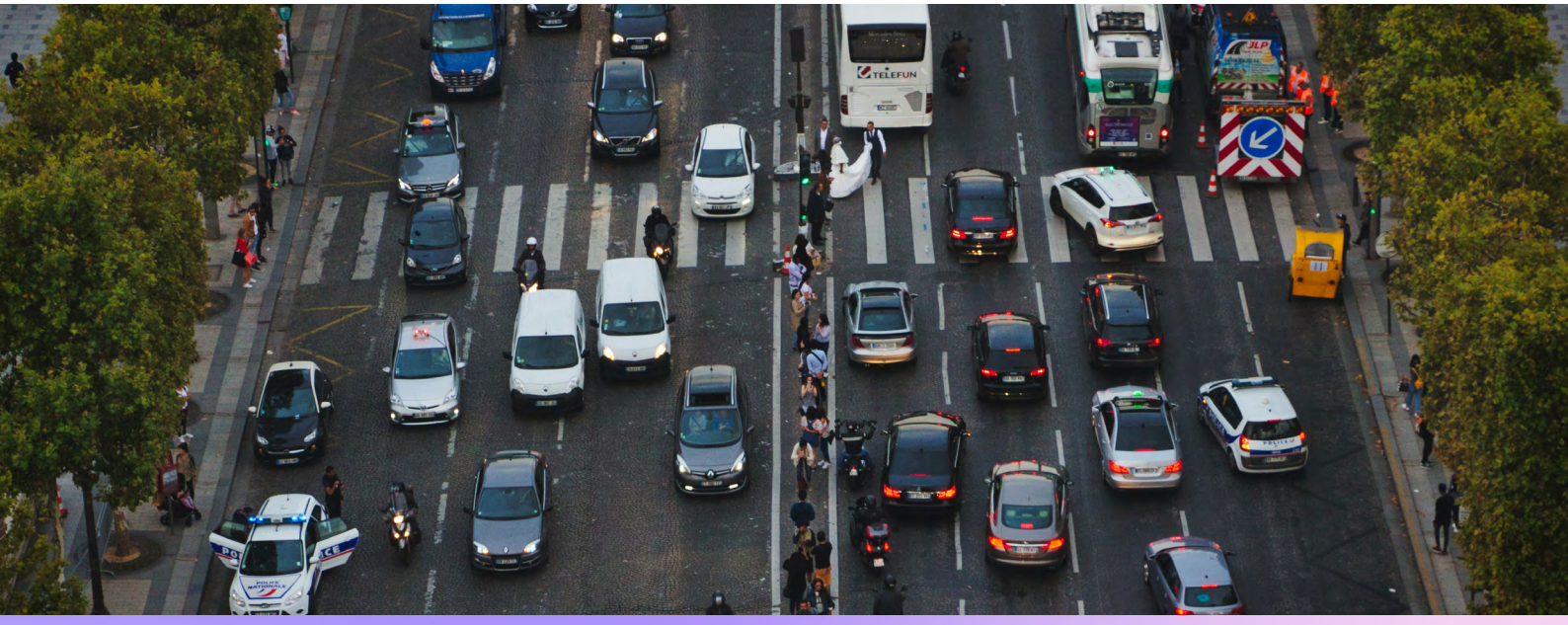
nexar

White Paper

How Nexar's Real-Time Mapping enables all vehicles to see all roads

Abstract

Today's digital maps fall short of the freshness and precision that software driven auto OEMs, autonomous vehicles, and mobility players need to delight their customers. Long thought to be impossible, real-time mapping is now revolutionizing how road information is captured and delivered to the mobility ecosystem. This white paper describes the key innovations in crowdsourcing, edge AI and change detection that allowed Nexar to make real-time mapping not only possible but also affordable and readily available.



Content

1. The problem with today's maps

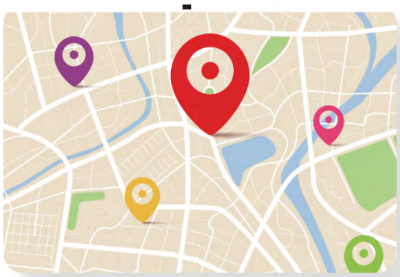
Whether it's connectivity or shared mobility, electrification or automated driving, today's automakers seldom agree on the speed at which vehicles will change [1]. Nonetheless, there is one basic fact that nobody disputes: software is eating the vehicle. And it's happening very fast. The implications are wide, in particular for the mapping industry. Whereas humans are able to handle incomplete data and project from a two-dimensional representation to the actual real world, software systems need fresh, precise mapping information and way more contextual data. Without it, they are unable to achieve the situational awareness that is necessary to assist the driver reliably let alone take over the steering wheel.

It follows that vehicles need better maps [2] — and not just the autonomous vehicles of the future. With customers expecting more and more advanced driver assistance systems (ADAS), live navigation features and location based services, all vehicles from levels one to five of automation need better maps already today.

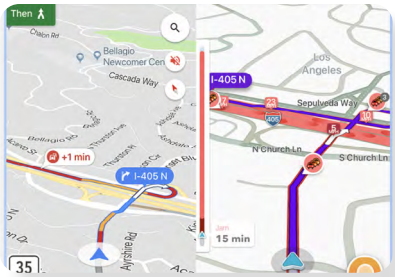
When you take a deeper look, it's actually more than just maps. Road signs that change from one day to another, work zones that block traffic for a few hours, parking spaces that become free this minute or collisions that happen in a second are just a few examples of life happening in real time. Clearly, to become safer and more comfortable, vehicles need more than just better maps: they need real-time mapping.

Contrast this vision with what cars have today and the picture is quite dismal [3]:

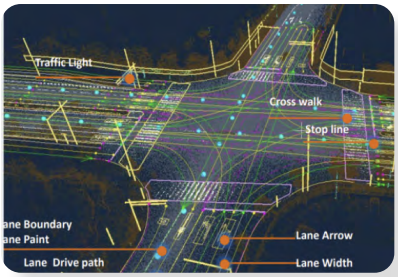
- **Map data is mostly stale.** Some cars get maps that update once a year, some every four or five years, others never at all. At the speed at which cities and infrastructure are evolving, this is no longer sufficient to satisfy consumers and commercial fleets.
- **Road information is incomplete.** As an example, in Phoenix Arizona 54% of the road information was incorrect or not even available in the Open Street Map (OSM) when compared against what the Nexar network was able to detect automatically [7]. (see Section 3)
- **Data sources are fragmented.** Scattered over different silos from city halls to highway contractors and mapping service providers, it becomes difficult if not impossible to obtain a complete data set depicting the ground truth that vehicles and people need.



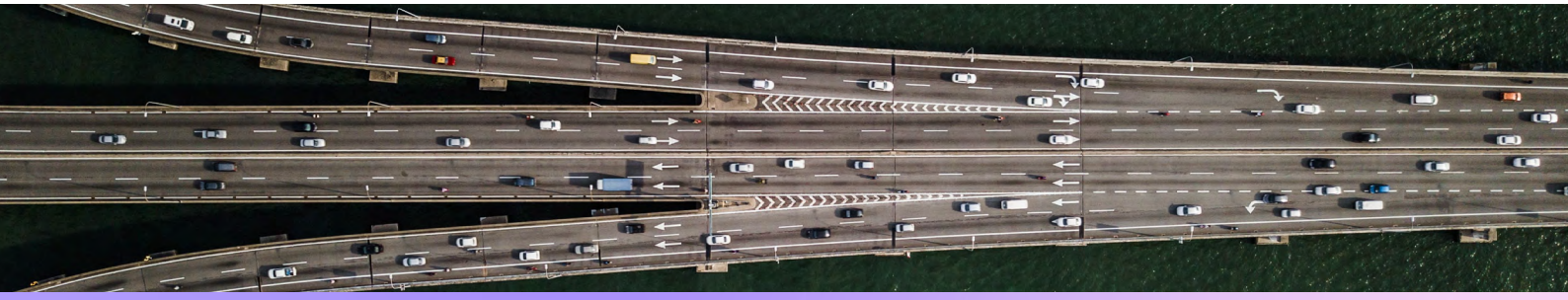
Standard Definition (SD) Maps



Traffic Maps



High Definition (HD) Maps



These old maps all suffer from the same malaise. They are so often wrong and outdated, because they are built more like inventories, structured lists of things that are pinned to the real-world via longitude and latitude with a semantic layer of connectivity. As shown in Table 1, even with recent advancements in aerial imagery, intelligent speed assistance (ISA) and real time traffic information, existing standard definition (SD) maps, traffic maps and even high definition (HD) maps fall short of providing high frequency of updates, high precision and data freshness at a low cost.

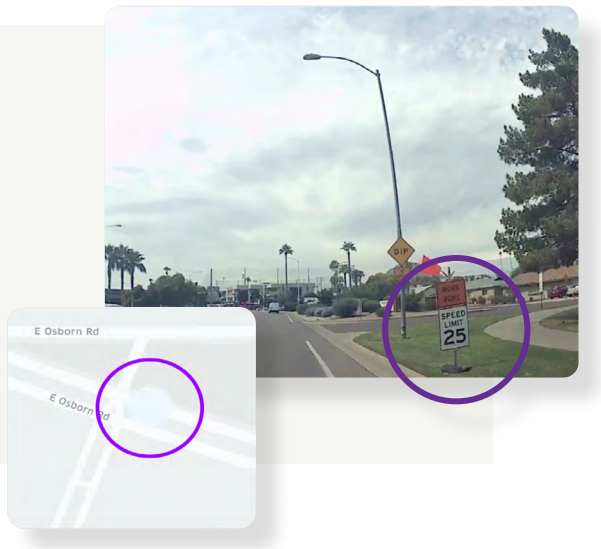
Map Types	Frequency / Freshness	Precision / Quality	Effort / Cost
Standard Definition (SD) Maps	Low	Low	High
Traffic Maps	**High**	Low	High
High Definition (HD) Maps	Low	**High**	High
Real-Time Maps	**High**	**High**	**Low**

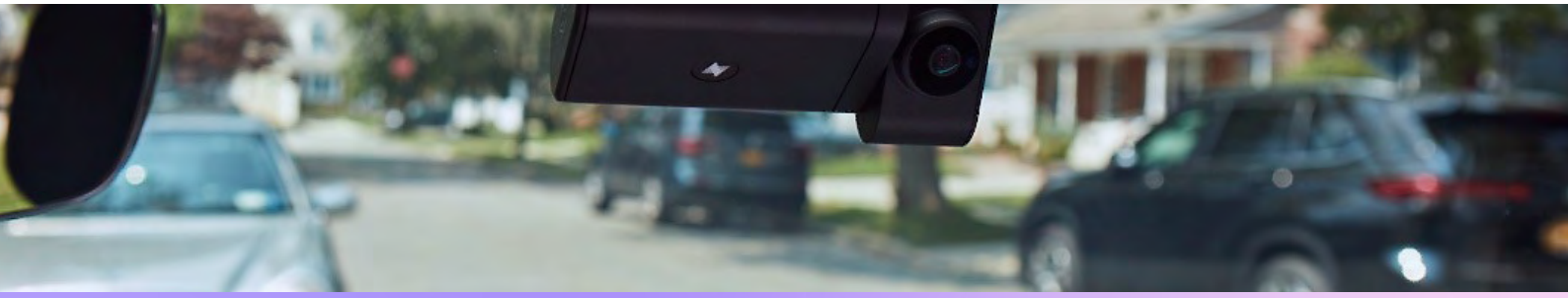
Table 1 Comparison between the map options available in the industry.

The main reason for this unsatisfactory state of affairs lies in the slow and expensive methods still in use by the traditional mapping industry.

Example 1:

To reach 100 visits per mile in a month, a city like Phoenix, Arizona with 5000 miles of roads would need to employ a dedicated mapping fleet of 360 vehicles.
For the entire United States, the required fleet size would be 180,000 vehicles. With a Lidar equipped car costing around $1.5M each and mapping costs reaching $30 per mile per car, it is no wonder that autonomous vehicle companies are paying tens of millions of dollars to cover a fraction of the US territory [6].





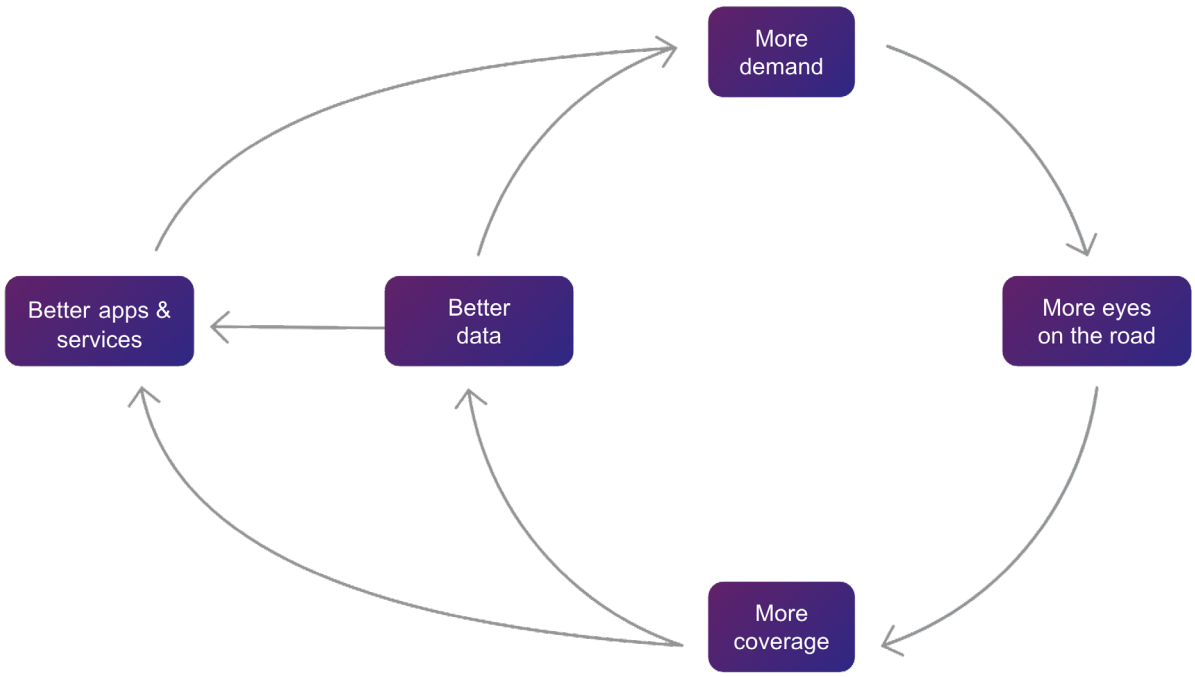
With the available maps and user experience falling short of expectations, it's no wonder consumers turn to their smartphone for real time turn by turn navigation. But even there, the delays and cost in collecting and processing large volumes of high-density data lead to incorrect and outdated map information. Add safe, reliable and user-friendly Advanced Driver Assistance Systems (ADAS) to the list of must-haves [3] and auto OEMs have no choice but to comply with intelligent speed assistance (ISA) regulation, limit hands on the wheel alerts (Level 2), navigate around work zones, mitigate crash liabilities (Level 3) and avoid aborting the mission in (Levels 4-5), to name just a few of the ongoing challenges.

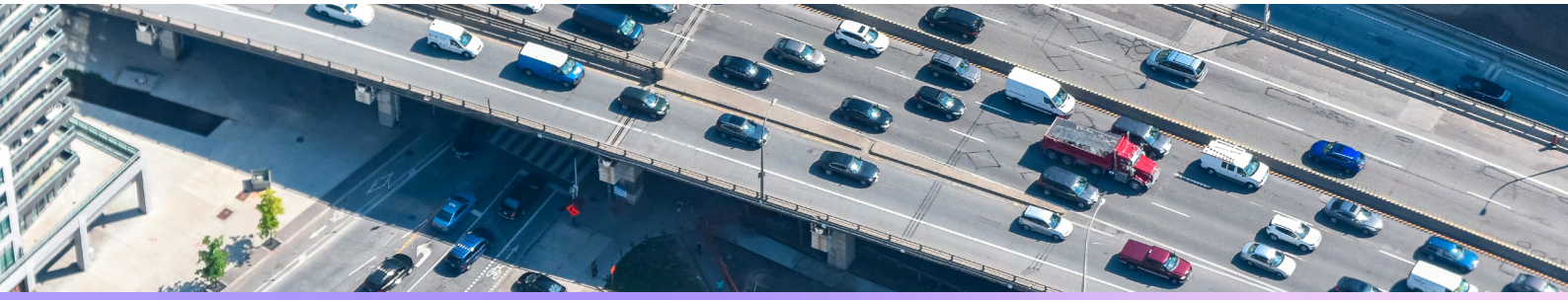
While the human-centric maps of incumbent map providers will likely still serve us for a number of years, the software-centric maps that will save lives, support seamless mobility and delight customers can only come from a radically new method to collect, process and distribute road information in a fast and scalable way. This revolutionary step is real-time mapping.

2. The real-time mapping revolution

Long thought impossible, real-time mapping has finally become a reality. Every second of every minute of the day, Nexar's platform is continuously at work, crowdsourcing 3 billion miles of road vision data per year, all of which is captured automatically and on the move by more than 700,000 vehicle cameras – and the network is only growing. This multitude of "eyes on the road" is what enables to see 94% of the roads in the United States within a month, as well as Japan and soon other countries in the world.

Vehicle cameras are ideal because the data source can be verified and trusted, plus no other sensor gives as much information gain at such low cost. When every vehicle in the network both consumes map data and produces map data, the flywheel in Figure 1 starts turning and it is finally possible to deliver the freshness, precision and situational awareness that all vehicles and mobility players need.





But it takes a lot more than a network of vehicle cameras to build the entire information value chain from the roads to the vehicles:

- **Low unit economics:**
  For real-time mapping to be economically feasible, it is necessary for the cost of mapping each mile to come down dramatically.
- **Relevance:**
  To deliver relevant information, real-time mapping must cover substantially more roads than any auto OEM or mobility player can achieve alone. Moreover, it must capture a variety of road topologies, road furniture, and road agents (even moving cars and emergency vehicles) with the right level of freshness (see Figure 2).
- **Scalable**:
  The infrastructure required to aggregate and process petabytes of information about the world's roads in real time is formidable. To achieve the necessary scale, we must go beyond the centralized cloud computing that incumbents use today and use edge AI.
- **Technology agnostic:**
  To serve as many people and vehicles as possible, real-time mapping must rely on standard data formats, be compatible with existing base map layers, and run on different types of hardware.

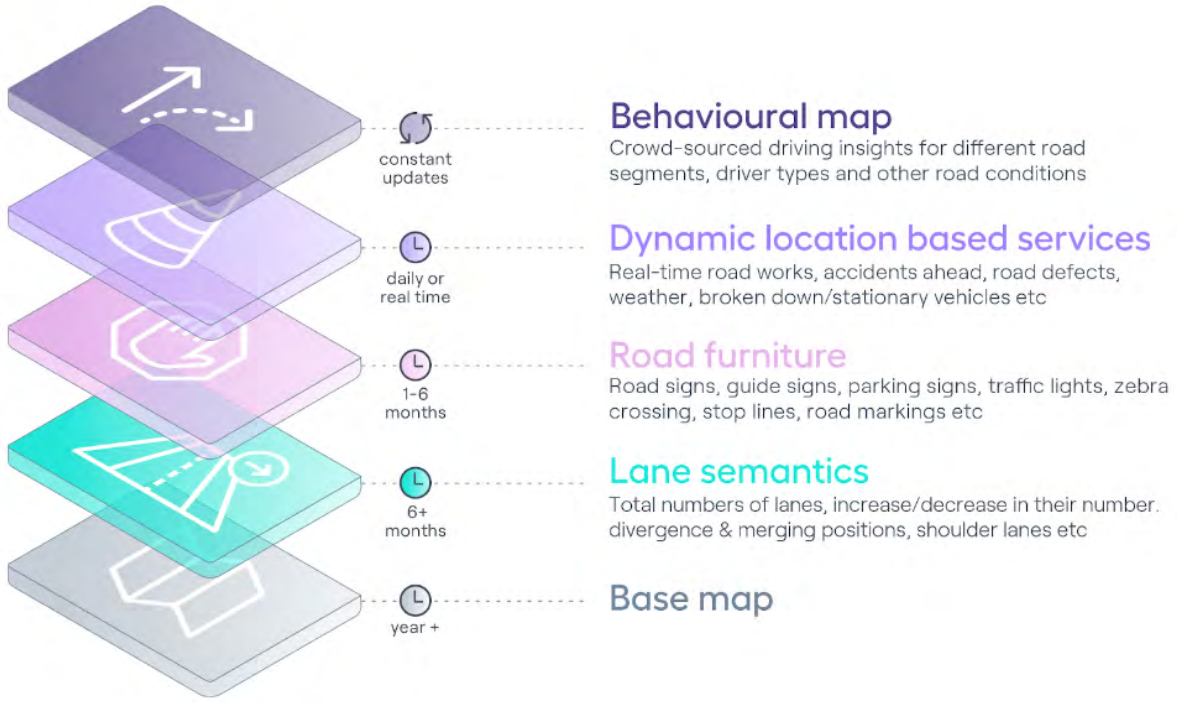


Figure 2 the different layers of freshness that assure the relevance of road information.

To solve each of the aforementioned challenges, Nexar developed several key innovations in edge AI, data aggregation and change detection, which the platform is now bringing to market.

3. How the CityStream™ Live platform delivers real-time mapping

Nexar's platform has been designed with two main goals in mind:

1. Aggregate, disambiguate and understand all of what cameras are able to capture;
2. Deliver the real-time mapping APIs on which developers and organizations can build products and services.

Towards that end, we see real-time mapping essentially as an information retrieval problem. Vehicles have specific information needs (e.g. "what is my speed limit?" or "is there a work zone?"). The role of the platform is to obtain the resources (images, detections, locations, contextual data, etc.) that are relevant to satisfy their information needs.

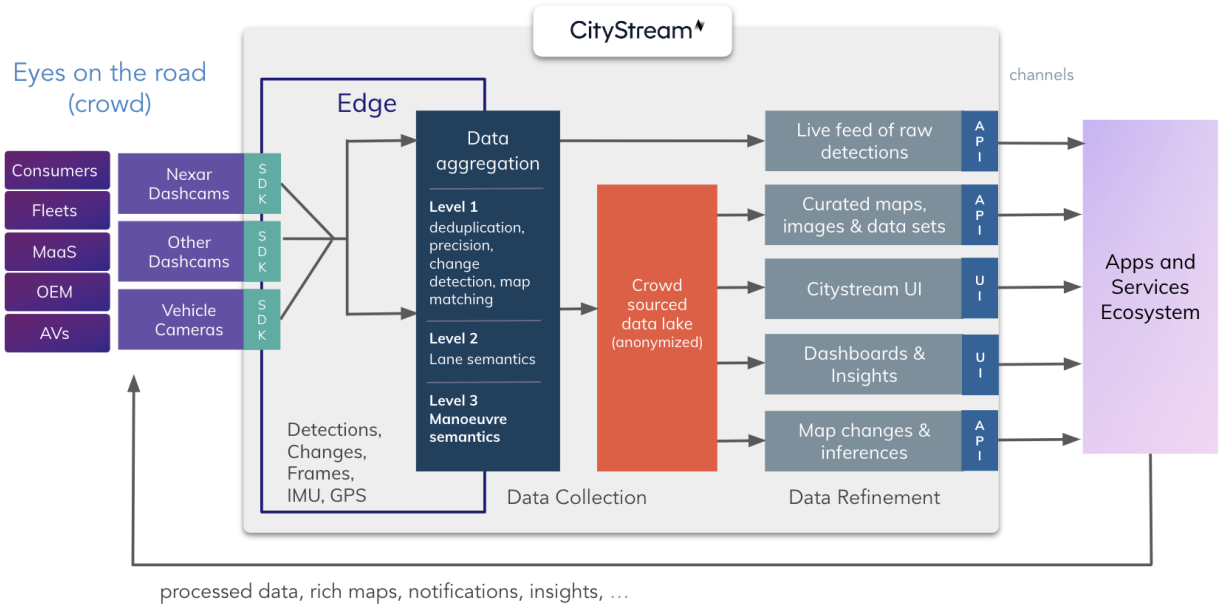
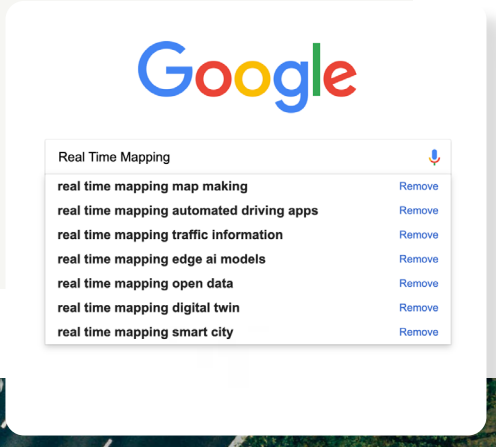


Figure 3 The platform implements all necessary functions and key APIs for real-time mapping.

Example 2:

Back in the nineties, under the motto that a cent multiplied by billions is worth billions (of dollars, of users, etc.), Google was able to bring down the costs of indexing the world wide web by 40x when compared to Altavista. The winning strategy was to rely on its PageRank algorithm and later more and more sophisticated AI web crawlers to crowdsource the wisdom of its users. This is the type of revolution that is happening with real time mapping right now.



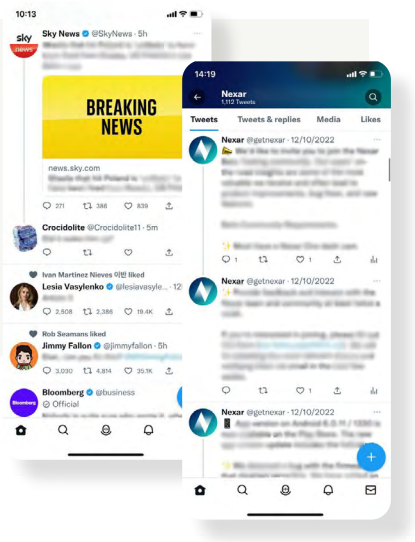
3.1 Reducing the unit cost of real-time mapping

In order to retrieve the information we must first need to collect it at an affordable unit cost. As shown in Figure 3, achieves this goal through the combination of four main innovations:

- **Crowdsourcing road data**: leverages consumer dash-cams, commercial fleets, mobility as a service (MaaS) providers, auto OEMs and autonomous vehicles as "eyes on the road" allowing for unprecedented density and coverage — at a fraction of the cost of dedicated mapping fleets. This network of "road crawlers" not only enhances precision by enabling multiple witnesses to validate the acquired road data in real time, but also caps the cost dramatically by transferring to the cloud only the delta difference between visits. An additional feature allows users to tune the detector flexibly to the required level of precision and computation.
- **Edge AI:** This includes both the consumer edge (vehicle cameras) and the provider edge (local infrastructure). The Nexar SDK (see also Section 4.3), which is installed in dashcams (and companion smartphone apps), vehicle cameras and multi-access edge computing (MEC) devices, enables to run AI models, detections and aggregation algorithms at the edge of the network.
- This form of distributed AI reduces the cost of transferring unnecessary images to the cloud, while increasing the trust that comes from making local decisions on what each camera is actually seeing. From a computational perspective, is also crowdsourcing the distributed storage and processing hardware that is required to realize the promise of real-time mapping.
- **Change detection:** Instead of sending all detections to the Cloud at a very high cost, Nexar's SDK is also able to make local decisions on what is different and what remains the same in every road. By concentrating on the much smaller set of differences (from what was mapped), change detection reduces even more dramatically the amount of data to be transferred, stored and processed in the Cloud.
- **Frame on demand (FoD):** Applications and services are given the option to fetch image frames just in time, based on the timestamps and georeferenced locations. This feature, which can be used for evidence-on-demand in the form of single images to short videos, is best achieved in a self-regulating dynamic manner, so as to further control the unit costs of real-time mapping.

Example 3:

Everyday, Twitter processes 400 billion events in real-time and generates petabytes of data. This is made possible in a scalable way by having hundreds of millions of users (data producers) post their updates in a distributed fashion and delivering a live feed that everyone can access and benefit from (data consumers). CityStream uses the exact same principle of Twitter's feed for crowdsourcing and delivering real-time mapping information from and to the broader mobility ecosystem — but without the need for user intervention.



3.2 Ensuring the relevance of real-time mapping

To meet the needs of users, focuses on achieving precision, recall, and freshness of the anonymized data. Towards those goals, data aggregation is implemented in three different levels (see Figure 3):

- **Level 1** - Eliminates duplicate detections, increases precision, detects changes and implements map matching;
- **Level 2** - Covers lane semantics;
- **Level 3** - Addresses the maneuver semantics.

Precision results also from automating the crowdsourcing of the data directly from the camera sensors and making sure that angle, direction, lane level and self localization are as accurate as possible. Freshness is achieved through the growing coverage and density of Nexar's network of "eyes on the road". A key differentiator here is Nexar's ability to rely on images captured both by its own camera products and those of partners and customers in the broader ecosystem. All contribute and all benefit from the aggregated data in terms of frequency, verification and completeness. The main key performance indicator (KPI) in this context is the mean-time between visits, as illustrated in Figure 4.

Although road information is detected and collected in real time, not all types of data require the same level of freshness. For that reason, considers four different map layers, each with different sampling rates:

- **Static data** collected monthly, such as lanes, road geometry, etc.
- **Semi-static data** collected hourly, such as traffic signs, weather, etc.
- **Semi-dynamic data** collected within minutes, such as accidents, congestion, parking, hazards, etc.
- **Dynamic data** collected in less than a second, such as cars, bikes, pedestrians, etc.

In this context, is designed to support common standards such as WZDX, ISA and NDS [4]. Nexar is also leading the IETF standardization of Nexagons [5], a virtual layer 3 routing and geospatial addressing method that divides the world in high-resolution tiles and makes it easy for vehicles to share and consolidate geo-referenced detections across the network.

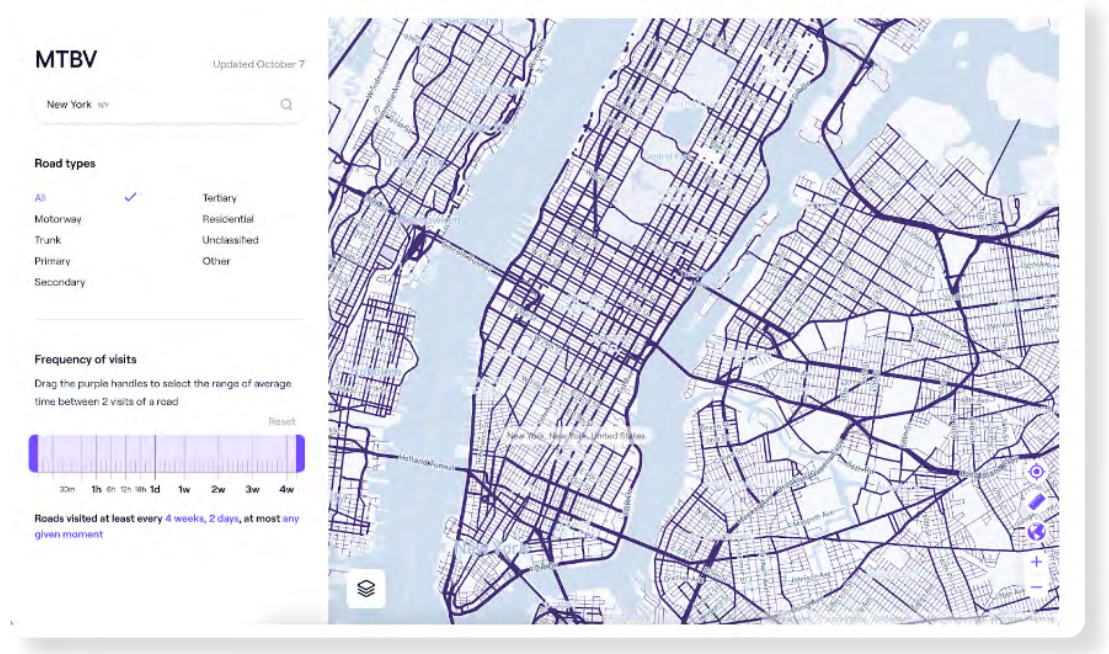
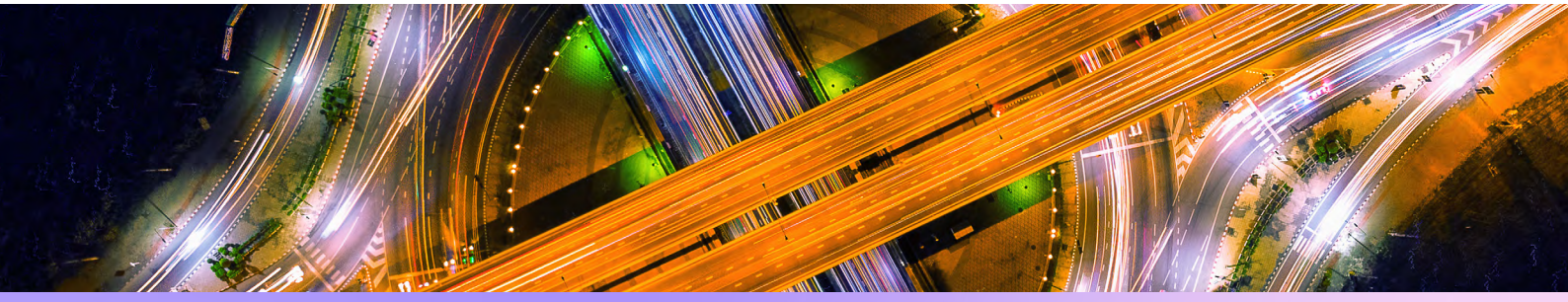


Figure 4 CityStream™ Live uses mean-time between visits to assess the level of freshness achieved by the Nexar network at different locations.



4. How you can ride the real-time mapping revolution

4.1 Use cases and real-time mobility apps

Road signs, variable speed limits, collisions, cars stopped on shoulder, parking, weather phenomena, lane markings and bike lanes are only a few of the use cases supported by . In the following, we give a few examples:

CityStream™ Live WorkZones

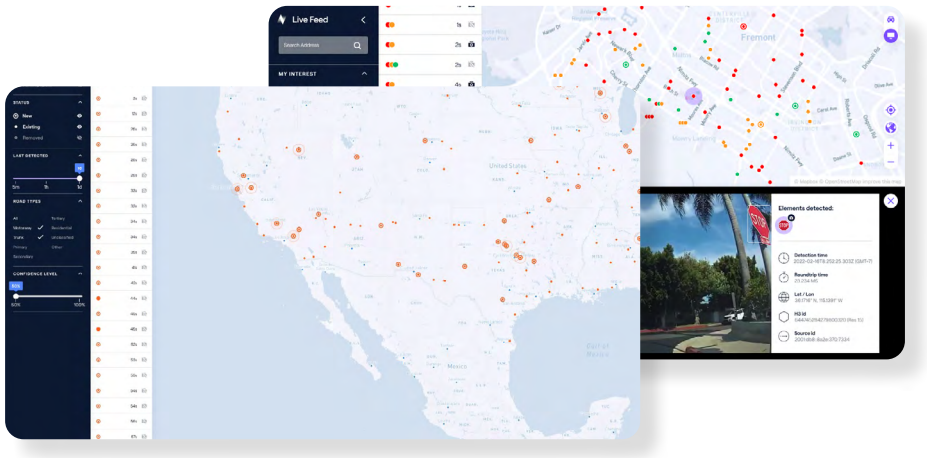
is Nexar's application for detecting and monitoring construction works in roads across the country. Using the corresponding API, customers and partners get a live feed of detected work zone elements, collected locally and sent by moving vehicles in the Nexar network. A user interface displays up-to-date locations where Nexar's AI saw one or more work zone elements, such as grabber cones, drum cones, diamond signs, rectangular signs, arrow/message boards, barricades, barriers and triangular cones. By selecting specific detections, customers are able to inspect the actual images of the elements that triggered the detection. All data is available through an API, with the option to be retrieved in WZDx format for easy integration with other systems. By knowing where they are and navigating away from work zones, OEMs and AV companies can avoid crash liabilities and deliver superior comfort and safety for drivers and passengers. Cities benefit for instance from better control work zones at lower inspection costs, more visual evidence of permit violations and less work accidents for which they are legally responsible.

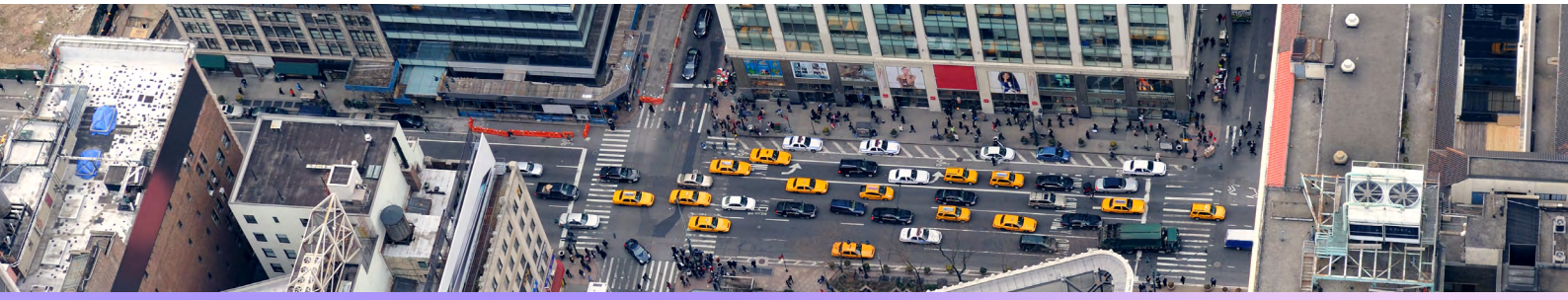
CityStream™ Live RoadInventory

gives users access to an online map and/or an API with up-to-date locations of traffic signs detected by vehicles. The list depends on the region and includes, for example, left arrow one way, right arrow one way, yield, no left turn, no right turn, pedestrian crossing, etc. Nexar collects and curates the images and locations of traffic signs over a configurable time window to prevent duplicates. Users are further able to see changes in road segments (new/gone), zones (new/gone) and traffic signs (new/gone), which Nexar detects over a period of 30 days. A collection of images of each detected traffic sign is made available for user verification.

CityStream™ Live VirtualCam

enables customers to access a large collection of images of every road segment visited by the vehicles of the network at different points in time. Think Google Street View with orders of magnitude greater coverage and freshness. The visual data, which is made available via an API and a web interface, can be filtered by date/time, location, and heading of the vehicle.





4.2 Tools, APIs and user interfaces

For partners and customers who are ready to consume the real-time detection feed, offers a well documented, easy to use API. In addition, as shown in the diagram in Figure 3, all ecosystem partners, from app developers to mobility players, benefit from the crowdsourced data lake in multiple ways:

- Curated maps, images and data sets (via APIs or as files).
- Streams of alerts, map changes and inferences (via APIs).
- A web based graphical user interface (CityStream UI).
- Dedicated dashboards with insights (UI).
- Just in time data fetching through frame-on-demand (as discussed in Section 3).

4.3 Nexar SDK

includes **The Nexar Embedded SDK**, an easy-to-use embedded software stack, which includes (a) all of the aforementioned edge AI capabilities and (b) the ability to offload both your data and the real-time mapping data on-the-move to millions of Wi-Fi hotspots. By bringing the SDK to their connected vehicles and edge devices, software developers, auto OEMs and technology partners are not only able to add edge detection functions but can also cut the cost of transferring data from moving vehicles to the cloud by up to 80% for each GB.

4.4 Business model and pricing

From day one, Nexar works closely with prospective customers to build a solid business case for bringing real-time mapping into current and future products, services and business operations. The first step is to identify what data you will use and determine the value this brings to your business. The analysis includes:

- **Freshness:**
  How often you need to get each type of data, i.e. monthly, weekly, daily, hourly, minute-by-minute.
- **Geography:**
  What coverage you need to have, i.e. district, highway, city.
- **Data format:**
  Which types of data, such as locations, images, videos, etc. and in what format.
- **Object type:**
  Work zones, road signs, potholes, intersections, etc.
- **Curation:**
  How curated the data must be, e.g. Raw, 10% mis-detections, human-verified.
- **Interface:**
  How you wish to consume the data, eg. via APIs, online map, dashboard, visualizer, etc.

A Nexar sales executive is ready to work with you on building a business case and reaching the final pricing.

Example 4:

A leading Mobility-as-a-Service (MaaS) provider approached Nexar because the maps that were available for a key market were insufficient to compute the estimated time-of-arrival (ETA) reliably. Equipping its fleet with Nexar One dashcams and making them part of the network enabled said MaaS provider not only to increase safety but also to obtain the real-time maps it needs to delight its customers with highly predictable on-demand mobility.

5. Conclusion

At a time where software is eating the vehicle at a fast pace, real-time mapping is the missing tool that enables the industry to collect and process much needed large-scale, high-precision, high-freshness, real-world data — and achieve that at an affordable cost. By building a massive network of "eyes on the road" and bringing AI to the network's edge, Nexar has built a high-performance platform that crowdsources millions of detections, builds new real-time maps and delivers petabytes of visual data from hundreds of thousands of vehicle cameras. By using Nexar CityStream APIs, all industry players can finally leverage the power of real-time mapping to improve comfort, increase safety and build the next generation of mobility solutions.

About Nexar

Nexar is the real time mapping company for future mobility. We help people, vehicles, cities and businesses avoid accidents, conserve energy and win back time on the world's roads. Today, our network collects billions of anonymized images, videos and sensor data from hundreds of thousands of vehicle cameras — all crowdsourced automatically and in real time. Nexar's AI platform maps roads, signs, collisions, work zones, parking spots and moving vehicles in a scalable and cost-effective way. Partners join the network and use Nexar's real-time mapping APIs to delight customers with better navigation, more comfort, higher safety, enhanced driving automation, and a whole new range of mobility apps and services.

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