCC is measured separately. Therefore, missed detections and false detections are out of scope of this metric.

A2.1 Definitions

Given the classes: **B** (Bicycle), **S** (Scooter), **P** (Pedestrian), and **U** (Undetermined), the following parameters are defined as:

- True Positives (TP): Correctly predicted instances for each class.
- False Positives (FP): Instances incorrectly predicted as a particular class.
- False Negatives (FN): Actual instances of a class that were predicted as another class.

A.2.1.1 True Positives (TP)

For each class, **TP** is the diagonal element in the confusion matrix where the actual class matches the predicted class:

- $TP_B = B_B$
- $TP_S = S_S$

- $TP_P = P_P$
- $TP_U = U_U$

For the overall classification evaluation:

- $TP = TP_B + TP_S + TP_P + TP_U$

A2.1.2 False Positives (FP)

For each class, **FP** is the sum of instances where other classes were incorrectly predicted as the target class (or the total predictions less the True positives):

- $FP_B = S_B + P_B + U_B = R_B - TP_B$
- $FP_S = B_S + P_S + U_S = R_S - TP_S$
- $FP_P = B_P + S_P + U_P = R_P - TP_P$
- $FP_U = B_U + S_U + P_U = R_U - TP_U$

For the overall classification evaluation:

- $FP = FB_B + FB_S + FB_P + FB_U$

A2.1.3 False Negatives (FN)

For each class, **FN** is the sum of instances where the target class was incorrectly predicted as another class (or the total actuals less the True positives):

- $FN_B = B_S + B_P + B_U = B_T - TP_B$
- $FN_S = S_B + S_P + S_U = S_T - TP_S$
- $FN_P = P_B + P_S + P_U = P_T - TP_P$
- $FN_U = U_B + U_S + U_P = U_T - TP_U$

For the overall classification evaluation:

- $FN = FN_B + FN_S + FN_P + FN_U$

A2.2 Precision, Recall and F1 score for each class

With the definitions above, **Precision**, **Recall** and **F1 score** for each class can be calculated as follows.

A2.2.1 Precision

The Precision of a class C, where C is (B, S, P, U), is given by:

$$Precision_C = \frac{TP_C}{TP_C + FP_C}$$

A2.2.2 Recall

The Recall of a class C, where C is (B, S, P, U), is given by:

$$Recall_C = \frac{TP_C}{TP_C + FN_C}$$

A2.2.3 F1 score for each class

The **F1 score** for each class C (B, S, P, U) is the harmonic mean of Precision and Recall, and is given by:

$$F1\ score_C = 2 \times \frac{Precision_C \times Recall_C}{Precision_C + Recall_C}$$
$$= \frac{TP_C}{TP_C + (FP_C + FN_C)/2}$$

A2.3 Micro F1 score

The **Micro F1 score** is the overall F1 score for a multi-class evaluation. This is equivalent to the overall accuracy.

$$Micro\ F1\ score = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$
$$= \frac{TP}{TP + (FP + FN)/2}$$

A2.4 Macro F1 score

The **Macro F1 score** is the average of the F1 scores for all classes, by treating each class with equal weighting:

$$Macro\ F1\ score = \frac{F1\ score_B + F1\ score_S + F1\ score_P + F1\ score_U}{4}$$

A2.5 Worked example

The following is a confusion matrix showing the actual data and the predicted data as captured by the classifier where the classes are Bicycles, Pedestrians, Scooters and Undetermined.

Actual \ Predicted	Bicycles	Scooters	Pedestrians	Undetermined	Total Actual
Bicycles	36	1	2	1	**40**
Scooters	1	45	2	2	**50**
Pedestrians	3	1	54	2	**60**
Undetermined	1	2	1	35	**39**
Total Predicted	**41**	**49**	**59**	**40**	**189**

The True Positives (TP), False Negatives (FN), False Positives (FP), Precision, Recall, and F1 scores are calculated as follows:

True Positives

$TP_B = B_B = 36$

$TP_S = S_S = 45$

$TP_P = P_P = 54$

$TP_U = U_U = 35$

$TP = 36 + 45 + 54 + 35 = 170$

False Positives

$FP_B = R_B - TP_B = 41 - 36 = 5$

$FP_S = R_S - TP_S = 49 - 45 = 4$

$FP_P = R_P - TP_P = 59 - 54 = 5$

$FP_U = R_U - TP_U = 40 - 35 = 5$

$FP = 5 + 4 + 5 + 5 = 19$

False Negatives

$FN_B = B_T - TP_B = 40 - 36 = 4$

$FN_S = S_T - TP_P = 60 - 54 = 6$

$FN_P = P_T - TP_P = 60 - 54 = 6$

$FN_U = U_T - TP_U = 39 - 35 = 4$

$FN = 4 + 5 + 6 + 4 = 19$

Precision

$$Precision_B = \frac{TP_B}{TP_B + FP_B} = \frac{36}{36 + 5} = 0.878$$

$$Precision_S = \frac{TP_S}{TP_S + FP_S} = \frac{45}{45 + 4} = 0.918$$

$$Precision_P = \frac{TP_P}{TP_P + FP_P} = \frac{54}{54 + 5} = 0.915$$

$$Precision_U = \frac{TP_U}{TP_U + FP_U} = \frac{35}{35 + 5} = 0.875$$

Recall

$$Recall_B = \frac{TP_B}{TP_B + FN_B} = \frac{36}{36 + 4} = 0.9$$

$$Recall_S = \frac{TP_S}{TP_S + FN_S} = \frac{45}{45 + 5} = 0.9$$

$$Recall_P = \frac{TP_P}{TP_P + FN_P} = \frac{54}{54 + 6} = 0.9$$

$$Recall_U = \frac{TP_U}{TP_U + FN_U} = \frac{35}{35 + 4} = 0.897$$

F1 score

$$F1\ score_B = 2 \times \frac{Precision_B \times Recall_B}{Precision_B + Recall_B} = 2 \times \frac{0.878 \times 0.9}{0.878 + 0.9} = 0.889$$

$$F1\ score_S = 2 \times \frac{Precision_S \times Recall_S}{Precision_S + Recall_S} = 2 \times \frac{0.918 \times 0.9}{0.918 + 0.9} = 0.909$$

$$F1\ score_P = 2 \times \frac{Precision_P \times Recall_P}{Precision_P + Recall_P} = 2 \times \frac{0.915 \times 0.9}{0.915 + 0.9} = 0.908$$

$$F1\ score_U = 2 \times \frac{Precision_U \times Recall_U}{Precision_U + Recall_U} = 2 \times \frac{0.875 \times 0.897}{0.875 + 0.897} = 0.886$$

Classifier Micro F1 score (Accuracy)

$$Micro\ F1\ score = \frac{TP}{TP + (FP + FN)/2} = \frac{170}{170 + (19 + 19/2} = \frac{170}{189} = 0.995$$

Classifier Macro F1 score

$$Macro\ F1\ score = \frac{F1\ score_B + F1\ score_S + F1\ score_P + F1\ score_U}{4}$$
$$= \frac{0.889 + 0.909 + 0.908 + 0.886}{4} = 0.898$$

A3 Speed accuracy

Speed accuracy metric compares the reported travelling speed of individual active transport users with their actual speed.

$$Individual\ speed\ error\ (\%) = \frac{Reported\ speed}{Actual\ speed} - 1$$

The active transport counter / classifier is deemed to have met the speed accuracy requirement if 99.7% or more individual speed errors lie within the prescribed tolerance.

A4 Wheelbase accuracy

Wheelbase accuracy metric compares the reported wheelbase of individual active transport devices, which have 2 or more wheels in tandem, with their actual wheelbase measurements.

$$Individual\ wheelbase\ error\ =\ reported\ wheelbase\ -\ actual\ wheelbase$$

The active transport counter / classifier is deemed to have met the wheelbase accuracy requirement if 99.7% or more individual wheelbase errors lie within the prescribed tolerance.

Wheelbase accuracy metric is applicable to sensor technology which can measure this parameter.

A5 Timestamp accuracy

Timestamp accuracy metric compares the time of (as stamped on) a reported individual active transport event with the actual time when the event occurs.

$$Individual\ timestamp\ error\ =\ timestamp\ on\ active\ transport\ event\ -\ actual\ time\ of\ the\ event$$

The active transport counter / classifier is deemed to have met the timestamp accuracy requirement if 99.7% or more individual timestamp errors lie within the prescribed tolerance.

Timestamp accuracy metric is applicable to active transport counter / classifier which reports event-by-event data. Generally, timestamp error can be reduced by synchronising the internal clock more frequently with the time server.