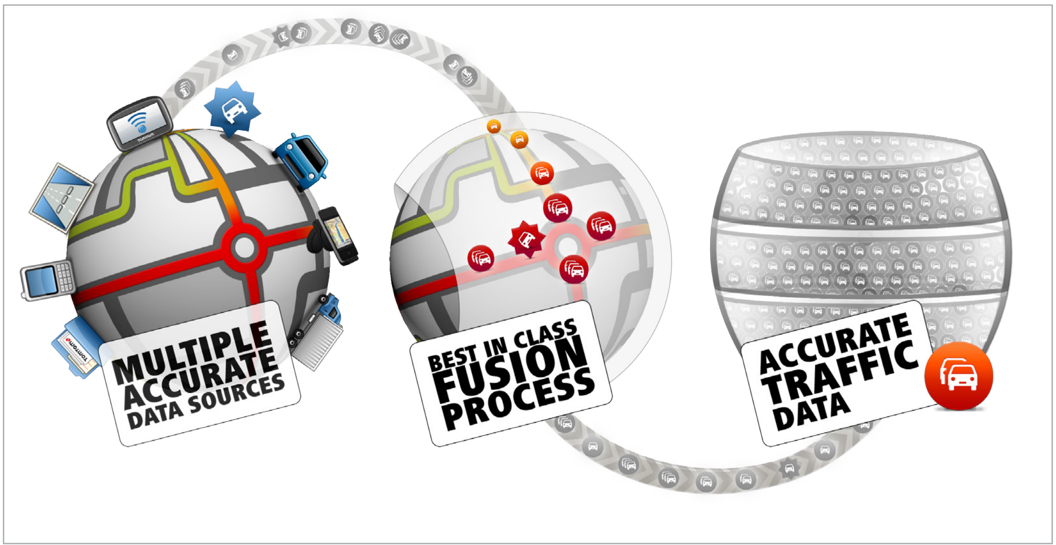
TOMTOM REAL TIME TRAFFIC INFORMATION

INTRODUCTION

With increasing traffic congestion causing delays for motorists, reliable traffic information is key for travellers all over the world. By knowing the actual traffic situation on the road, users can save time and money by planning their trips at the best time of the day or by taking an alternative route.

Drivers can receive traffic information in many different ways – on the internet, on their radio from a broadcast service, on signs above or beside the road or in navigation devices.



With the introduction of TomTom Traffic, TomTom launched a traffic service of unrivalled quality for navigation device users. TomTom Traffic, along with the other real time traffic products from TomTom Traffic Flow, TomTom Traffic Route Times and the Internet and Media products - are also available for licensing by partners in the automotive, enterprise, wireless, government and media sectors.

Details of TomTom's data collection and fusion system are outlined in this document, along with the different products that are available to licensed customers as a result.

NOTE: TomTom Traffic Flow, TomTom Traffic Route Times and the internet and media products are products of the same real time traffic system but the output is a specific version of the complete data to suit particular use cases.

Input Sources

The TomTom real time traffic information system generally relies on high volumes of anonymous probe data measurements to generate traffic flow data – and this is supplemented by incident data to provide the causal data.

GPS PROBES

GPS probe data is collected from personal navigation device users who have opted to share travel time information on an anonymous basis. These are largely from connected TomTom navigation devices (PND), TomTom Business Solutions devices, TomTom embedded navigation devices in cars (e.g. Renault) and TomTom navigation applications on Smartphone (e.g. iPhone). In some countries additional GPS measurements are collected from 3rd party fleet management companies.

Not all TomTom PNDs are connected. The connected devices have a modem and simcard that enables them to share data with a central server at TomTom using the GPRS data service from a Telecom network. These devices all subscribe to TomTom LIVE Services - so where relevant to the country they are operating in, they receive real time information on traffic, speed cameras and other services every two minutes.

The sharing of data is a two-way process, and in exchange for receiving the LIVE Services data on the user's device, anonymous GPS traces are sent from users who have opted to share travel time information on an anonymous basis to contribute to the information sources for the next traffic situation update.

JOURNALISTIC DATA AND ROAD SENSOR DATA

Journalistic data provides a very valuable source of information for drivers, including road closures, lane closures and accidents on the road. As there is no speed attached to a closed lane, TomTom isn't able to generate this information from it's GPS probe sources. TomTom receives this information from 3rd party suppliers who are actively monitoring the road network. This incident data information is also known as 'journalistic' or 'causal' information as it describes the reason for delays rather than the extent, or effect, of the delays.

Traditional road sensor data is also often collected in the TomTom real time traffic system – either directly from the operator of the sensor (government bodies) or through the 3rd party incident data aggregator. Where available, this additional flow data is fused with the probe flow data to provide the most robust data set from the available sources.

FUSION PROCESS

TomTom's patented data fusion engine calculates reliable aggregate speed information for every road stretch where input sources are available. The system compares and combines the multiple input sources using a series of algorithms and confidence levels to determine the most likely output speed for each road stretch.

This is done at the most detailed road segment level possible, using a finer road segment level than TMC. Output can be provided at TMC level or based on open location referencing (OpenLR).

The fusion process includes these steps:

1. Raw Data Collection: transmitting and receiving data from each data source

2. Data Alignment: matching the data from all sources with a common map reference and time stamp

3. Data Assessment: assessing data quality by source, age and other characteristics

4. Data Combination: performing classification, filtering and combination of the data into a final, single data stream

The data sources are combined in real time based on algorithms which continually recalculate speeds on every part of the road network. These calculations take into account the age and reliability of each data observation by data source. The journalistic data regarding, for example, road closures, is directly passed through to the traffic service feed and displayed on the map of the navigation device. This data bypasses the fusion process.

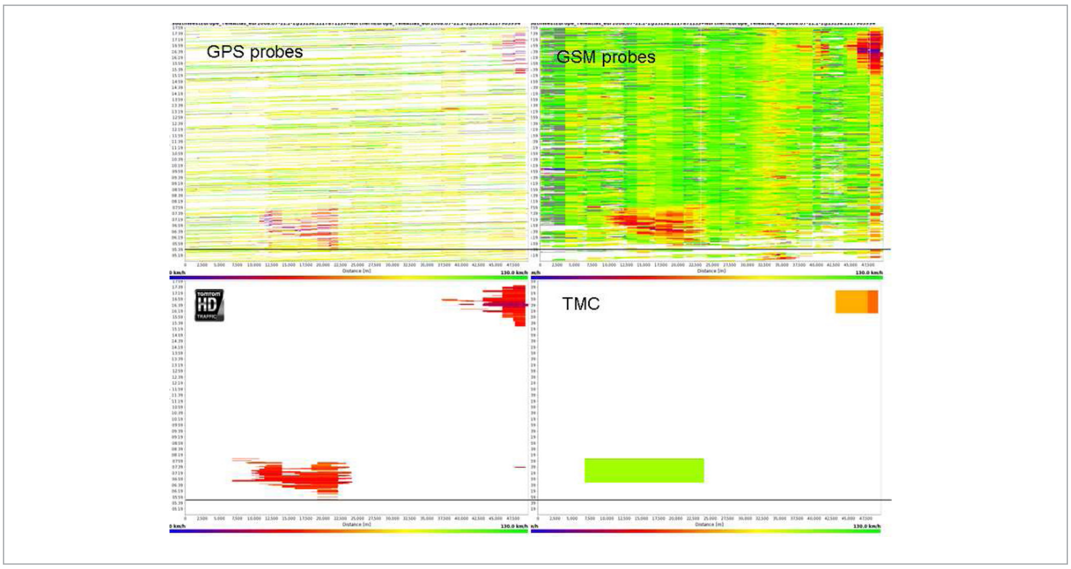


Figure 2: Example of input data source aggregations, with the resultant traffic system congestion output (TomTom Traffic) and equivalent TMC output.

In figure 2, a set of time distance diagrams is plotted showing the granularity and scope from different sources contributing to the data fusion process and the resulting output of the congestion detection process for TomTom Traffic. For comparison reasons, the public TMC messages broadcast in the same area are plotted as well (lower right).

The x-axis shows a section of the A3 highway in Germany, between the junction at "Seligenstädter Dreieck" and the junction at "Wiesbadener Kreuz", while the y-axis shows the time throughout the day (6th March 2009). The speed is indicated by various colours, blue for speeds close to stand-still (0 km/hr) and green for free flowing traffic. The example shows the existing high coverage of TomTom traffic data generated by monitoring probe data, both from GPS and GSM sources. The calculated congestion measurements are far more accurate and precise compared to the TMC messages which are broadcast in the same area.

The TomTom traffic information system observes congestion very rapidly due to the frequent updates from the input sources and is able to rapidly calculate a file representing the current traffic situation. This minimises the elapsed time from the congestion starting to form on the road and the warning messages being received by the customer devices (smart phones or PNDs) or servers.

The TomTom real time traffic system also looks at recent history of each road stretch to determine the "probability" that congestion will occur. For example, if there is traffic congestion on a specific road segment 90% of the time at Monday morning rush hours, fewer observations are needed from probes or mobile phones indicating a jam before the system can be confident to publish a congestion event in the feed to customers. The left hand in image figures 3 shows the observed jams on the road network around Utrecht in the Netherlands. If you compare this to a "normal rush hour" as displayed on image on the right hand side you can see that a large part of the rush hour jams are daily jams. TomTom has the largest database of historical speed data available, collected from tens of millions of consenting users. As a result, TomTom has confidence in sending congestion reports to customers where they are observed with relatively few GPS or GSM observations.

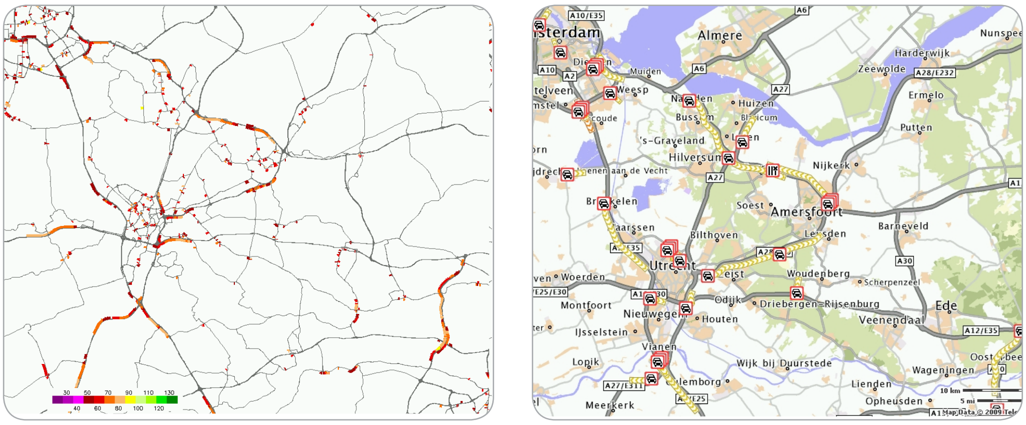


Figure 3: Observed speeds on roads around Utrecht, Netherlands in the left hand image and the published road segments experiencing congestion in the right hand image.

QUALITY

TomTom has the unique ability to check the quality of TomTom Traffic by comparing it with ground truth information. The ground truth data is collected independently of TomTom Traffic data sources. TomTom uses this data to confirm the accuracy of TomTom Traffic and when necessary to adjust the data fusion engine to improve quality.

To put this ground truth data base into perspective – TomTom collect millions of kilometres of driven road data each day from TomTom navigation devices to create this ground truth database. All countries where TomTom offers TomTom Traffic have a comprehensive ground truth database for quality check that is used to cross-check the data quality as part of the ongoing internal quality assurance program.

One important definition in the quality system is the threshold at which congestion is assumed to be significant and worthy of reporting to road users. TomTom uses congestion as an interruption to traffic flow such that it results in:

- At least a 1km road stretch
- Exhibiting vehicle speeds lower than 56% of normal free-flow speed AND
- Causing a delay of more than 90 seconds to a road user at this moment in time

If each of these criteria is met, TomTom classifies the segment as congested – and this situation can vary with each update each minute. The congestion threshold has been set at this level as customer research suggests this gives the best user experience. There is no global standard for jam threshold however, so different traffic services may publish some jams that others do not consider significant.

TomTom uses this data to check if the congestion messages that were sent out were correct – to provide a quality measure and to help improve the system for the future. This is done by comparing per segment the ground truth data with the message sent to users in a similar way to the BMW QKZ1 and QKZ2 quality system:

- If analysis of the ground truth data shows congestion on a road segment which was also reported in the real time traffic system - TomTom records a jam "hit" in the quality system.
- If the ground truth indicates a jam where the real time traffic system reported nothing, TomTom records a "miss" in the quality system.
- If the real time traffic system reported a jam where there is no evidence to support that there really was a jam in the ground truth data, this is recorded as a "ghost jam or error".

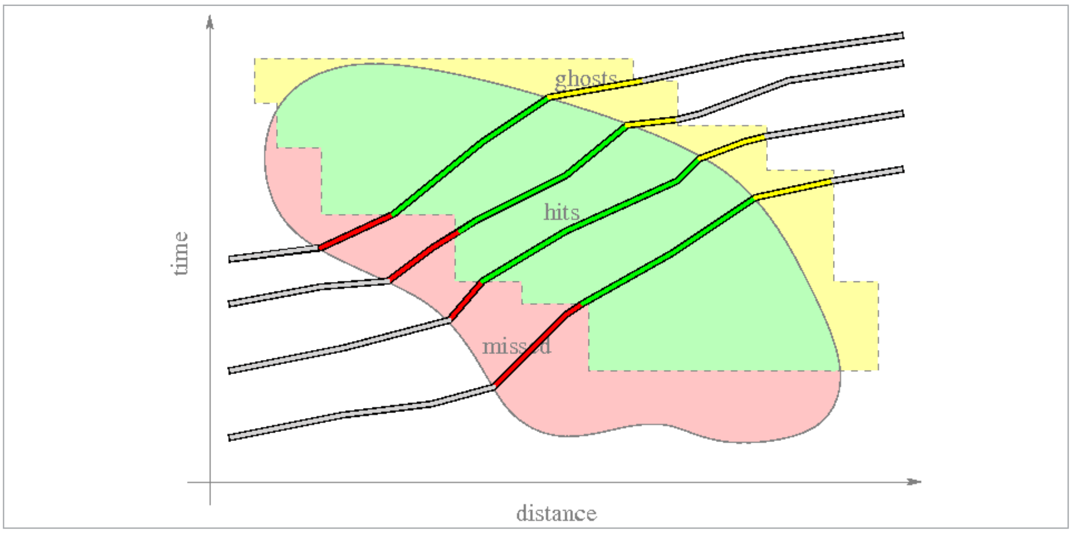


Figure 4: Image illustrating the definition of hits, misses and ghosts in the traffic quality system.

In the time distance chart above in figure 4 (where y-axis = time and x-axis = distance) this comparison is explained in more detail. The traffic messages sent out are represented by the dotted line (the course block shape) and the actual jams on the road at the time are represented by the oval inside the solid line. The ground truth traces are the lines passing diagonally through the actual jam 'cloud'. A steeper ground truth trace line represents slower traffic (takes more time and covers less distance) on this particular road stretch.

- Correctly reported jams are represented by the green shading
- The time between a jam occurring on the road and the time the real time system start publishing the jam to the user (i.e. the input / fusing / publishing cycle) is counted as a 'missed jam' and is represented by the red shading
- The time between the end of the jam on the road and the time TomTom stops publishing the congestion is a ghost and is represented by the yellow shading

By measuring the hits and comparing this with ghost and missed jams we can measure the performance of the system. An example can be found in the picture below (figure 5) where we compared the TomTom Traffic system with a competitive traffic information source where:

Coverage rate is defined as:

- Number of hits (number of hits + number of misses) (equivalent to QKZ1)
- If TomTom reports 80 congestion messages but there are 100 congestion locations found in the same minute in the ground truth traces, the traffic feed has 80% coverage

Error rate is defined as

- Number of missed/ number of missed + number of hits (QKZ2)
- If TomTom reports 100 congestion messages but only 80 are found in the ground truth traces, the feed has 20% error rate (ghost congestion)

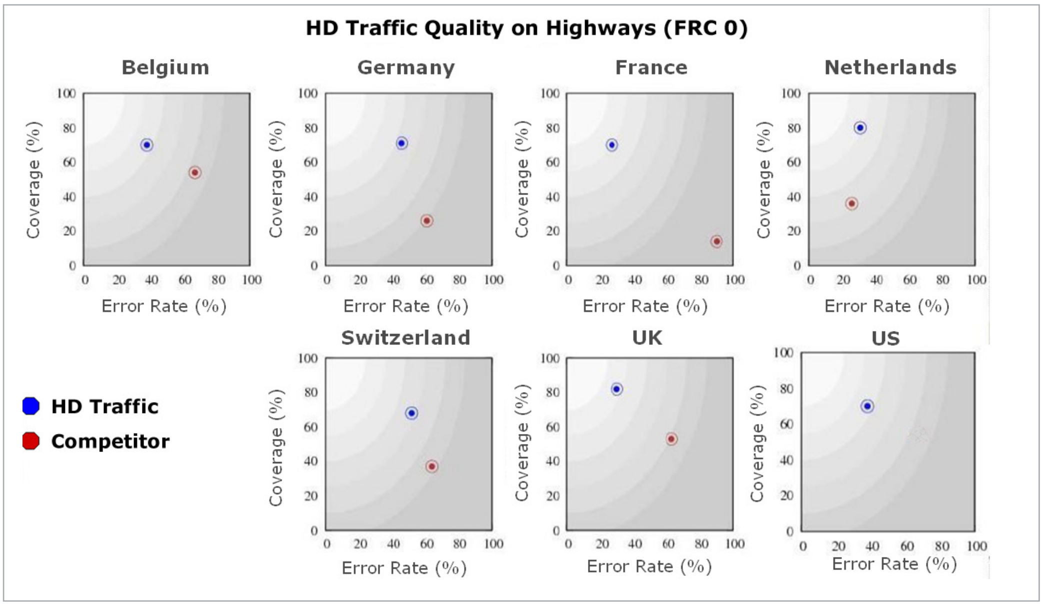


Figure 5: Sample quality report generated from TomTom internal quality system using QKZ as basis.

By automatically tuning our systems based on these analyses TomTom makes sure to deliver the best quality of traffic information available in the market to end users.

EXTERNAL QUALITY TESTING

TomTom Traffic data is also validated by the German external independent quality institute TÜV. They awarded a certificate for TomTom Traffic concluding:

- TomTom Traffic is precise and accurate
- TomTom Traffic covers highways and secondary roads

LOCATION REFERENCING SYSTEM TO DESCRIBE CONGESTION AND INCIDENTS

Good traffic information needs a precise location referencing system as the user will want to have the start of the jam displayed on the exact location where he or she is entering the congestion. Therefore in the fusion system, which is described earlier in this document, a very detailed internal map is used to locate the traffic jam very precisely.

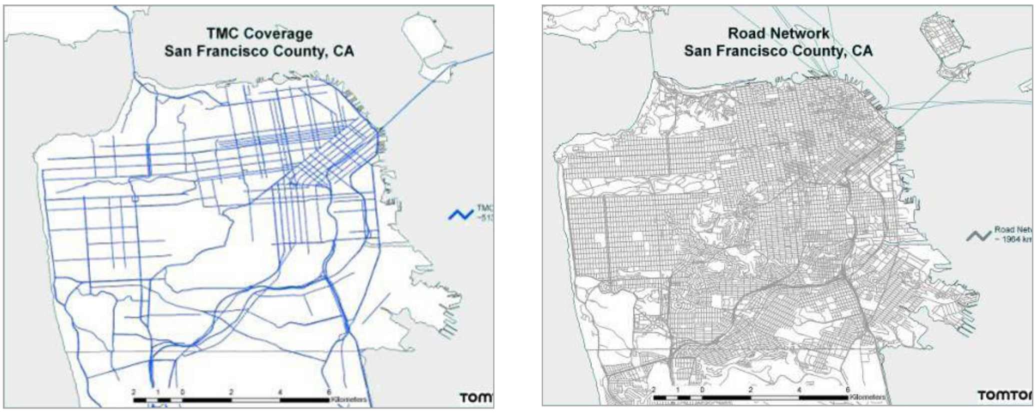


Figure 6: TMC road network of San Francisco compared to full extent of the road network.

Figure 6 shows the difference between the TMC network and the full extent of the existing road network. This clearly illustrates the limitations of the TMC road network which is restricted in the number of reference points (by the technology), and highlights the advantages that exist if it is possible to describe congestion on ANY road in the network. TomTom has developed a location referencing system, OpenLR, that is capable of accurately describing the location of congestion on ANY road.

In order to be as flexible as possible to the end users receiving traffic information TomTom support both the TMC location referencing system and OpenLR location referencing system.

TMC LOCATION REFERENCING

The best known and most widely used system to describe the location of traffic information is TMC. The location referencing method used in TMC makes use of pre-coded location tables which relate to the corresponding locations in the digital map by the map provider in a 'conflation' process.

All traffic information is related to a road stretch and the corresponding TMC location identity is found and this location reference is attached to the incident for forwarding to the user. The user system then decodes the information by looking up the relevant road segments which relate to the TMC location described.

TomTom also uses the offset information in conjunction with the TMC location reference information to more accurately describe the start and end point of the congestion. This is known as Precise TMC and particularly helps on longer TMC segments which may over 20kms.

Incident Description	TMC Link ID	Internal segm. ID
• TMC link ID • Positive or negative direction on road • Offset from start of link • Offset from end of link	09876	12345
		12346
		12349
		12462
		12675
• TMC ID = 09876 • Positive direction • + 200 yds from start • - 150 yds from end	09875	12676
		12678
		12679
		12732
		12765

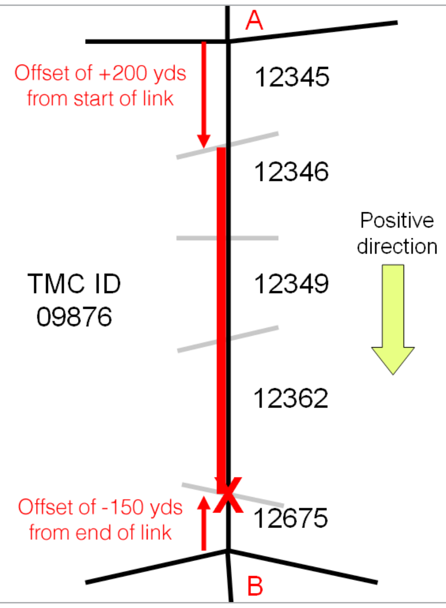


Figure 7: Simplified illustration of how TMC describes the accurate location and extent of congestion on a TMC road stretch using offset information.

By adding the direction of the traffic jam, the offset from beginning point A and ending point B a traffic jam can be located very precisely.

TMC can easily be integrated into user systems, but there are limitations to this method of location referencing:

- Because TMC cannot describe the full road network, there are locations that cannot be described using TMC (particularly on secondary roads) – so customers might miss traffic congestion that TomTom is capable of observing;
- A TMC table needs to be installed on the user device / server
- Not all countries have a certified TMC table created for the road network
- Not every map will have a conflation table for the TMC tables / versions

Although most jams occur on roads covered by the TMC road 'network', TomTom is able to observe congestion on secondary roads. Where these delays are significant, they should be made available in the feeds to navigation devices and to third party feed users.

OPENLR LOCATION REFERENCING

In most countries TomTom Traffic can deliver much more data than the network covered by TMC as can be seen in figure 8. In order to provide these messages to the end user TomTom developed Open LR which is an open standard for use by any user without license fees.

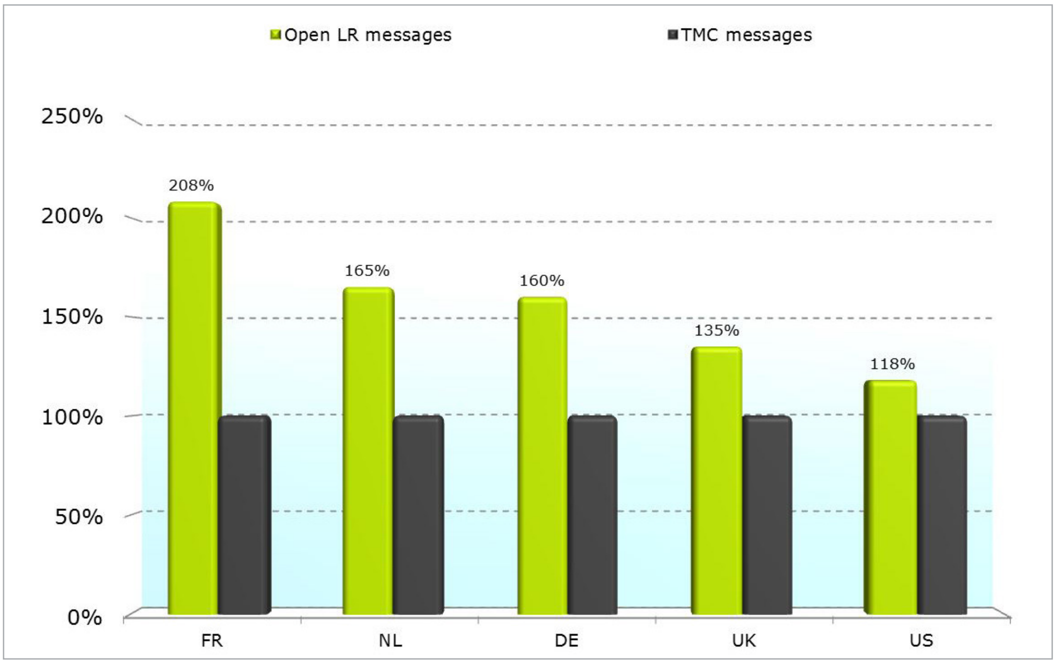


Figure 8: Illustration of increase in messages that can be published in OpenLR compared to TMC

Instead of a pre-coded road network as in TMC, the OpenLR referencing system can be related to any map and can describe any road dynamically.

The basis of OpenLR is to describe an incident / congestion location by using a series of points that when put together in sequence following the road in a 'shortest path' precisely describe the road stretch of interest. The start and end points and any intermediate waypoints to ensure the correct route is followed require a few simple facts:

- Start of incident - A:
  - Lat / Long
  - Road Attributes (FRC, Form of Way)
  - Bearing leaving
- End of incident – B:
  - Lat / Long
  - Road Attributes (FRC, Form of Way)
  - Bearing arriving
- Optional
  - Intermediate point (s):
    - Lat / Long
    - Road Attributes (FRC, Form of Way)
    - Bearing leaving

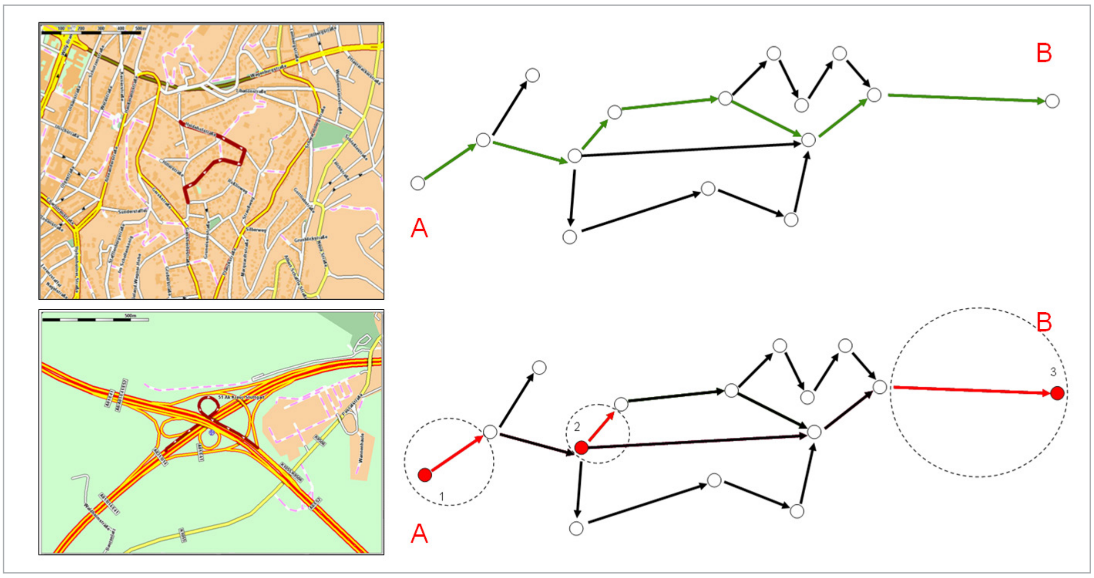


Figure 9: Illustration of OpenLR ability to describe the green route from A to B, using just A as Start, B as End and 2 as intermediate point

The principle can be described by the example in figure 9. If a jam starts at point A and ends at point B and is covering the path as displayed in the green route, it would require three points to precisely describe it. If only points A and B were described, the shortest path would not cover the correct route, so a third point (2) must be used as an intermediate.

With this technique of OpenLR to describe a path, it can be decoded onto any detailed map from any vendor and vintage so long as the road network is up to date in the relevant area. Simply communicating these three points from sender to decoder makes it easy and bandwidth consumption of the messages is very low.

For more information visit the website: http://www.openlr.org

As mentioned before, TomTom is delivering the data in both formats to be flexible to the end user, so it is possible to either receive messages in a file using TMC location referencing or a file using OpenLR format.

PRODUCTS

TomTom delivers its real time traffic data to the market in different products in order to meet user requirements in the most optimal way.

TomTom Traffic

Congestion / delay information and journalistic information describing the cause of the incident (where available).

Each file only contains information for roads with delays or incidents and is hence very compact. Files are updated every minute on the server (updates frequency to the device e.g. PND are determined by the device traffic service provider). Can be used, for example, in navigation devices.

TomTom Traffic Flow

Traffic Flow information with data in each file with speeds for all significant roads in the area – both congested roads and those performing normally (flowing freely). The file is updated every minute at the server.

Can be used, for example, in traffic control centres or navigation devices.

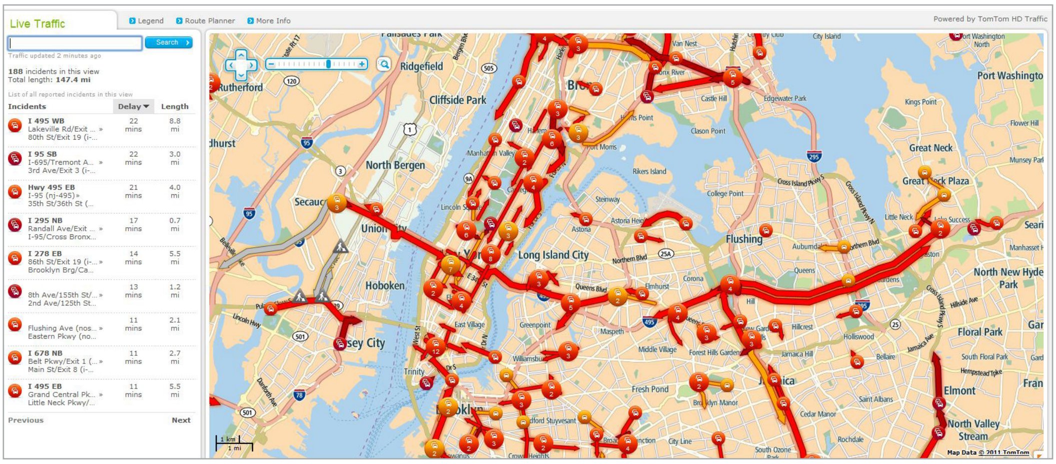
TomTom Traffic Route Times

Real time travel times for any specific customer defined road or route information refreshed every minute.

Can be used on variable message signs (VMS) to inform road users of delay information, and can be set up very quickly for temporary or long term use.

TOMTOM TRAFFIC

TomTom Traffic is a bulk feed of traffic information that comprises the same traffic components as used in TomTom PNDs. The primary uses of this type of data are for dynamic routing in navigation or routing engines – to continuously update the fastest route and ETA using real time traffic and travel times to add the correct time penalties to each alternative route option.



To address this use case, TomTom Traffic contains information on roads that are exhibiting delay characteristics or information on incidents. It will include data on roads that have delays compared to the speed normally experienced at that time of day, but it will not include data for a road that is behaving normally. In this way the file can be kept compact so that it can be transmitted efficiently to an on-board navigation device that can then process the relevant data quickly and make changes accordingly for dynamic routing / re-routing if necessary.

Every minute an xml feed can be retrieved from the TomTom server. TomTom uses the Datex2 standard format to deliver the real time data to the end user. The TomTom Traffic feed will return a list of incidents including:

- LOS data: Traffic incidents including speed and delay
- NON LOS data: Incidents such as road closures, road works and closed lanes

A typical message will contain information on:

- Start point of incident
- End point of incident
- Length of the incident
- Delay for users of the road stretch caused by the incident (if there is congestion)
- Cause of the incident (if applicable)
- Jam tendency (getting worse, stable, improving)
- Expected duration of the jam

Overview:

- Bulk feed can be retrieved from the TomTom server every minute
- Traffic delays & incidents are described in XML / Datex II standard format
- Information is positioned on map using local TMC table as location referencing system or using OpenLR to offer extended coverage on secondary roads
- Only roads with incidents are included in file updates

Sample output XML:

<?xml version="1.0" ?>
- <d2LogicalModel xmlns="http://datex2.eu/schema/1_0/1_0" modelBaseVersion="1.0">
- <exchange>
- <supplierIdentification>
<country>nl</country>
<nationalIdentifier>TomTom Tele Atlas TomTom Traffic Service</nationalIdentifier>
</supplierIdentification>
</exchange>
- <payloadPublication xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:type="SituationPublication" lang="en">
<publicationTime>2011-05-31T18:54:50+02:00</publicationTime>
- <publicationCreator>
<country>other</country>
<nationalIdentifier>f35a3f11-e538-4d54-871b-3f11c36d7f0d</nationalIdentifier>
</publicationCreator>
- <situation id="TTI-f35a3f11-e538-4d54-871b-3f11c36d7f0d-TTL2588084">
- <headerInformation>
<confidentiality>internalUse</confidentiality>
<informationStatus>real</informationStatus>
<urgency>urgent</urgency>
</headerInformation>
- <situationRecord xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:type="AbnormalTraffic" id="TTI-f35a3f11-e538-4d54-871b-3f11c36d7f0d-TTL2588084-1">
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- <validity>
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- <comment>
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- <groupOfLocations>
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- <alertCLinear xsi:type="AlertCMethod4Linear">
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- <alertCDirection>

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- <alertCLocation>
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- <offsetDistance>
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- <situationRecordExtension>
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</situationRecordExtension>
<abnormalTrafficType>stationaryTraffic</abnormalTrafficType>
- <abnormalTrafficExtension>
<averageSpeed>7.0</averageSpeed>
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</situationRecord>
</situation>

TOMTOM TRAFFIC FLOW

TomTom Traffic Flow is a bulk feed of traffic information that comprises data for the current flow speed for all significant road stretches. The primary uses of this type of data are for traffic management and control centres to visualise the state of their road network, or for dynamic routing in navigation or routing applications to facilitate faster routes and better ETAs.

To address these use cases, the file contains speed values and delays across every significant road stretch (e.g. all TMC roads, or all roads in FRC 0 to FRC 4 on MultNet map). TomTom Traffic Flow is a larger file than TomTom Traffic due to the richness of the data.

Characteristics and format for each TomTom Traffic Flow file:

The data which can be retrieved from the server is generated directly from the TomTom real time traffic system. There are a number of file formats offered for TomTom Traffic Flow: XML using Datex2, FastInfoset, Protobuf

It is possible to request compressed files for quicker download and it is possible only to download the information on road segments with speed below 80% of free flow which further limits the data file size.

The content for each published road segment is:

- The identity of the published road segment (including a direction indicator)

If the current speed is less than 80% of free-flow speed the file contains the:

- Current total travel time across the published road segment (the summation of travel times from each component road segments that make up the published road segments in the case of TMC) and
- Current average speed across the published road segment
- If the current speed is 80% of free flow speed the file contains the:
- Free flow travel time for the published road segment (i.e. the travel time which would be expected under ideal free flow conditions)
- The free flow speed for the published road segment
- The quality index (calculated from a number of factors including number of observations, age, etc.)

The roads included in the feed for specific customers can be a sub-set of the complete country file (e.g. just a city within a bounding box or only the main roads for a country).

TOMTOM TRAFFIC ROUTE TIMES

TomTom Traffic Route Times is a feed of traffic information that comprises data for the current travel time and delays for a specific user-defined route. The primary uses of this type of data are for:

- Traffic management and control centres to provide drivers with information on best route where there are alternatives so that they are able to make the best use of the road network (fastest times to destination) – generally using roadside variable message signs (VMS).
- Event management companies to provide visitors or local road users information about the best routes to or from an event to help ease the traffic bottlenecks
- Corporate offices or information kiosks to provide travel times for visitors / customers / staff to popular destinations such as an airport or train station

To address these use cases, the file contains the current travel time across the route, and the delay time compared to the normal travel time for that route at that specific time of day, and is refreshed every minute.

Each TomTom Traffic Route Times file placed on the TomTom server can be collected from a dedicated url using an approved API key. The user server that collects the file must have the external IP address white-listed on the TomTom firewall.

Characteristics and format for each TomTom Traffic Route Times file:

An example of output (for a VMS sign with two alternative routes):

```
<vmsResponse name=”” version=”0.62.5”>
<vmsRoute travelDistanceMeters=”43721” trafficDelaySeconds=”747” totalTimeSeconds=”2516” id=”Via_E19/A1”/>
<vmsRoute travelDistanceMeters=”40294” trafficDelaySeconds=”1707” totalTimeSeconds=”3869” id=”Via_A12”/>
</vmsResponse>
```

The published content for each specified route is:

- Total route length in metres (the same static value in each file as a reference)
- The current predicted total travel time for the route (seconds)
- The current total delay time[1] on the route (seconds). This is the summation of any current delays on each of the component road segments that comprise the route.

The published travel time in each of the routes is constructed from:

- Each component road segment **without** observed congestion has the predicted (Speed Profiles[2]) travel time associated to it
- Each component road segment **with** observed congestion has the observed travel time associated to it

To create a route for reporting in TomTom Traffic Route Times, the user defines the start point, the end point and as many intermediate via points as necessary to ensure the desired route is taken by the TomTom routing engine.

New routes or edits agreed with the user can be uploaded to the TomTom traffic information system within an hour and the customer can then start downloading the data. This quick turnaround time has been established to ensure that the route times can be used for temporary or emergency situations (e.g. extreme weather).

[1] The delay time is the excess time to travel the road segment compared to the predicted travel time for the day and time of day

[2] Speed Profiles provides the predicted travel time for the component road segment for the specific day and time of the day (5 minute period)

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