DATA & FORMAT for MOBILITY OFFER & DEMAND

Corso di: Big Data Architectures

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Statistics

Statistical data include **surveys**, **reports**, **census information**

Can be used to obtain a description of the

- Population, according to gender, age, wealth
- Vehicle models, motorizations, registration dates
- Distribution of urban services
- …

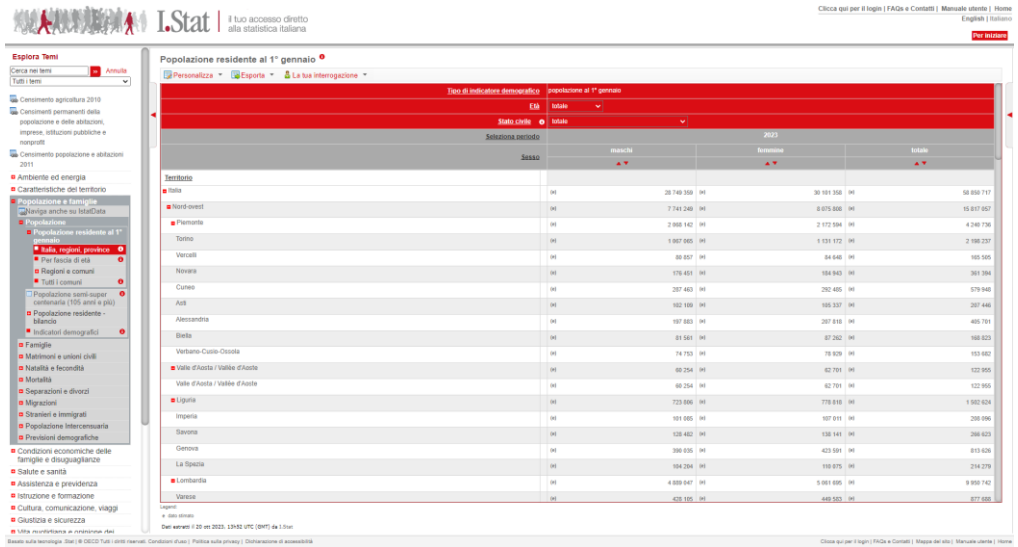
Statistics are particularly useful to **compute the KPIs** → SUMI, PUMS

Statistical data are mainly distributed by **national institute of statistics**

Statistics

In Italy we can use the ISTAT portal (https://www.istat.it/)

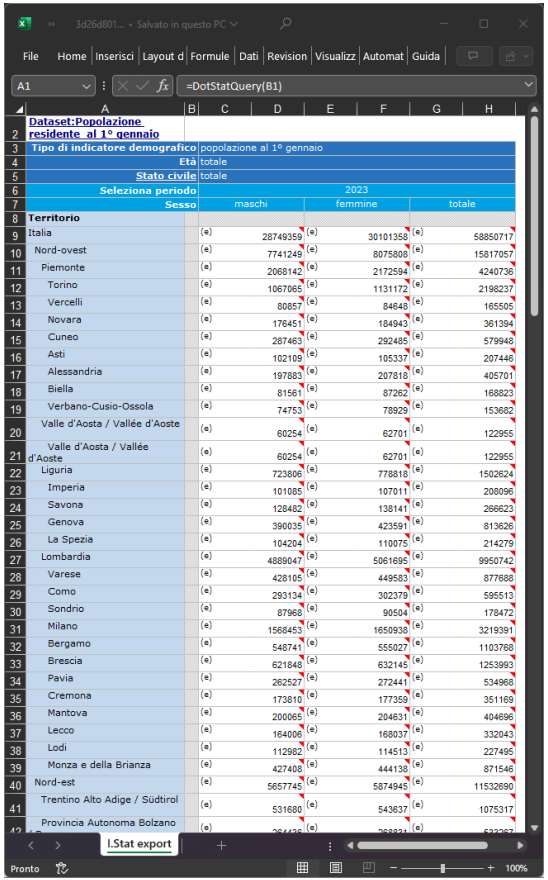
The portal I.Stat (http://dati.istat.it/) let to search and download data about different categories



Statistics

Data can be exported in different formats

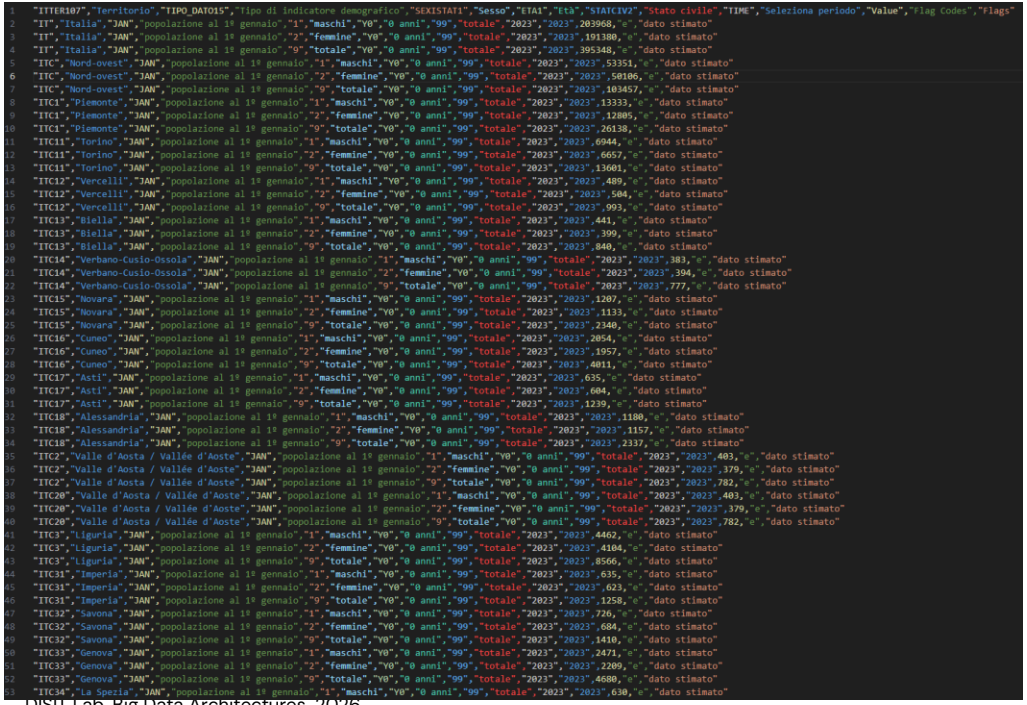
- Microsoft Excel



Statistics

Data can be exported in different formats

- Microsoft Excel
- CSV

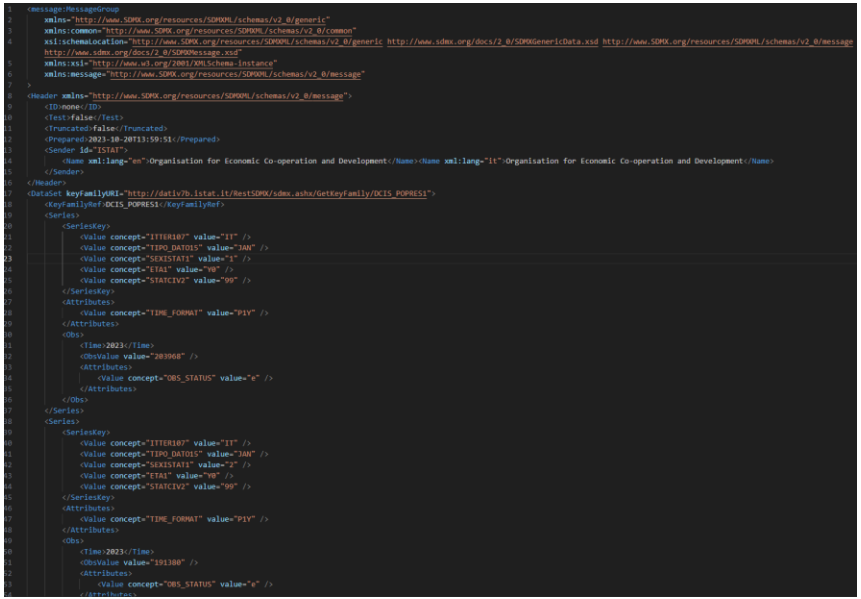


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```

Statistics

Data can be exported in different formats

- Microsoft Excel
- CSV
- SDMX (Statistical Data and Metadata eXchange),
  - see https://sdmx.org/
  - ISTAT seems to implement the SDMX-ML based on XML



Mobility offer

The mobility offer includes all the available **public mobility services** offered by public or private companies

- Bus
- Tram
- Train
- Ferry
- Bike sharing
- Car sharing
- Scooter sharing
- Taxi
- Car hailing (e.g., Uber, Lyft)



Mobility offer – Public transport

For the public transports (bus, tram, etc.) a mobility offer must include

- Routes, that are the trajectories covered with indication of the stops
- Trips, that are the specific instances of a route at given time with give schedule

This and other information are distributed from the transport operator using standards like **GTFS/GTFS-RT** and **NeTEx/SIRI**

Mobility offer – GTFS Schedule (static)

The **General Transit Feed Specification (GTFS)** is an Open Standard used to distribute information about transit systems

It is composed by **a list of CVS text files** archived in a zip file

The text file list includes:

- agency.txt: info on the transit operator
- stops.txt: stop list
- ruotes.txt: route list
- trips.txt: trip list for each route
- stop_times.txt: arrival and departure times for each stop and each trip
- calendar.txt / calendar_dates.txt: working days and exceptions
- shapes.txt: lat/long coordinate to draw the routes on a map
- fare_attributes.txt: prices of the service
- …

Mobility offer – GTFS Schedule (static)

routes.txt

route_id,agency_id,route_short_name,route_long_name,route_type,route_color,route_text_color
"2182839646","303","T1.3","Servizio Tramvia Firenze - Linea T1.3","0","D86018","000000"
"3209345033","303","T2","Servizio Tramvia Firenze - Linea T2","0","D86018","000000"

trips.txt

route_id,service_id,trip_id,trip_headsign,trip_short_name,direction_id,shape_id
"2182839646","4527_593642","4527_549189","Careggi - Ospedale","","0","2182839646"
"2182839646","4527_593642","4527_549190","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549191","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549192","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549193","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549194","Villa Costanza","","1","978952710"

stops.txt

stop_id,stop_name,stop_lat,stop_lon,stop_code
"FM9004_103","De Andre","43.7547865043581","11.1790362683518","FM9004"
"FM9005_103","Resistenza","43.7579847316209","11.1822112945389","FM9005"
"FM9006_103","Resistenza","43.7580441494077","11.1822068713052","FM9006"
...
"FM9035_103","Vittorio Emanuele Ii","43.7958712112307","11.2415139153139","FM9035"
"FM9036_103","Morgagni-Universita","43.7995953955465","11.2439861801234","FM9036"
"FM9037_103","Careggi - Ospedale","43.8033027414408","11.2465976104274","FM9037"

stop_times.txt

trip_id,arrival_time,departure_time,stop_id,stop_sequence,shape_dist_traveled
"4527_549189","05:29:00","05:29:00","FM9004_103","1","0"
"4527_549189","05:30:00","05:30:00","FM9006_103","2",".44279"
"4527_549189","05:32:00","05:32:00","FM9008_103","3","1.04775"
"4527_549189","05:34:00","05:34:00","FM9010_103","4","1.93364"
"4527_549189","05:36:00","05:36:00","FM9012_103","5","2.96611"
"4527_549189","05:37:00","05:37:00","FM9014_103","6","3.46874"
"4527_549189","05:38:00","05:38:00","FM9016_103","7","4.00089"
"4527_549189","05:40:00","05:40:00","FM9018_103","8","4.34465"
"4527_549189","05:41:00","05:41:00","FM9020_103","9","4.66609"
"4527_549189","05:42:00","05:42:00","FM9022_103","10","4.98182"
"4527_549189","05:43:00","05:43:00","FM9024_103","11","5.41694"
"4527_549189","05:45:00","05:45:00","FM9026_103","12","6.08557"
"4527_549189","05:49:00","05:49:00","FM9027_103","13","6.92863"
"4527_549189","05:51:00","05:51:00","FM9028_103","14","7.3331"
"4527_549189","05:54:00","05:54:00","FM9029_103","15","7.84536"
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"4527_549189","05:59:00","05:59:00","FM9032_103","18","8.9197"
"4527_549189","06:00:00","06:00:00","FM9033_103","19","9.29738"
"4527_549189","06:02:00","06:02:00","FM9034_103","20","9.66363"
"4527_549189","06:04:00","06:04:00","FM9035_103","21","10.00552"
"4527_549189","06:06:00","06:06:00","FM9036_103","22","10.53703"
"4527_549189","06:08:00","06:08:00","FM9037_103","23","11.03527"

Mobility offer – GTFS Schedule (static)

routes.txt

```
route_id,agency_id,route_short_name,route_long_name,route_type,route_color,route_text_color
"2182839646","303","T1.3","Servizio Tramvia Firenze - Linea T1.3","0","D86018","000000"
"3209345033","303","T2","Servizio Tramvia Firenze - Linea T2","0","D86018","000000"
```

trips.txt

```
route_id,service_id,trip_id,trip_headsign,trip_short_name,direction_id,shape_id
"2182839646","4527_593642","4527_549189","Careggi - Ospedale","","0","21828396[illegible]"
"2182839646","4527_593642","4527_549190","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549191","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549192","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549193","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549194","Villa Costanza","","1","978952710"
```

stops.txt

```
stop_id,stop_name,stop_lat,stop_lon,stop_code
"FM9004_103","De Andre","43.7547865043581","11.1790362683518","FM9004"
"FM9005_103","Resistenza","43.7579847316209","11.1822112945389","FM9005"
"FM9006_103","Resistenza","43.7580441494077","11.1822068713052","FM9006"
...
"FM9035_103","Vittorio Emanuele Ii","43.7958712112307","11.2415139153139","FM9035"
"FM9036_103","Morgagni-Universita","43.7995953955465","11.2439861801234","FM9036"
"FM9037_103","Careggi - Ospedale","43.8033027414408","11.2465976104274","FM9037"
```

stop_times.txt

```
trip_id,arrival_time,departure_time,stop_id,stop_sequence,shape_dist_traveled
"4527_549189","05:29:00","05:29:00","FM9004_103","1","0"
"4527_549189","05:30:00","05:30:00","FM9006_103","2",".44279"
"4527_549189","05:32:00","05:32:00","FM9008_103","3","1.04775"
"4527_549189","05:34:00","05:34:00","FM9010_103","4","1.93364"
"4527_549189","05:36:00","05:36:00","FM9012_103","5","2.96611"
"4527_549189","05:37:00","05:37:00","FM9014_103","6","3.46874"
"4527_549189","05:38:00","05:38:00","FM9016_103","7","4.00089"
"4527_549189","05:40:00","05:40:00","FM9018_103","8","4.34465"
"4527_549189","05:41:00","05:41:00","FM9020_103","9","4.66609"
"4527_549189","05:42:00","05:42:00","FM9022_103","10","4.98182"
"4527_549189","05:43:00","05:43:00","FM9024_103","11","5.41694"
"4527_549189","05:45:00","05:45:00","FM9026_103","12","6.08557"
"4527_549189","05:49:00","05:49:00","FM9027_103","13","6.92863"
"4527_549189","05:51:00","05:51:00","FM9028_103","14","7.3331"
"4527_549189","05:54:00","05:54:00","FM9029_103","15","7.84536"
"4527_549189","05:56:00","05:56:00","FM9030_103","16","8.339"
"4527_549189","05:57:00","05:57:00","FM9031_103","17","8.61417"
"4527_549189","05:59:00","05:59:00","FM9032_103","18","8.9197"
"4527_549189","06:00:00","06:00:00","FM9033_103","19","9.29738"
"4527_549189","06:02:00","06:02:00","FM9034_103","20","9.66363"
"4527_549189","06:04:00","06:04:00","FM9035_103","21","10.00552"
"4527_549189","06:06:00","06:06:00","FM9036_103","22","10.53703"
"4527_549189","06:08:00","06:08:00","FM9037_103","23","11.03527"
```

Mobility offer – GTFS-RT (RealTime)

The GTFS-RT is a feed specification that allows public transportation agencies to **provide real-time updates** about their fleet

Provide three types of real-time updates to users:

- **Trip updates** - delays, cancellations, changed routes
- **Service alerts** - stop moved, unforeseen events affecting a station, route or the entire network
- **Vehicle positions** - information about the vehicles including location and congestion level

Feeds are served via HTTP as binary files based on Protocol Buffers

Mobility offer – NeTEx

The **Network Timetable Exchange standard** is intended to be a general-purpose XML format designed for the exchange of transport data

NeTEx is the first standard that also covers multimodal fares

NeTEx includes

- Schedules
- Stops
- Routes
- Service days
- Fares

Mobility offer – NeTEx

NeTEx is described in six parts

- Part 1: Public transport network topology exchange format
- Part 2: Scheduled timetables exchange format
- Part 3: Fare information exchange format

Transport system description

- Part 4: Passenger Information European Profile (EPIP)
- Part 5: Alternative modes exchange format
- Part 6: European Passenger Information Accessibility Profile (EPIAP)

Extend NeTEx towards:
Multimodal +
Passenger-centric +
Accessible mobility information

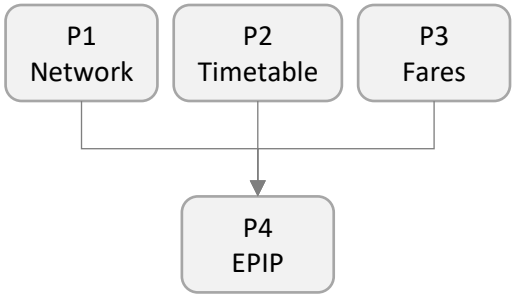
NeTEx is based on the **Transmodel conceptual model** and provides a **standardised XML-based** exchange format for public transport and related mobility information.

More info:
https://netex-cen.eu/
https://github.com/entur/profile-examples

NeTEx Part 4 — EPIP

European Passenger Information Profile (EPIP) selects and constrains NeTEx elements to **facilitate interoperable exchange across European systems**

Part 4 does **not define new transport concepts.** It selects and constrains existing NeTEx concepts **for a specific use case**. It provides a common European profile suitable for **passenger information** and **journey planning**



Examples of information covered

- Passenger-facing service and journey information
- Information about stops, services and facilities relevant to passengers
- Accessibility and other information needed to present transport services to passengers

NeTEx Part 5 — Alternative Modes

Extends NeTEx beyond conventional public transport, providing a common exchange format for **alternative and shared mobility services**. Supports the integration of alternative modes with public transport in multimodal mobility services and **MaaS**

Main information

- Mobility services and their operators
- Vehicles and available equipment
- Sharing/rental stations and locations
- Areas of permitted use and geofencing
- Products and prices
- Information needed for multimodal journey planning

🚲 Bike sharing
🚗 Car sharing
👥 Carpooling
🚲 Bicycle rental
🚗 Car rental
...

NeTEx Part 6 — Accessibility Profile

Defines a European profile for exchanging accessibility information to enables passenger information systems to describe accessibility conditions consistently

- Accessibility of stops and stations
- Accessible entrances and facilities
- Access paths and connections
- Accessibility of vehicles and boarding/alighting
- Equipment and facilities supporting passengers with reduced mobility
- Accessibility limitations and conditions

NeTEx vs GTFS — Adoption

GTFS

- De facto **global standard** for public transport schedule data
- Used by t**housands of transit agencies** worldwide
- **Strong ecosystem** of journey planners, mapping services and mobility applications
- Particularly widespread in North America and internationally

NeTEx

- European CEN standard based on Transmodel
- Strongly adopted in Europe, especially for **National Access Points** (NAPs)
- Required/recommended as the European exchange standard for static multimodal travel data
- **Richer and more comprehensive model, but more complex than GTFS**

Many European transport authorities and operators provide **both NeTEx and GTFS**

NeTEx and GTFS are therefore often **complementary rather than competing standards**

Conversion between the two is possible, but some information may not map one-to-one

Mobility offer – SIRI

SIRI is a standard for exchanging **real-time information about public transport services** between computer systems.

It **complements NeTEx**, which primarily supports the exchange of static transport data (networks, stops, scheduled timetables).

Messages are encoded in **XML**, with structures and elements defined by the SIRI XML schemas.

SIRI supports both **request/response** communication and **subscription-based publish/subscribe** communication.

Examples of real-time information

- Vehicle positions and estimated arrival times
- Real-time departures and arrivals
- Service disruptions and delays
- Changes to vehicle journeys and operating conditions

SIRI and **GTFS-RT** serve a similar purpose but follow different approaches:

- SIRI defines real-time information exchange services and XML messages,
- GTFS-RT defines a standardized data format for publishing real-time updates, typically through HTTP feeds.

Mobility offer – Shared Mobility

Shared mobility services generally do not rely on fixed routes or scheduled trips; therefore, **real-time vehicle availability and location** are particularly important.

Static data remain relevant, including service areas, stations, vehicle types, pricing and operating rules.

Two important standards for shared mobility data are:

- **General Bikeshare Feed Specification (GBFS):** provides public, near-real-time information about shared vehicles and their availability.
- **Mobility Data Specification (MDS):** supports data exchange between mobility operators and public authorities for service monitoring and regulation.



Mobility offer – GBFS & MDS

GBFS — User-oriented information

- Provides publicly accessible data about shared mobility services.
- Supports journey planning, vehicle discovery and checking availability.
- Typically exposes vehicle and station information through JSON feeds.

MDS — Operator–authority data exchange

- Defines APIs for exchanging data between mobility providers and public authorities.
- Supports operational monitoring, regulatory oversight and policy enforcement.
- Can include real-time vehicle information and trip-related data, depending on the APIs and implementation.

Potential benefits

- A clearer picture of the availability and spatial distribution of shared mobility services.
- Better understanding of service usage and mobility patterns, subject to data availability, quality and privacy constraints.

Adoption and implementation vary across countries and cities; the availability of data is not uniform.

Mobility offer – GBFS

Main GBFS feeds (GBFS 3.0)

`gbfs.json` — Discovery file containing links to the available feeds.

`system_information.json` — General information about the service and its operator.

`vehicle_types.json` — Types and characteristics of available vehicles.

`station_information.json` — Station locations and capacities, for station-based services.

`station_status.json` — Current station status, including available vehicles and docks.

`vehicle_status.json` — Locations and status of vehicles available for rental; required for free-floating services.

`system_pricing_plans.json` — Pricing plans.

`system_alerts.json` — Current service alerts.

`geofencing_zones.json` — Operating zones and associated rules.

Key characteristics

- Separates relatively static information from frequently updated availability data.
- Designed for public access and integration into user-facing applications.
- Does not expose vehicles that are currently being rented in the vehicle availability feed, helping protect user privacy.

Mobility offer – GBFS

gbfs.json


```
{
  "last_updated": 1698165756,
  "ttl": 0,
  "version": "2.2",
  "data": {
    "en": {
      "feeds": [
        {
          "name": "gbfs_versions",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/gbfs_versions.json"
        },
        {
          "name": "system_information",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/system_information.json"
        },
        {
          "name": "vehicle_types",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/vehicle_types.json"
        },
        {
          "name": "station_information",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/station_information.json"
        },
        {
          "name": "free_bike_status",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/vehicle_status.json"
        },
...
```


vehicle_status.json


```
{
  "last_updated": 1698166031,
  "ttl": 0,
  "version": "2.2",
  "data": {
    "bikes": [
      {
        "bike_id": "X8CS5R",
        "lat": 43.788457,
        "lon": 11.271341,
        "is_reserved": false,
        "is_disabled": true,
        "vehicle_type_id": "moped",
        "rental_uris": {
          "android": "https://...
          "ios": "https://...
        },
        "last_reported": 1660338193,
        "current_range_meters": 13.5,
        "pricing_plan_id": "price_moped"
      },
...
```

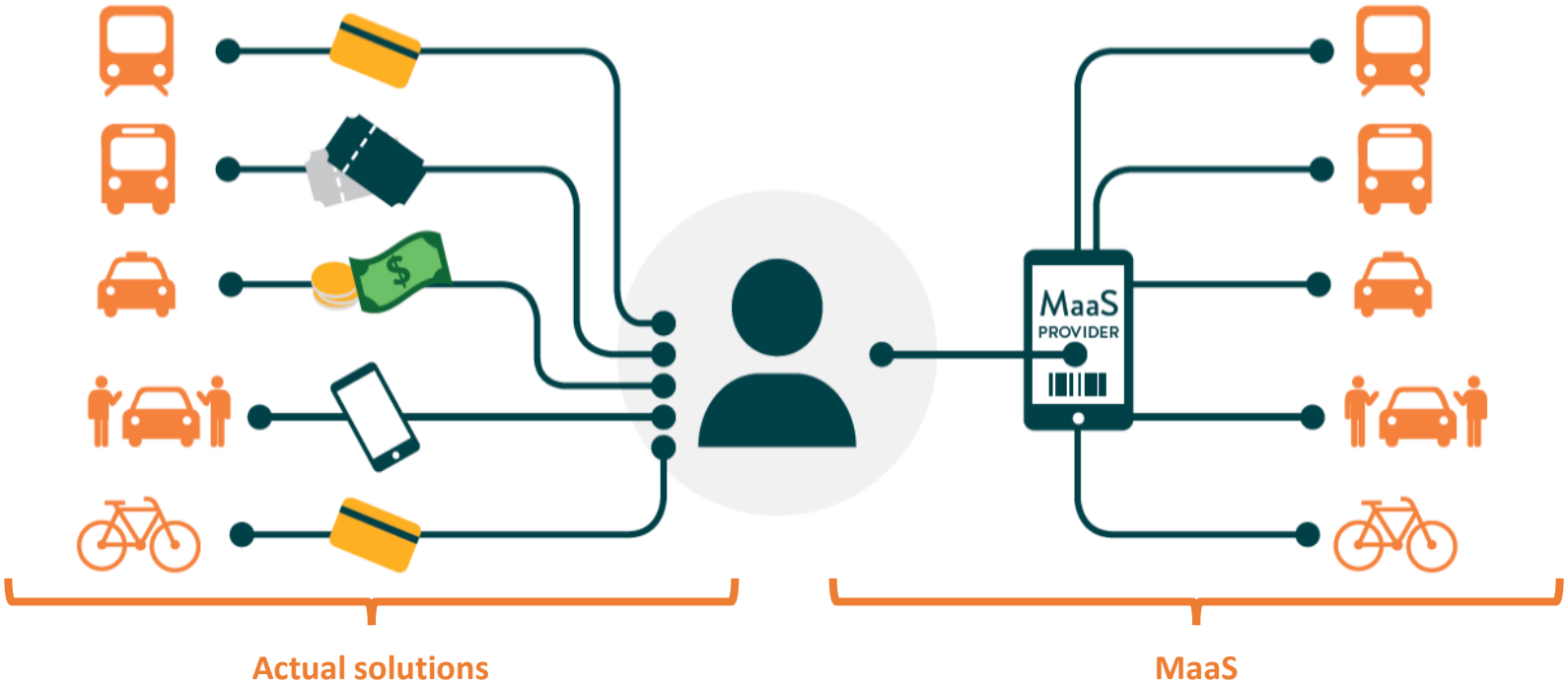
MaaS – Mobility as a Service

MaaS **integrates the whole mobility offer**, and constitute the main interface (via dedicated apps) for the user to access to the transport services

- Integrates public and private mobility services
- Provide multimodal urban and extra-urban travel solutions
- Offers service to plan, book, pay, and use mobility solutions

Mobility-as-a-Service technologies could provide a valuable source of information

MaaS



MaaS Levels

Level 0: No integration

Each mobility operator provide to the user his specific offer, using his app/website. The user must provide for himself to plan, book, and pay his travels

MaaS Levels

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

A first level of integration. A single app/website can provide the user with a multimodal travel solution and give to the user information on pricing (maybe link to the mobility operator payment service). The user still must book/pay his travels independently.

MaaS Levels

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

At this level the system provides an integrated travel solution that the user can book or pay directly from the MaaS app/website. The MaaS acts as a fare collector and then redistributes the payments to the involved mobility operator. The MaaS handle ticketing and vehicle access.

MaaS Levels

Level 3: Full integration of services, including subscriptions, passes, best-fares, bundled offers

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

With the full MaaS integration, the system is able to provide the user with bundled offers, including subscriptions and best-fares

MaaS Levels

Level 4: Integration of social goals though public-private cooperation, rewards, and incentives

Level 3: Full integration of services, including subscriptions, passes, best-fares, bundled offers

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

Finally, using rewards and incentives the Public Administrations can drive the change towards more sustainable and green mobility solutions with the aim to avoid the use of private cars

Transport Operator to MaaS API

TOMP-API (Transport Operator to MaaS Provider API) is an open API specification enabling interoperable communication between Transport Operators (TOs) and MaaS Providers (MPs) to connect journey planning with booking and actual service use.

Main functional modules

- **Offers:** search for available mobility services and obtain offers.
- **Purchase:** book or purchase services and mobility packages.
- **Execution:** manage trip legs, including starting, pausing and ending a service.
- **Support & After-sales:** handle operational issues, notifications and payment-related processes.

Complements data standards such as **NeTEx, GTFS and GBFS**, which describe transport services and availability rather than the complete booking and execution workflow.

Technical characteristics

REST API:
HTTP-based requests and responses, with JSON data structures.
OpenAPI specification:
machine-readable API definition supporting implementation and integration.
Modular architecture:
implementations can select the modules and endpoints relevant to their services.
Bidirectional communication:
supports interactions between MaaS platforms and transport operators.

MaaS as demand data sources

MaaS platforms can collect information about **travel demand and mobility patterns**, based on trip searches, bookings and journeys performed through the platform.

When shared with public authorities, appropriately aggregated and anonymised data can support **mobility analysis, transport planning and smart mobility platforms**.

Mobility Demand – Data Sources

Mobility demand describes **who travels, where, when, how and for what purpose**. It cannot usually be observed directly and must be estimated from multiple data sources.

- **Mobile devices:** mobile network records and smartphone location data.
- **Vehicle-based data:** GPS traces, connected vehicles and vehicle probe data.
- **Public transport transactions:** smart cards and automatic fare collection systems.
- **Traffic monitoring systems:** traffic counters, cameras and automatic passenger counters.
- **Surveys and digital traces:** travel surveys, travel apps and selected social media data.

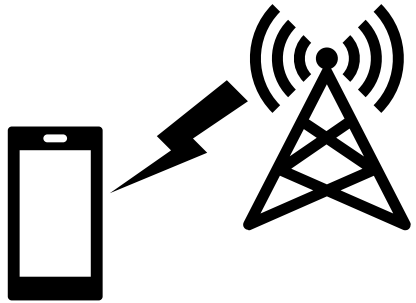
Key challenges

- Data availability, cost and access restrictions.
- Spatial and temporal resolution.
- Representativeness of the observed population.
- Privacy, data protection and interoperability.

Mobility Demand – Mobile Network Data

Mobile network operators can derive mobility indicators from mobile devices connected to their networks.

Operators collect (aggregated) **device connections to cellular base stations**.



Useful for

- Regional and inter-urban mobility analysis.
- Commuting patterns and temporal variations in travel demand.
- Analysis of large-scale population movements.

Limitations

- Spatial accuracy depends on network configuration and the type of data available.
- Observations are not continuous GPS trajectories.
- False or missed movement possible

Mobility Demand – Smartphone Location Data

Smartphones and **mobile applications** can provide location observations that help reconstruct mobility patterns.

- GPS and other location services can provide geographically detailed position observations.
- Navigation, journey-planning and mobility applications may collect location data during app use, subject to their permissions and policies.
- Repeated observations can be processed to infer trips, routes, travel times and activity locations.

Can provide information of urban mobility analysis at **fine spatial and temporal scales**.

Limitations

- Coverage is limited to participating users and applications.
- Sampling and demographic biases can affect representativeness.
- Location accuracy and observation frequency vary.
- Data access is often commercial and subject to privacy and contractual restrictions.

Mobility Demand – Vehicle-Based Data

Vehicles can act as mobile sensors, generating data about their position, movement and operating conditions via **GPS / GNSS traces, On-board units (OBUs)**, and **Roadside sensors and V2X** infrastructures.

Potential applications

- Traffic flow and route choice analysis.
- Travel-time estimation and congestion monitoring.
- Origin and destination inference from vehicle trajectories.
- Monitoring of connected and automated mobility.



Limitations

- Data coverage depends on the equipped fleet and participating providers.
- Vehicle movements do not necessarily represent person trips or occupancy.
- Access may be restricted by vehicle manufacturers, fleet operators or data providers.

Mobility Demand – Vehicle Data Standards

Several standards and interfaces support the representation and exchange of vehicle-related data.

- **Abstract Syntax Notation 1 (ASN.1)** is a standard interface description language (IDL) for defining data structures that can be serialized and deserialized in a cross-platform way, more recently adopted for V2X communications
- **SENSORIS** is a global standardized interface to exchange information between in-vehicle sensors and a dedicated cloud, as well as between clouds. It enables real-time, cloud-based information services that support mobility and automated driving
- **Extended Vehicle (ExVe)** is a concept that allows external service providers to access vehicle data and functions via a standardized interface
- **Open Diagnostic Data Exchange (ODX)** is a standard that defines a common data format for exchanging diagnostic data between vehicle manufacturers, suppliers, and service providers

These standards and interfaces support data generation, representation or exchange; they do not, by themselves, provide a complete mobility-demand dataset.

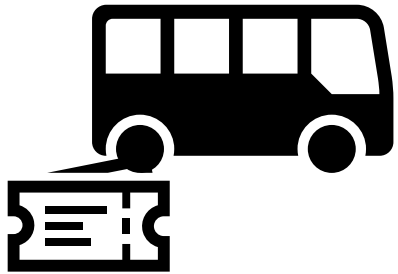
Mobility Demand – Smart Cards and Ticketing Data

Automatic Fare Collection (AFC) systems record passenger transactions when travellers validate tickets or smart cards, collecting **identifier**, **timestamp**, **station**, **stop or boarding location**.

Entry-only systems record boarding or entry; **entry–exit** systems can also record alighting or exit. Trip chaining and destination inference may be needed to reconstruct complete journeys.

Limitations

- Not all passengers use an identifiable electronic ticket.
- Entry-only systems do not directly record the destination.
- Transfers and linked journeys may need to be inferred.
- Data access and retention are subject to privacy and governance constraints.
- It is obviously limited to people using public transport



Mobility Demand – Other Sources

Traffic and passenger counters. Inductive loops, radar, cameras and other traffic sensors measure vehicle flows, speeds and traffic composition. Automatic passenger counters estimate passenger boarding and alighting on public transport. These sources provide valuable counts but usually do not identify complete individual journeys.

Travel surveys. Household travel surveys and stated-preference surveys collect trip purpose, travel mode, socio-demographic information and travel behaviour. They provide contextual information that passive digital traces often cannot capture. Their main limitations are collection cost, limited sample size and possible recall or response bias.

Social media and digital traces. Geotagged posts and check-ins can provide indications of visits, activities and event-related mobility. Coverage is selective, and location information may be sparse or imprecise. These data are best treated as a complementary source rather than a representative measurement of total travel demand.

Combining data sources. Integrating observed movements, passenger counts and surveys can improve coverage and help validate demand estimates. Data fusion requires attention to differences in spatial and temporal resolution, population coverage and uncertainty.

Origin–Destination Matrices

An **Origin–Destination (OD) matrix** represents the number of trips between geographical areas during a specified time period.

The study area is divided into **traffic analysis zones (TAZs)**.

Each matrix element (T_{ij}) represents the number of trips from origin zone (i) to destination zone (j).

Rows represent origins; columns represent destinations.

OD matrices can be defined for different time periods, transport modes, user groups or trip purposes.

Main applications

Understanding spatial mobility patterns.

Estimating travel demand between areas.

Supporting transport planning and infrastructure design.

Providing input to traffic assignment and transport simulation models.

Example: daily trips between four zones

Rows = origins · Columns = destinations · Values = trips/day

Origin \ Destination	A	B	C	D
A	0	120	80	50
B	90	0	150	60
C	70	110	0	100
D	40	75	85	0

ODM Visualization

