

BTS TRANSPORTATION PROBE DATA GUIDE: AGGREGATE LOCATION BASED-SERVICES (LBS), NAVIGATION (LBS OR GPS), AND POINT-OF-INTEREST DATA

Aggregate location based-services (LBS), navigation, and point-of-interest (POI) probe data products (“aggregate products”) summarize temporal-location information that is originally collected from a probe at a finer, disaggregate spatial scale. These products are only available to end users in an aggregate format. They can rely on any form of probe source data as long as the data come with spatiotemporal information that can be meaningfully summarized vis-à-vis a larger study area or site. As such, they depend on whichever location-detection technology was used to generate their source of probe data (e.g., LBS, connected-vehicle [CV], and Global Positioning System [GPS] data from navigation applications [apps] and platforms; synthetic data; and transaction counts tied to specific business locations).

For these products, aggregation is performed against sightings (e.g., GPS, LBS, financial or commercial transactions), which are summarized against provided or known areas of interest, whether they be polygonal geographic areas (e.g., states, traffic analysis zones [TAZs], metropolitan planning organizations), linear features (e.g., road networks, rail networks), or targeted points (e.g., businesses, addresses). Examples of aggregate outputs include device or vehicle counts associated with highway network links, origin-destination (OD) matrices mapped to geographic polygons, or business visitation counts tied to building footprints.

The following are predominant examples of aggregate probe data products:

- LBS data are aggregate to a geographic polygon or developed into an OD matrix within a specified date or time range.
- Navigation data are aggregate to roadway segments and include metrics about speed by mode (truck or car).
- POI data include activity patterns within preset business locations and/or parking lots as well as breakouts of the previous and subsequent places each observed device visited before and after that location.

The primary advantage of aggregate products is that they do not require an end user to acquire and process the enormous amounts of disaggregate probe data that would otherwise need to procure and analyze to produce commensurate outputs. Vendors of these products can customize outputs to the specific needs of customers, who get to use probe data-derived insights without needing data science resources. Aggregate products sold by vendors may also incorporate disaggregate data not otherwise available to the public since their end products are aggregate and will inherently mask any private or sensitive information.

The main downside to these products, however, is that their vendors do not have to disclose anything about the underlying disaggregate data to their buyers, an inherent constraint on the usability of their products when compared those done directly on or with disaggregate data. The acquisition of aggregate products, which may significantly reduce computational burden on a customer, inherently comes with less control over the generation of probe-based statistics. This trade-off remains for vendors that aggregate the data underlying their products themselves as well as those that resell or repurpose other vendors' products.

Because end users of aggregate products are not guaranteed access to the raw or disaggregate data points that contributed to the aggregate outputs that they purchased, they are beholden to whatever documentation on processing methods, sample sizes, or quality metrics the vendor makes available. Vendors typically provide limited transparency into how they process, aggregate, or derive analytics from the underlying data sources,¹ and little is known about sample sizes over time or descriptive statistics, such as data composition.

1. CAPABILITIES

Aggregate products offer several distinct advantages for generating transportation statistics:

- Standardized outputs—Preprocessed data products reduce initial technical barriers for agencies and provide consistent formatting across vendors for shared attributes (most commonly the base metrics and filters, like speed, time of day, and date). While these tables' attributes will vary between vendors, even when they are selling similar aggregate products (e.g., OD tables), products from one vendor will likely be standardized and familiar over time.
- Privacy protection by design—Vendors' aggregation techniques inherently protect and promote privacy by preventing identification of specific device movements. Customers do not need to be as concerned with the more expansive data privacy procedures that would need to be included when working directly with disaggregate probe datasets.
- Real-time capabilities—Many aggregate products offer near real-time updates for operational applications, leveraging vendors' abilities to compute and process data at scale much more quickly than less-resourced customers attempting to work with their own databases of disaggregate data.

2. LIMITATIONS

Aggregate products have the following known limitations when generating transportation statistics:

- Limited customization options—Customers will be inherently limited by the degree to which they can modify the vendors' aggregation methods,² geographic boundaries, or temporal windows when building outputs and are beholden to the parameters the vendor makes available for adjustment.

¹ Most vendors are transparent about their methodologies as they are sensitive about being perceived as black boxes. However, their methods and assumptions are often highly complex, involving numerous edge cases and sophisticated data processing that can be difficult to adjust or tailor to individual use cases or methodological differences.

² The aggregation level is typically predetermined by the platform, requiring buyers to either find a platform that supports their specific requirements or adjust their requirements to match the platform's capabilities.

- Reduced quality-assessment capability—Customers should not expect to be able to examine the raw or disaggregate data, which may prevent them from getting a complete, granular understanding of variance, outliers, or other quality issues.
- Uncertain sample composition—Customers’ lack of guaranteed access to the underlying data and any corresponding metadata will make it difficult to identify, verify, or adjust for unknown or variable demographic, socioeconomic, or behavioral biases present in the disaggregate data population.
- Geographic aggregation constraints—Customers are beholden to vendors’ predefined geographic units of analyses and corresponding, potentially-proprietary road network datasets when consuming their aggregated products. Accordingly, customers should be mindful that these products may not align or match with their planning boundaries or networks.
- Limited trip detail—Aggregated products, especially those centered on trip making and origins and destinations, may obscure important characteristics of the trips underlying those end products, like intermediate stops, route choices, or long-distance trips.

3. VENDORS

Aggregate data are available from an array of private vendors, although these vendors vary significantly regarding their sources of underlying disaggregate probe data. While this discussion is limited to vendors that provide aggregate data relevant to the transportation industry, these products have many uses outside transportation. Such uses are not covered here, but customers are encouraged to engage with vendors to ascertain their level of familiarity aggregating probe data to transportation use cases. Some vendors may be primarily oriented toward other markets that may have data quality and use standards inappropriate for transportation applications.

Aggregate data products are typically a set of flat files³ in CSV format and the corresponding geographic files (lines, polygons, and/or points provided as shapefiles, GeoJSONs, or other common geospatial file types) that were used to produce the aggregation. Users, in turn, can join these files in a tabular output.

Vendors may also offer an Application Programming Interface (API), a type of file access that grants the user programmatic retrieval of preprocessed datasets⁴ in standardized formats and allows their data to be integrated with customer dashboards or analyses. The type of disaggregate data underlying these products is primarily LBS and/or CV, but buyers should request details on the source data. Users’ ability to customize these API files, however, is constrained by the vendor’s overarching aggregation methodology.⁵

³ Data file formats are not standardized across vendors. Vendors may receive data in various formats, including cloud-to-cloud transfers, bulk files in CSV or Parquet format, or data firehoses to blob storage in native formats, such as JSON.

⁴ API-driven data access is typically preconfigured and nonnegotiable without vendor-feature requests. However, customers can filter or exclude attributes in API calls and provide parameters, such as geographic boundaries (e.g., GeoJSON polygon sets) and date and time filters.

⁵ Many vendors preprocess data by associating them with specific geographic units, allowing API calls to aggregate data based on these geographic boundaries and user-defined parameters, such as date and time filters.

Vendors may additionally offer varied access with a software-as-a-service business model, although the ultimate outputs of these software will always be aggregated.

POI data are a subset of all aggregate products. Some vendors specifically sell POI data that summarize the disaggregate LBS probe data detected within building footprints and/or near building or business points. In some cases, they may license the building footprint or building point location geospatial files separately.

The costs of aggregate products vary based on their spatial and temporal extent and the degree to which disaggregate data need be pre-processed. Costs incurred by customers on these products are generally seen as a trade-off for not needing to acquire and process the large amount of disaggregate data otherwise required to generate probe-based transportation statistics. To get precise estimates of the costs of working with aggregate products, customers are encouraged to engage directly with vendors.

4. MARKETS

The following sections list the primary and secondary markets for aggregate products.

4.1. Aggregate Data or API Markets

The following are primary markets for aggregate products:

- Transportation agencies
- Planning and engineering consultants
- City and county governments
- Research institutions

The following are secondary markets for aggregate products:

- Financial services
- Site-selection firms

4.2. POI Data Markets

The following are primary markets for POI-specific aggregate products:

- Application development
- Commercial real estate for site-selection and valuation

Transportation constitutes a major secondary market for POI-specific aggregate products.

5. SCALES OF AVAILABILITY

Aggregate products are available for national (highest quality appears to be for urban areas within the contiguous United States), state, and local use. They support custom development for regional applications (e.g., real-time traffic apps). Existing nationwide datasets include speed (National Performance Management Research Data Set [NPMRDS]), POI, and synthetic volume data.

6. GENERAL DETAILS

The following sections detail background information on how aggregate products are generated, why they exist as a data type, and the pieces of information commonly found in available products.

6.1. How Are Data Captured

The following sections detail the generation, capture, conveyance, and protection of aggregate product data.

6.1.1. Trigger Mechanisms and Frequency

How vendors generate the data points underlying each aggregate product is dictated by the sources of disaggregate probe data.

LBS and GPS sources use the methodologies described in the LBS [Titlow et al. 2026a], CV [Titlow et al. 2026b], and Fleet GPS [Titlow et al. 2026c] Guides.

Little is known about POI data other than the summary documentation provided by vendors on their respective websites.

6.1.2. Location-Determination Technology

The location component of the data points underlying each aggregate product is dictated by their corresponding sources of disaggregate probe data as follows:

- LBS and GPS sources use similar methodologies as described in the LBS [Titlow et al. 2026a], CV [Titlow et al. 2026b], and Fleet GPS [Titlow et al. 2026c] Guides.
- POI data are collected using the same sources of disaggregate data, but the exact ways these disaggregate points are associated with a building or point are not known.
 - LBS sightings could be geolocated to a building footprint or parking lot.
 - Transaction counts and records for a business location sourced from a credit card reader vendor or vendors [Kressner 2014].

6.1.3. Data Transmission

The method of transferring data points from the original probe underlying each aggregate product is dictated by their corresponding sources of disaggregate probe data as follows:

- LBS and GPS sources use similar methodologies as described in the LBS [Titlow et al. 2026a], CV [Titlow et al. 2026b], and Fleet GPS [Titlow et al. 2026c] Guides.
- For other sources, like credit card transactions and resellers of aggregate data, data collection and transmission are sparsely documented.
- Data-transmission methods are always evolving to meet user requirements.

6.1.4. Identifiers and Privacy

The method of protecting identifying information—whether specific to person, vehicle, or business—underlying each aggregate product is dictated by their corresponding sources of disaggregate probe data as follows:

- Little is known about the privacy protections used by vendors who process and provide aggregate data products. Aggregate data are assumed to have better privacy protections than disaggregate sources because the underlying disaggregate data cannot be reengineered.
- With POI data, total visits to a store by time of day and trends can be identified, which may have business privacy implications [SafeGraph 2025]. However, little research exists on this topic.
- Some vendors may not report aggregate results when observations fall below a certain threshold, sometimes denoting these values in their data (i.e., null values in a flat file for a given location and time).
- In some cases, results may be further aggregated in time bins to hours, days, or months and exclude information about specific times for a specific day.
- Since the data are aggregated, unique identifiers noting the zones or areas for which the disaggregate data have been summarized are tied to the following:
 - Public geographic data, such as the following:
 - U.S. Census or other geographic region polygons
 - OpenStreetMap (OSM), most notably the OSM road network and its identifiers
 - Transportation network files (roadway, trails, transit lines)⁶
 - Proprietary building and parking lot footprint polygon files
 - Custom geographic polygon files as provided by the buyer

6.1.5. Observation Unit

The unit of analysis of each aggregate product varies based on their corresponding source of probe data and the subsequent levels of spatial or temporal aggregation.

The unit of analysis will depend on the level of aggregation performed on the underlying disaggregate data. All the while, these aggregations will likely be done along two dimensions:

1. A unit of geography, which could include the following:
 - POI locations and attributes⁷
 - Map or network segments
 - Geographic points and polygons
2. A unit of time (i.e., per minute, hour, week, etc.)

A sample row of POI data might include the location of interest, the period in question, and an estimated count of visits [Hleileh, Lagoë, Ouyang 2021]. For outputs that involve summarizing travel between more than one location (i.e., an OD table), this output would have multiple locations of interest accompanying the period and count variables.

⁶ Whether a vendor or customer can use a proprietary transportation network file will depend on the vendor and the negotiations that take place before the purchase of a data product.

⁷ These can be owned by the vendor or customer and represented as either points or polygons. The attributes associated with a location are dependent on the source of the POI information.

6.2. Data Source Background

The following sections provide background on the history, development, and application of aggregate products, especially vis-à-vis the generation of transportation statistics.

6.2.1. Original Purpose

The development of aggregate products has been centered on the following goals:

- Network-based data were originally developed for commercial and consumer navigation systems and applications that sought to ingest live and current traffic conditions on a road network.
- POI data were created to enhance navigation with destinations beyond addresses and street networks. These data were later associated with location data and marketed to the advertising and tourism industries.⁸
- Core applications of network and POI data include the following:
 - Location searches
 - Busy period detection
 - Traffic congestion and routing optimization
 - Site location assessment
 - Location and/or context-based advertising

6.2.2. Transportation Focus

As aggregate products have developed and evolved as a source, so has their integration into transportation planning and statistics.

Applications of aggregate data can be found in the following fields:

- Route planning and optimization
- Congestion monitoring and management
- Electric vehicle charging location site selection
- Truck parking studies and site selection
- Safety and speed studies
- Travel and traffic model development

Applications of POI data can be found in the following fields:

- Land-use and travel market analysis
- Activity and access analysis
- Site location studies

Aggregate data can be integrated with custom, secondary transportation systems through specialized APIs and data services. These services include StreetLight's Construction Solutions

⁸ A simple address on a map provides minimal contextual information. Searching for restaurants reveals names and locations, but true POI data emerge when these locations are mapped with building footprints, access points, operating hours, and real-time activity patterns by time of day. This comprehensive dataset requires an extensive background processing and data integration that remains invisible to end users but creates substantial added value beyond basic geographic coordinates.

use by the Georgia Department of Transportation (DOT), Flow Labs for traffic signal timing by the North Carolina DOT, and the Regional Integrated Transportation Information System, which is used by state DOTs and other agencies.

Integration of POI data in transportation can be found mostly within research, especially during the COVID-19 pandemic, and for travel model applications by Replica [Hleileh, Lagoe, Ouyang 2021; Replica 2025].

6.3. Data Contents

The following sections note the pieces of information contained in aggregate products, recognizing that each product type is beholden to the constraints and elements represented in their corresponding sources of disaggregate probe data.

6.3.1. Core Attributes

Data elements for aggregate products vary based on their source(s) of underlying probe data and the level(s) to which these data have been spatially or temporally aggregated.

6.3.1.1. Core Attributes: Geographic Aggregations

For network-based aggregations, the following attributes are standard:

- Latitude–longitude coordinates and/or geographic identifiers (e.g., U.S. Census Tract’s federal information processing standard [FIPS] code) of the area or of the area where the network link resides
- Timestamp bins (i.e., quarter-hour, half-hour, hour, day, month, year, etc.)
- Observation count
- Summary statistics of travel on the link (i.e., average travel speed, 85th-percentile travel speed, average speed broken out by vehicle type or mode, etc.)

6.3.1.2. Core Attributes: POI Data

For POI data specifically, the following attributes are standard:

- Official place name
- Industry and/or POI category classification (e.g., North American Industry Classification System [NAICS] code)
- Address components
- Contact information
- Hours of operation
- Observation count
- Unit of time of observations

6.3.2. Non-Universal Attributes

Data elements vary by product, hinging on their respective underlying source(s) of disaggregate probe data and level(s) of spatial or temporal aggregation.

6.3.2.1. Non-Universal Attributes: Geographic Aggregations

For network or polygon data on travel patterns, the following non-universal attributes may be included:

- Variance statistics of speed (network)
- Circuitry ratios (polygon and network)
- Margin of error (polygon and network)
- Observation counts expanded to the population⁹

6.3.2.2. Non-Universal Attributes: POI Data

For POI data, the following additional attributes may not be available for all locations:

- Accessibility information
- Service offerings
- Demographic bins of visitors¹⁰
- Building polygon and a parking lot footprint
- Broad (zip code or county) home locations of visitors

6.3.3. Derived Attributes

Derived attributes may be attached to an aggregate product by linking their output files with secondary datasets based on common geographic locations or time periods.¹¹

6.3.4. Sample Characteristics

The sample penetration of each aggregate product vis-à-vis the traveling American population hinges on the source(s) of disaggregate probe data underlying their output tables.

Oftentimes, little information is available about the number or total population (and their variance) that contributes to the counts included in these sources.¹² For POI data, most claims indicate the availability of more than 60 million locations, but visitation metrics are not available for all locations.

⁹ Sample size and penetration rates vary continuously across time and geography, creating a moving target for population expansion calculations. This variability necessitates ongoing data science work to account for the constantly shifting sample characteristics, much like squeezing a water balloon where adjustments in one area affect others.

¹⁰ Demographic bins of POI visitors are typically estimated using various data sources. While census data are commonly used, some systems rely on credit market data and user categorization rather than traditional demographic sources to infer visitor characteristics.

¹¹ Deriving additional attributes from geographic associations requires specialized data science and engineering skills, such as developing travel sheds and travel time contours. While some agencies, like the Bureau of Transportation Statistics, possess these capabilities, many transportation agencies lack the necessary staff or training to correctly derive attributes beyond those initially provided by vendors.

¹² Buyers should inquire about vendors' data sources, including the broad types of disaggregate data used (LBS, CV, etc.) and sample population characteristics, even though detailed information may be limited. The quality and detail of responses will vary depending on the contact; buyers should seek to speak with the vendor's lead Data Scientist or Product Manager as these roles are typically closest to the actual data product.

6.3.5. Data Quality

Documented concerns about the quality and usability of aggregate products include the following:

- Data quality is typically assessed by the customer based on comparative and validation studies. The following comparisons are common:
 - Studies compare OD flows from other sources, like the U.S. Census Journey-to-Work data or transportation surveys.
 - Customers may also compare network-based data to speed studies and traffic counts.
- Industries outside the transportation sector may not have as much demand for accuracy of estimated statistics (i.e., POI visits, link traversals, OD trips) and might be comfortable with relative estimates (i.e., is the business busier in summer or fall).¹³
- The representativeness of the sample cannot be conclusively ascertained.
- Data are exclusive to vehicles versus other modes. For vehicles, aggregate data are usually differentiated between passenger vehicle data and commercial vehicle data.
- If an aggregate dataset is dependent on disaggregate vehicular data, round trips may be overrepresented since the vehicle continued to produce data if it was not keyed off during intermediate stops (e.g., drive-throughs or school drop-offs).
- Certain input disaggregate data sources may not be linkable, so knowing when a series of trips is actually a long tour or long-distance trip is difficult or impossible.

7. TEMPORAL AND SPATIAL SCALES OF THE DATA

The following sections characterize the historical, temporal, and spatial coverage, availability, and precision of aggregate products.

7.1. Temporal Coverage

The historical penetration and availability of each aggregate product in the United States hinge on the source(s) of disaggregate probe data underlying their respective output tables.

Temporal coverage varies based on the availability of the underlying disaggregate data and the type of aggregate product. All aggregate products will only be available for the same dates for which the underlying data are also available. As most forms of high-quality disaggregate data became more ubiquitous in the late 2010s, aggregate products will likely not be available for earlier years.

Historical snapshots may be maintained for quality comparison and trend analysis.

¹³ Transportation professionals should be prepared to either conduct their own postprocessing to meet exact specifications or adjust their analytical methods to use vendor data directly. Both approaches involve significant tradeoffs: Postprocessing becomes labor intensive and reduces data value, while method adjustment may require abandoning legacy analytical frameworks that lack direct replacements in new data sources. This challenge has been widespread across transportation agencies adapting to emerging data types.

7.2. Temporal Resolution

The precision of each aggregate product's temporal information hinges on its source(s) of disaggregate probe data and level(s) of spatial and temporal aggregation.

The temporal resolution of these products generally falls into one of the following three levels:

- Real-time location updates (seconds) (i.e., network-based congestion and traffic metrics)
- Near-real-time traffic (minutes) (i.e., network-based congestion and traffic metrics and business visitation and crowding metrics on phone apps)
- Weekly or monthly update cycles for less critical data

7.3. Spatial Coverage

The geographic coverage of each aggregate product in the United States hinges on its source(s) of disaggregate probe data underlying their respective output tables. As such, the spatial coverage will depend on the availability of the underlying disaggregate data.

One known vendor of aggregate products offers global coverage with the following data [TomTom 2025]:

- Comprehensive availability of POI and road network data in over 200 countries
- Detailed street networks in major markets
- POI coverage emphasizing commercial and urban areas
- Traffic services linking vehicle probe data to networks in over 75 countries

Transportation-oriented aggregate data vendors will generally have data available for most U.S. routes and geographies.

Little is known about the coverage of POI data other than that most sites are in urban and suburban regions, partially driven by the less stringent requirements for data representatives from nontransportation data customers.¹⁴

7.4. Spatial Resolution

The precision of each aggregate product's spatial information hinges on its source(s) of disaggregate probe data and level(s) of spatial and temporal aggregation. Spatial resolution generally falls into one of the following four levels:

- POI street-level mapping (meter-level precision)
- POI positioning (3–5-meter accuracy in ideal conditions when relying on GPS technology)
- Traffic data (road segment level)
- Administrative boundaries (official definitions)

¹⁴ POI data coverage is primarily a function of population-distribution patterns. When inquiring about coverage in their area of Interest, buyers should expect varied responses that depend on the vendor's business model. Some vendors minimize customer contact to reduce costs, while others are more customer-oriented and will work to provide coverage estimates. The level of detail available depends on whether such requests align with the vendor's service approach.

8. USE CASES OF THE DATA

The following sections list documented use cases and applications of aggregate products. Specific attention is given to use cases that are related to transportation planning and statistics.

8.1. Transportation Use Cases

Aggregate datasets simplify transportation analysis by providing ready-made metrics (e.g., precalculated OD matrices, travel-time indices, and performance measures) without requiring specialized transportation modeling staff, complex data-processing skills, or extensive research to develop insights for corridor studies, performance monitoring, and compliance reporting.

Aggregate data can be used in the following transportation applications:

- OD studies
- Travel time–reliability analyses
- Special event studies and impacts
- Studies of activity, speed, and access patterns on specific roads or corridors
- Site visitation estimates and evaluations
- Bottleneck identification
- Safety analyses, particularly those that depend on network speed data
- Corridor and network performance analyses

Aggregate data can be used to generate the following travel statistics:

- Peak period seasonal trends
- Travel Time Index and Planning Time Index analyses
- Federal performance measure compliance reporting (NPMRDS)

8.2. Nontransportation Use Cases

Aggregate datasets simplify market segmentation by providing ready-made analytics (e.g., visitor travel sheds and demographic breakdowns by state) without requiring specialized staff, skills, or research to develop market insights for store siting or advertising targeting.

Aggregate data have the following applications within business intelligence:

- Site-selection analytics
- Competitor analyses
- Trade area definitions (i.e., from where are the customers for this location coming?)
- Customer journey mapping (i.e., to what other locations did visitors travel?)

Aggregate data have the following applications within marketing, tourism, and advertising:

- Location-based sales
- Market segmentation
- Roadside advertising placement
- Seasonal visitation metrics

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