Traveller Information Services Association

TISA Guideline

Estimated Travel Time (ETT) Metrics and Tests

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List of abbreviations and acronyms

Abbreviation	Meaning
ATT	Actual travel time in seconds.
ETT	Estimated travel time in seconds.
GNSS	Global navigation satellite system used to compute positional data in a navigation application.
Length/distance	The distance travelled on a trip, measured in meters.
Navigation application	Any application or device a user can use to navigate. E.g. apps on a mobile device, or in-dash automotive applications.
Speed	The average speed of a trip, measured in meters per second.
Travel time	Any time required for a trip, measured in seconds.
Trip	A single-purpose journey from a certain origin to a destination.

Symbols

Symbol	Meaning
$\mathrm{ATT}(trip)$	The actual travel time of a $trip$ in seconds.
$\mathrm{ETT}(trip)$	The estimated travel time of a $trip$ in seconds.
$\Delta\mathrm{TT}(trip)$	The difference between estimated and actual travel time of a $trip$ in seconds.

1 INTRODUCTION

1.1 Purpose of this document

This document describes metrics and processes for evaluating the quality of traffic services or data, specifically in the context of routing and navigation applications. It specifies the Estimated Travel Time metric, primarily useful in routing applications.

Examples of traffic services (or data to be evaluated) may include:

- a live travel time service for a specific road network,
- a live service that provides congestion information as incidents,
- a predictive traffic feed or statistical data that describes typical traffic patterns in a road network,
- or any other data that may influence the calculation of route travel times in an application.

The intended audiences for these guidelines are:

- providers of traffic and travel information, such as developers of navigation applications,
- suppliers of traffic and travel information, and
- automotive manufacturers, (as well as intermediaries and third-party stakeholders).

The document consists of two parts, the specification of the metric itself and the way it may be used to evaluate the service quality on a large scale using statistical methods. Some parts of the latter leave room for interpretation. Therefore, decisions must be made transparent between clients when sharing results based on this metric.

This standard enables navigation providers, buyers, and procurement departments with creating requirements on the end-to-end performance of navigation.

1.2 Rationale and Antecedents

It is considered that this standard is necessary in order to provide the industry, the public sector, and the general public a transparent, meaningful, and easy-to-grasp metric for the quality of travel time information.
In particular, the ETT metric can be positioned complementary to the Q-Bench approach which focuses on evaluating delay estimations primarily in congested traffic scenarios whereas the ETT metric aims at analyzing the general travel time estimation accuracy in all traffic situations. Additionally, the ETT metric keeps a more driver-centric perspective as it measures quality 'per trip' in contrast to QBench's aggregated and abstract benefit ratio.

1.3 Summary

The quality of the estimated travel time (ETT) can be used to evaluate travel and routing products with a user-centric point of view. It’s the single easiest-to-grasp metric, since it measures what matters the most to users.

By optimizing ETT accuracy, the result is improved route quality. Routing engines are more likely to find the optimal route when they can calculate accurate ETTs.

Users start a trip using their chosen navigation application. Once they arrive at the destination, they can determine the accuracy of the planned trip duration. In contrast, several other metrics measure the quality of various traffic services by focusing only on single components, e.g., maps, traffic, or the routing engine.

The ETT can be used to evaluate the whole chain of the navigation application, but also certain static products providing speeds or traversal times for road elements. ETT quality is measured with actual trip analytic data that is gathered by from navigation applications. To compute routing service quality, we compare the ETT, as given to the user at their start time, with the actual travel time (ATT) for multiple trips.

The results of this comparison are then analyzed by applying statistical methods. A quick way to grasp the quality is by computing the share of accurately and inaccurately estimated trip durations. The completed quality analysis from a whole trip set is a histogram of the various categories.

The following sections describe a framework to evaluate the quality of a large-scale routing service by using trip sets and explaining the evaluation metric for single trips.

2 ETT FRAMEWORK

The ETT framework defines a procedure for exchanging quality information by traffic service providers and their clients. For meaningful results, both parties must align on evaluation parameters and properties.

The remaining framework uses a batch scenario, evaluating the ETT with archived trips. This can be used:

- to test products for quality deterioration prior to release,
- to develop product improvements, and
- to provide quality information in proposals.

Batch evaluation is also ideal for static traffic products such as traffic speed profiles or patterns. This is best suited to detect trends.

It is also possible to evaluate live data, e.g. traffic flow, by applying the same methodology. In this scenario new incoming trip data is continuously analyzed during collection. Over time, the amount of incoming data and its quality likely varies. Thus, live evaluation is best suited for monitoring. Due to the restrictions in a live setting some of the parameters defined later are not applicable. We will make a note if this is the case.

2.1 Workflow

The workflow for an ETT evaluation is depicted in Figure 1. The client and service provider agree on the trip sets and their respective properties. The service provider then collects all trip data, map matches the data on a digital map, and runs the evaluation with the ETT metric for each of the trips. Finally, the results are aggregated, and the results are delivered to the client.

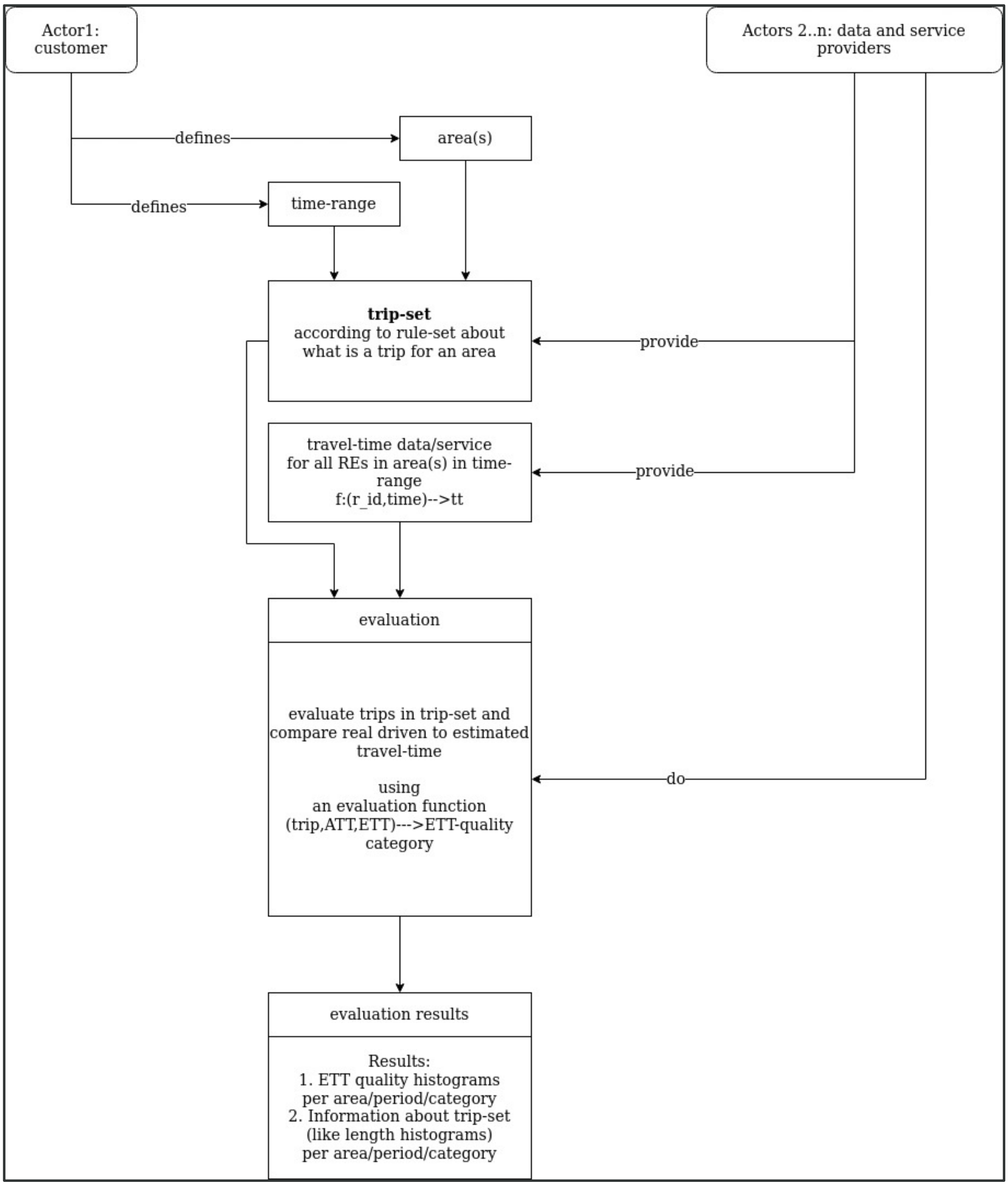

Figure 1: Schematic view of the evaluation procedure of traffic data/services with respect to ETT quality.

2.1.1 Data sources

We recommend that the client and service provider use a well-defined set of trips which, ideally, is provided by the client. However, this best case is difficult to achieve due to various reasons: the client might not have trip data, or the data cannot be shared due to legislative reasons such as data protection.

When the data cannot be shared, the data provider creates a trip set performing the ETT evaluation using the agreed parameters. More information about the definition of trip sets is found in section Trip set.

3 INPUT DATA

3.1 Digital map and map matching

Trip input data is usually GNSS positioning data and corresponding time stamps. These originate from devices inside vehicles (e.g., navigation devices, smart phones, location trackers). The raw data is map-matched onto a digital road map to produce a map-related trip. This is required for using traffic data for the ETT computation.

3.2 Trip

A trip is defined as a single-purpose journey from a specific origin to a destination. It has a start time $trip_{start}$ and end time $trip_{end}$. The ATT is defined as:

$$\mathrm{ATT}(trip) := trip_{end} - trip_{start}$$

Trips are defined as a continuously driven distance. By definition, every break within the trip is interpreted as a result of traffic, e.g., due to traffic jams. In other words, trips that contain non-traffic related delays like petrol station stops or picking up passengers shall be discarded and not considered for ETT evaluation.

3.3 Extracting trip data

Technically a trip is a sequence of road elements on a map that are driven from a start road element to an end road element. During the map matching process, application of filtering is necessary to remove unwanted artifacts, e.g., artificial stops due to non-traffic related breaks.

Depending on the source of the input data some additional steps may be required to generate a proper trip from the raw input data. Input mostly contains not only the interesting part for the trip from the origin to the destination, but additional positioning data. This can be because the device is always on, or the navigation application is started before the user actually begins the trip.

1. Detected trips: The data is parsed and filtered to detect the actual trip(s). Ambiguous data at the beginning and end (e.g., when the vehicle hasn't even moved yet/anymore, due to parking search, loading and unloading etc.) should be filtered out at best effort. The trip starts with the first fully-traversed road element and ends with the last fully-traversed road element. This data is suitable for evaluating ETT. However, the actual selection of trips is implementation-dependent and may vary between different implementations.
2. Tagged trips: Trips that have additional events assigned to them. The events are generated by the navigation application and can be elements like *Navigation started*, *Destination reached*, or others. This data is suitable for evaluating ETT. When the input data is the source and an agreement on the tags is made, this allows for independent implementations with similar results.

In general, it shall be stressed once more that, when deciding for a trip set, any kind of bias should be reduced to the most possible extent.

3.4 Traffic data

Traffic data refers to the data upon which the ETT quality is to be evaluated. It can originate from historical travel-time data products, or it can be archived data from live Traffic Services. It is important that this data is present for the complete time-range and the entire region of interest for all road elements of a trip within the trip set.

NOTE: Depending on the actual selection of trips, provision must also be made for road elements outside the actual study area. See the next section for more details.

4 TRIP SET

The quality of a navigation or traffic service based on ETT cannot be determined with one or only a few single trips. It requires a large number of reference trips that are evaluated and whose ETT quality distribution defines the quality of the travel-time estimator. We refer to that as *trip set*.

We consider many aspects when defining a trip set:

- Geographical spread,
- Time-range,
- Size,
- Source Data, including trip characteristics.

4.1 Geographical spread

The most important aspect is the definition of the area or region of interest. In our context, a traffic service usually shall be evaluated for a city, a greater urban area, or a country. This means that the trip set must exclusively contain trips from that area. It is an important detail to specify if a filter shall be applied to the trips with respect to the area. Several options exist:

- Consider only trips that start **and** end in the area
- Consider only trips that start **or** end in the area
- Consider trips that enter the area at least once

A related aspect is deciding whether the entire trip is always evaluated or if only the part of the trip inside the area shall be considered.

4.2 Time-range

It is very important to specify upfront in an ETT evaluation which time-range is of interest. One option is to collect trips in the trip set that span an entire year. This balances the seasonal effects of the reference or the estimator. However, some ETT evaluations may also focus on analyzing one or more particular (shorter) time-ranges.

4.3 Size

The size of the trip set is also important; it guarantees that the trip set is large enough to be statistically reliable. This is especially true in the subsequent analysis, when further sub-dividing the ETT quality results based on time-of-day or trip-length. We recommend using trip sets with >500K trips to obtain meaningful results, for example, also covering night hours.

4.4 Duration

We recommend that trips shorter than 5 minutes shall not be evaluated since meaningful quality thresholds are hard to define.

Furthermore, trips longer than 120 minutes shall be excluded from the evaluation as well, because they are more likely to contain breaks.

4.5 Source data including trip characteristics

The selected evaluation trip set should represent the main characteristics of the target user group of the routing application. For example, if the final use case targets common car routing and navigation, the trips in the trip set should be unbiased. This means they should represent typical trips driven in the area.

In practice, some biases may occur, caused by several reasons. One must realize that probe data comes from various sources, e.g. delivery vehicles, ride hailing, trucks, or data from different platforms like in-dash devices or smartphones. These disparate sources may have slightly different properties. Another cause may be due to data privacy related post-processing measures, which may, for example, affect trip length distribution or filtering of positioning data in the proximity of origin or destination. The extent to which those potential biases may influence the results must be determined on a case-by-case basis. It is not part of this proposal.

4.5.1 Examples

Typical examples for trip set regions are metropolitan areas like the Bay Area in the US State of California, or larger cities like Berlin, Germany or Moscow, Russia. Trip sets can also be defined on a country level, such as Germany or California (for the US, these are on a state level). The latter is primarily used for the evaluation of long-distance trips.

Typical test trip sets are often defined to cover the time-range of a full year. Using shorter periods increases the risk of influences from seasonal traffic patterns. Moreover, usage of most traffic products is not temporally restricted. However, longer time ranges are also unfavorable since traffic patterns change slowly over time, and evaluating very old traffic is therefore inaccurate.

5 EVALUATION

The ETT metric measures the difference between the ATT of a trip and its ETT, as modeled by a traffic product. Besides the calculation of the absolute error values, the ETT metric classifies the quality of a trip into five categories: Major Under, Minor Under, Accurate, Minor Over, and Major Over.

This section describes the details of the process for a single trip. Then, in the section Evaluation results it is described how these results are aggregated and, finally, how all this can be used to define a score function for the ETT quality.

5.1 How to calculate the ETT for a single trip

In the approach of this document, we intend to evaluate the ETT quality of traffic data or a traffic service at the specific moment when the trip started. The only information that should be used is what was known at the trip's start time. If a service includes predictive travel time information, all the available information at the respective point in time should be used for the evaluation.

For example, if the traffic data is from an archived live-traffic service, it may consist of five-minute snapshots of speeds on the road network. Then, when evaluating a trip, only the freshest snapshot should be used for the entire trip. On the other hand, when the traffic data is from an offline/historical data product, complete information is available when the trip starts.

5.2 Travel time deviation

The trip's accuracy is measured in seconds as the difference between the trip ATT and the ETT. The *travel time deviation* $\Delta TT(trip)$ is defined as:

$$\Delta \mathrm{TT}(trip) := \mathrm{ETT}(trip) - \mathrm{ATT}(trip).$$

Overestimation happens when the ATT is smaller than the ETT. In this case $\Delta \mathrm{TT}(trip) > 0$ and the trip is called *overestimated*.

Underestimation happens when the ATT is higher than the ETT. In this case $\Delta \mathrm{TT}(trip) < 0$ holds. In this case the trip is called *underestimated*.

Almost all trips are either overestimated or underestimated. In rare circumstances, a trip travel time is estimated exactly in which case $\Delta \mathrm{TT}(trip) = 0$ holds.

5.3 Quality categories

Depending on the amount of relative deviation trips are sorted into five categories, namely:

- *Major Under*,
- *Minor Under*,
- *Accurate*,
- *Minor Over*,
- *Major Over*.

As defined above, the under- and overestimated trips are those where the ATT was significantly longer or shorter than the ETT, respectively. Accurate trips are trips whose ATTs do not deviate too much from the ETTs, with their ETTs being perceived as of good quality by a potential end user. They can be either slightly over estimated or underestimated.

Trips that have a somewhat larger deviation are considered *Minor*. Such deviations are not expected, but can happen from time to time. All trips with relatively large deviations between actual and expected travel times are *Major*. These deviations are not desired and should be related to either severe traffic impact or trips having different and unexpected or unusual characteristics.

5.3.1 Motivation

It is straight-forward to see that the definition of the quality categories must depend on the duration of a trip. However, it is not immediately obvious which thresholds should be used to define quality categories.

For a shorter trip of, say, 10 minutes a $\Delta TT(trip)$ of 4 minutes should probably not be considered as being Accurate whereas for a longer trip of an hour this might still be the case. Traffic for short trips has a higher variance due to the impact of external influences like traffic signals.

This is backed by non-representative user surveys indicating that users consider hour long trips with a deviation of 5 minutes still accurate, while they only accept 1 to 2 minutes for short trips of 10 minutes.

5.4 The ETT quality thresholds

The assignment of one of the quality categories is done based on the ATT of a trip. Given a trip with its ATT and the travel time deviation, it's possible to determine which category it belongs to based on certain threshold functions.

Following above considerations, we propose to use a linear function to distinguish between Accurate, Minor and Major deviating trips. Notice, that the function is not intended to make it equally likely for trips of various durations to be evaluated into certain categories. Rather, the category thresholds are defined from a user perspective.

As mentioned in the Trip set section, a meaningful trip has a minimum duration of 5 minutes. Higher relative deviations should be allowed for these short trips. Table 1 shows thresholds derived by a linear function for various actual travel times. For 10 minutes up to 2 minutes (20 %) of travel time deviation are still considered accurate, while for 1 hour 5 minutes (8.3 %) are still considered accurate. The double amount of deviation is used as threshold to distinguish a Minor from a Major deviation.

ATT (min)	Accurate threshold (to Minor deviation)	Relative deviation Accurate to Minor	Minor threshold (to major deviation) (min)	Relative deviation Minor to Major
5	1 min 42 s	34.0 %	3 min 24 s	68.0 %
10	2 min	20.0 %	4 min	40.0 %
20	2 min 36 s	13.0 %	5 min 12 s	26.0 %
30	3 min 12 s	10.7 %	6 min 24 s	21.3 %
45	4 min 6 s	9.1 %	8 min 12 s	18.2 %
60	5 min	8.3 %	10 min	16.7 %
100	7 min 24 s	7.4 %	14 min 48 s	14.8 %
120	8 min 36 s	7.2 %	17 min 12 s	14.3 %

Table 1: Example thresholds for the proposed linear threshold functions

In the remainder of the section, the threshold functions are formally defined and their use cases are described. Table 2 defines the thresholds for the trip categories.

Quality category	Tresholds
Major over	$\Delta\mathrm{TT}(trip) > 168\ \mathrm{s} + 0.12 \cdot \mathrm{ATT}(trip)$
Minor over	$168\ \mathrm{s} + 0.12 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip) > 84\ \mathrm{s} + 0.06 \cdot \mathrm{ATT}(trip)$
Accurate	$84\ \mathrm{s} + 0.06 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip) > -84\ \mathrm{s} - 0.06 \cdot \mathrm{ATT}(trip)$
Minor under	$-84\ \mathrm{s} - 0.06 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip) > -168\ \mathrm{s} - 0.12 \cdot \mathrm{ATT}(trip)$
Major under	$-168\ \mathrm{s} - 0.12 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip)$

Table 2: Definition of all quality thresholds

The thresholds for minor and major over estimation are:

$$\mathrm{minOver}(trip) \coloneqq 84\ \mathrm{s} + 0.06 \cdot \mathrm{ATT}(trip),$$

and

$$\mathrm{majOver}(trip) \coloneqq 168\ \mathrm{s} + 0.12 \cdot \mathrm{ATT}(trip),$$

respectively.

The metric is symmetrical, and therefore the thresholds for minor and major under estimation are defined as

$$\mathrm{minUnder}(trip) \coloneqq -\mathrm{minOver}(trip) = -84\ \mathrm{s} - 0.06 \cdot \mathrm{ATT}(trip),$$

and

$$\mathrm{majUnder}(trip) \coloneqq -\mathrm{majOver}(trip) = -168\ \mathrm{s} - 0.12 \cdot \mathrm{ATT}(trip),$$

respectively.

Figure 2 shows how trips are grouped into the distinct categories. The *x*-axis shows the ATT in seconds and the *y*-axis shows the travel time deviation in seconds. The distinct colors represent the quality category. The gray lines separating the regions of the quality categories are the threshold functions.

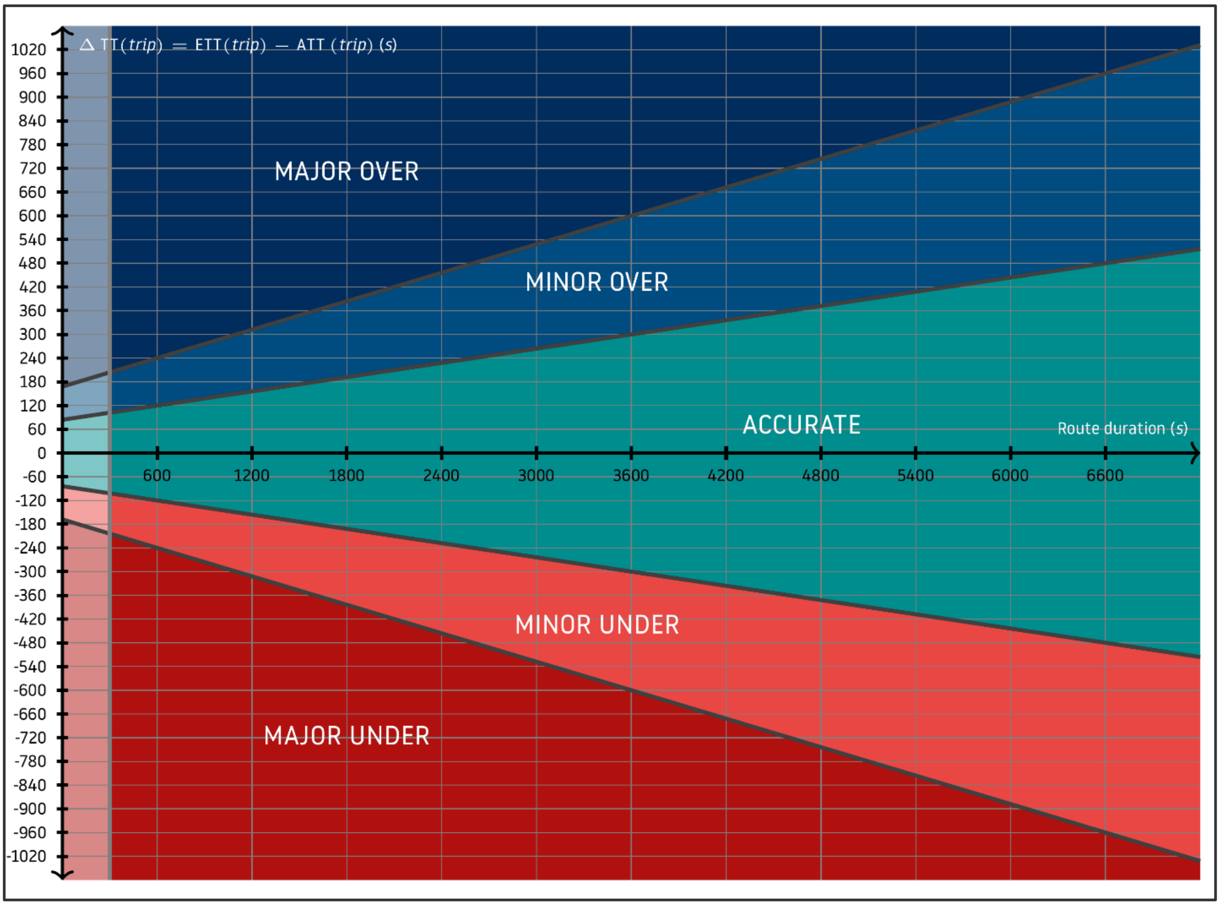

Figure 2: Trip evaluation by duration and ETT deviation

5.4.1 Example

During the evaluation of a trip its ATT is already known, and, given its ETT at trip start the deviation can be computed. As an example, a trip with an ATT of 3600 s (1 hour) is classified as accurate if and only if the absolute deviation is less than 300 s (5 minutes), as can also be seen in the diagram. The allowed deviations per category are symmetrical.

Observe, that when taken the user perspective this is slightly different. Consider a planned trip with an ETT of 720 s (12 minutes). The minor over threshold is reached when $84\,\mathrm{s} + 0.06 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip)$ holds with equality. This is the case for $\Delta\mathrm{TT}(trip) = 600s$. Any trip that arrives up to 120 s (2 minutes) early is considered accurate. A similar computation can be done for the under estimation by solving $-84\,\mathrm{s} - 0.06 \cdot \mathrm{ATT}(trip) \geq \Delta\mathrm{TT}(trip)$ yielding approximately 855 s. Thus it is feasible for an accurate trip to have a slightly larger delay of 135 s. For trips with an ETT of 12 minutes a deviation of approximately 20% is considered accurate.

The acceptable relative travel time deviation decreases when the trip is longer. For a trip with an ETT of 3600 s (1 hour), only a deviation of 8.3% is acceptable for accurate trips.

The selected functions to model the categorization of the trips into quality buckets aim to represent the ETT acceptance criteria of an end user of a routing application. In particular, they are not specifically designed to ensure a similar or equal distribution among the quality categories for trips of different lengths.

However, since user perception and use case requirements may vary, other choices might sometimes be more appropriate. Finally, it is up to the customer of the traffic service to request an evaluation against a different or modified quality function.

6 EVALUATION RESULTS

6.1 Statistical evaluation

The evaluation of a trip set yields a stacked horizontal bar diagram as shown in **Figure 3**. The groups partition the trips in the trip sets, based upon their evaluated quality. Therefore, the range of the bar is 100%. From left to right, the groups represent trips classified as Major Under, Minor Under, Accurate, Minor Over, and Major Over, respectively.

In **Figure 3**, 10.4% of the evaluated trips are major underestimated, 11.4% of the trips are minor underestimated, 60.5% of the trips are considered accurate, 12.2% are minor overestimated, and 5.4% of the trips are major overestimated.

Figure 3: Evaluation of trip set for a single period

6.2 A Score function

Additional to the 5 values for the quality categories as described above, we suggest to introduce a score function which translates the results into a single value, a score, and hereby enables ranking the evaluation results of different data providers.

The score is defined as follows on the shares of trips in the respective categories (in percent):

$$\textit{score} \coloneqq \textit{Accurate} + 0.5 \cdot \textit{Minor Under} + 0.5 \cdot \textit{Minor Over}$$

With this definition the score is a value between 0 and 100 and the higher it is, the better the ETT results are.

Following the example from the last section, the distribution of 10.4%, 11.4%, 60.5%, 12.2%, 5.4% would yield a score of $60.5 + 0.5 \cdot 11.4 + 0.5 \cdot 12.3 = 72.35$.

6.3 Additional output

Additional to the specific ETT evaluations certain other values must be enclosed within the evaluation. As said previously, in most evaluation scenarios the exact trip set is not specified. Thus, the selected properties of the trip set must be contained in the results as well as certain parameters of the trip set that may have an influence on the outcome.

6.3.1 Length distribution

The most important property of a trip set is its length distribution (e.g. as in **Figure 4**). Short and long trips behave differently. Thus, evaluation results are only comparable when the trips have similar lengths.

A distribution of the trip length in km should be contained in the output of the evaluation.

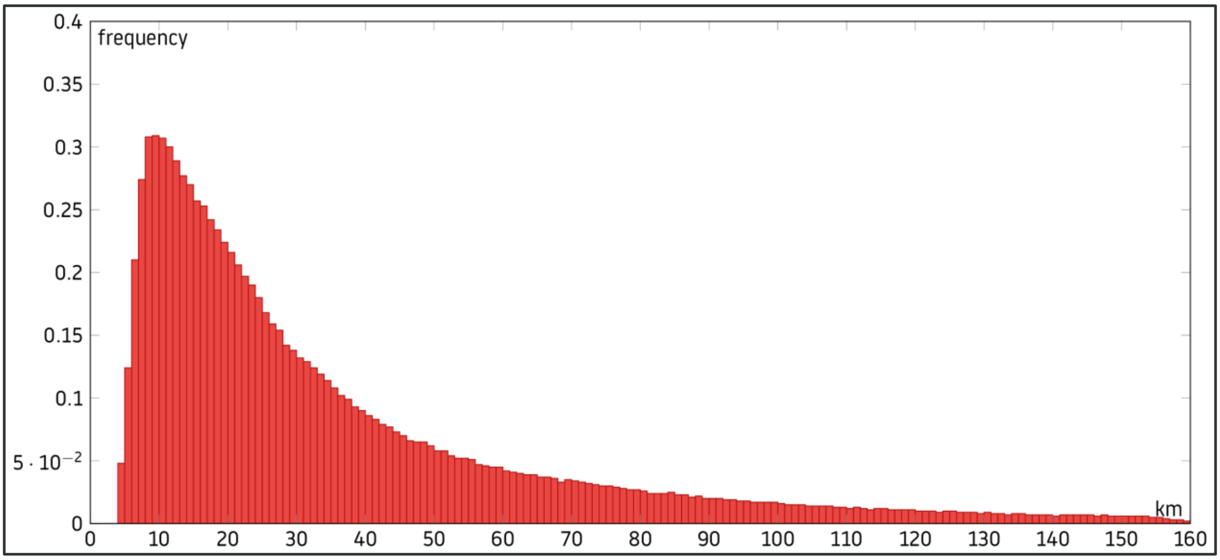

Figure 4: Length distribution of an example trip set

6.3.2 Trip set parameters

When the trip set is not fixed and provided by the client but instead created automatically with respect to certain parameters, consideration of these parameters must be taken into account in the evaluation.

These parameters include, but are not limited to,

- Regional spread
- Time-range
- Number of trips
- Trip characteristics (as far as discloseable)
- Filtering
- Extraction method

Any other custom agreement must be included in the result.

6.4 Traffic data

The exact type, product name, and version of all traffic data used for the evaluation must be specified.

ANNEX A: RESULT CATEGORIES

To gain more information from the ETT evaluation, it is useful to provide results in a more detailed way. In the following section we briefly describe the most important categorizations.

A.1. Time periods

A trip can be evaluated based upon the period when it was driven. The time periods used for evaluation are defined in **Table 3**.

Period	Trip property.
ALL	All trips in a trip set.
Weekday	***Starts*** on a weekday.
Weekend	***Starts*** on a weekend.
Peak hours	***Starts*** on a week day and spends at least ***50% of its traveled distance*** during peak hours, for example: 06:00 - 09:00 16:00 - 19:00
Night	***Starts*** on a weekday after 21:00 (evening) before 05:00 (morning).

Table 3: Trip evaluation by time period

The evaluation for all periods is combined in a single diagram. There is an example evaluation shown in **Figure 5**, based on data from California, USA.

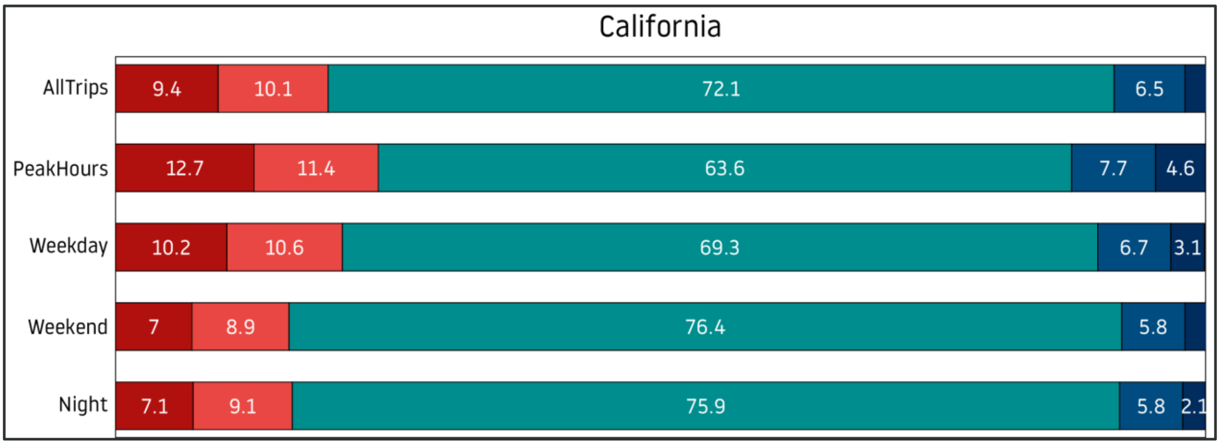

Figure 5: Sample evaluation for all periods: California, USA

A.2. By trip duration

Another insightful categorization is the per-trip-duration. An example for categories are shown in **Table 4**.

Trip type	Durtation (s)
Short	ATT(trip) < 600 s
Medium	600 s ≤ ATT(trip) < 1800 s
Long	600 s ≤ ATT(trip) < 6000 s
Very Long	6000 s ≤ ATT(trip)

Table 4: Trip evaluation by duration