Future-Proofing the NSDI of The Netherlands: OGC API Innovation with an Open Source Cloud Strategy (13887)

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Key words: PDOK, API, Open Source, Cloud, Innovation

SUMMARY

Public Services on the Map (PDOK) is a leading open geodata service provider and has been an integral part of the Dutch National Spatial Data Infrastructure (NSDI) for over a decade. By providing access to approximately 270 datasets and processing more than 30 billion annual requests, PDOK plays a major role in the national digital information ecosystem. The exponential growth in data usage has increased pressure on service performance and availability, which has been successfully addressed through improved standardization, generic workflows, and a fully automated production pipeline for data services.

A key pillar of PDOK's approach is its open source policy, fostering technological transparency and promoting reuse of developed technical components through cloud solutions. This strategy supports efficient, sustainable, and open development of the NSDI, while encouraging collaboration and knowledge sharing.

In addition to ensuring continuity and reliability, PDOK actively responds to evolving user demands, including the provision of INSPIRE and high-value datasets for dataspaces, interactive data visualization, querying of (large-scale) datasets, integration of 3D geospatial data, and improved discoverability of open geodata. To meet societal and technological needs and the FAIR principles, PDOK has expanded its services by implementing OGC APIs alongside traditional web services.

This strategic expansion strengthens the resilience of the national spatial data infrastructure and enables innovation within the NSDI by facilitating participation from a broader range of stakeholders, including non-Geo entities. PDOK is the first service provider worldwide to make all national spatial datasets available via the latest OGC APIs, resulting in national recognition such as the Best Dutch API Award 2025 and international recognition as a best practice for OGC standards implementation.

In this paper, we share our challenges, solutions, and implementations, providing insight into future-proofing the NSDI.

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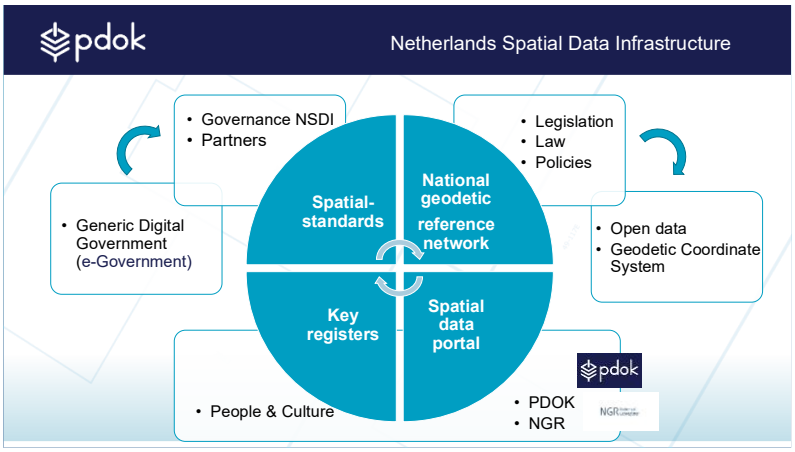
1. PDOK as service provider an essential part of the NSDI

For more than a decade, Public Services on the Map (PDOK) has been providing access to open governmental spatial data for societal reuse. PDOK was established by several (national) governmental organisations with the objective of jointly and efficiently making open geodata available. PDOK is now embedded within the statutory responsibilities of the Dutch Cadastre (Kadaster) and functions as a central facility used by the Kadaster and other public authorities.

Any (semi-)governmental organisation wishing to make its open geodata available for reuse can act as a data provider through PDOK. PDOK publishes these data as datasets with a range of reusable data products. With approximately 270 datasets and more than 30 billion annual requests to these data products, PDOK, as a leading open geodata service provider, makes a substantial contribution to the digital information provision in the Netherlands and, consequently, to the National Spatial Data Infrastructure (NSDI).



A defining characteristic of the Dutch NSDI is the framework within which close collaboration takes place between the national government, provincial and regional authorities, executive agencies, and various advisory bodies with regard to spatial standards, the national geodetic reference framework, key registers, and the spatial data portal.

1.1 The importance of spatial standards and the national geodetic reference network

Standards are essential for PDOK to ensure the reliability, scalability, and consistency of the platform, particularly given the large data volumes, diverse datasets, and varied user base. By consistently applying international standards such as OGC API and W3C, European directives

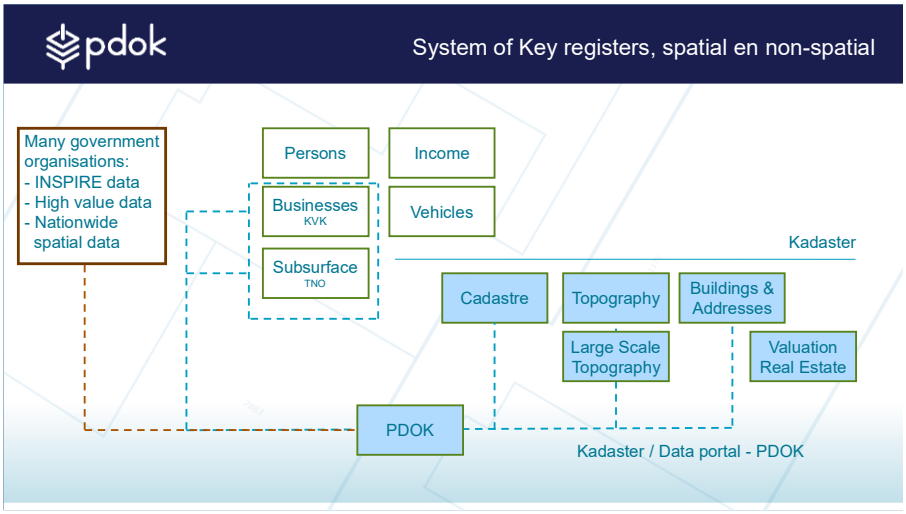
(INSPIRE, EU Digital Strategy) and national frameworks (API Design Rules, Geonovum guidelines), PDOK delivers open geodata in a generic, automated, and standardized manner.

Geodetic reference system standards, such as RD-NAP (Dutch national grid tied to Normaal Amsterdams Peil) and ETRS89/ETRS-LAEA, are also strictly adhered to. This ensures that all spatial data is consistent and interoperable both nationally and internationally. The use of uniform coordinate systems allows reliable and reproducible analyses, visualizations, and data combinations across datasets and time periods.

Applying these standards reduces errors, shortens implementation times for updates and new data products. It ensures stable, predictable access to large-scale geodata. At the same time, data providers can deliver more efficiently, and all users, can access information in a uniform manner. In this way, standards form the fundamental basis for continuity, performance, innovation, and future-readiness of the Dutch Spatial Data Infrastructure, reinforcing PDOK's role as a central and reliable service provider within the NSDI.

1.2 Key registers

A large share of governmental data is recorded in the Dutch key registers and designated as open spatial data. These legally mandated, authoritative data sources are maintained by public authorities and must be made available to society free of charge for reuse.

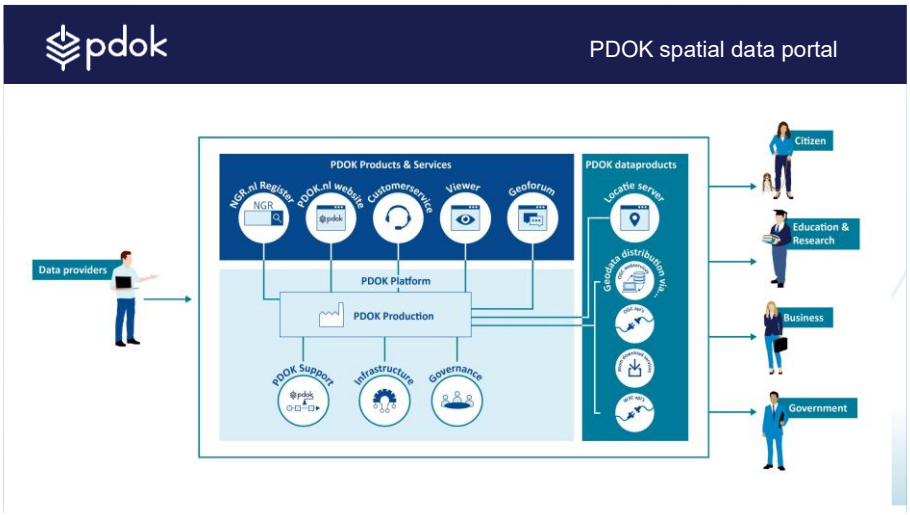


Within the NSDI, PDOK acts as the central service provider for publishing and distributing (INSPIRE) open geospatial data from Dutch public authorities, including data derived from the key registers. This is based on the principle *"the data provider pays, the user consumes"*, ensuring low-threshold, sustainable, and uniform access to open geospatial data.

1.3 The spatial data platform PDOK and NGR

PDOK is a scalable, robust, and highly available platform for the distribution of up-to-date open geospatial data. Its services include standardized view and query services as well as downloadable datasets, delivered via web services and APIs. All datasets are accompanied by structured metadata and technical documentation, ensuring they are findable, accessible,

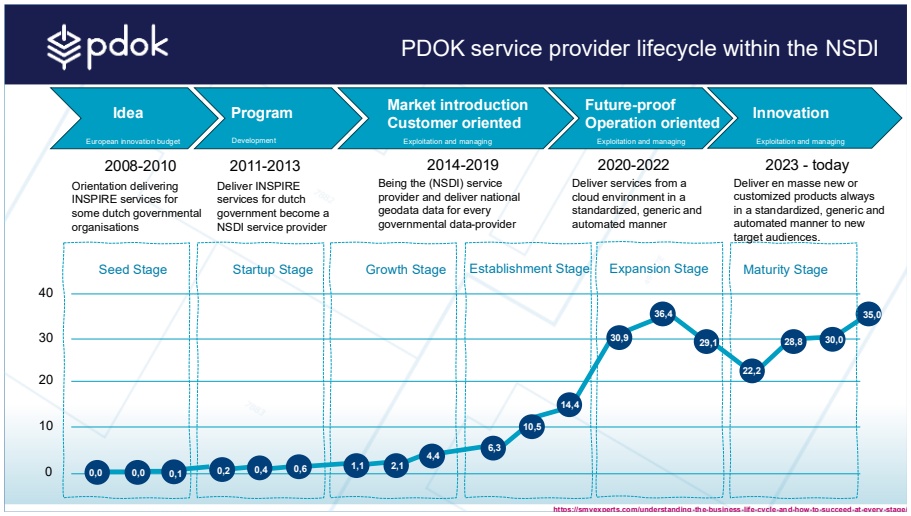
interoperable, and reusable in accordance with the FAIR principles. The data products comply with national and international interoperability standards, including OGC and W3C standards, the European INSPIRE specifications, and Dutch e-government standards. Technical coordination, knowledge sharing, and continuous development are facilitated within the geospatial community, for example through the GeoForum.



The National GeoRegister (NGR) serves as the national metadata catalog and access point for geospatial datasets and services in the Netherlands. The NGR supports the discovery, access, and use of location data, including INSPIRE-compliant open geodata, and is managed by PDOK as an integral component of the National Spatial Data Infrastructure.

2. Exponential growth on the use of open geodata

The exponential growth in data usage has increasingly stressed the performance, scalability, and availability of PDOK's services. Initially, PDOK's primary objective was to efficiently provide (INSPIRE) geodata to its partners. Over time, PDOK has matured into a fully operational, resilient, and service-oriented platform, capable of supporting high-demand geospatial data distribution within the NSDI framework.



2.1 PDOK service provider lifecycle within the NSDI

The lifecycle of PDOK as a service provider within the NSDI is briefly outlined based on the various stages linked to the growth in PDOK's data usage. Opportunities and challenges are presented as context. The paper primarily focuses on recent developments and illustrates how these developments impact the NSDI as a whole.

Seed Stage

In the idea phase, the concept of a government service provider was developed, and the platform was concretely established. PDOK received geodata in various formats from participating organizations and, where necessary, transformed and enhanced it to comply with applicable laws and regulations. The processed geodata was then made available as usable INSPIRE services and published through the PDOK platform, the National GeoRegister (NGR), and the European INSPIRE portal.

Startup Stage

During the program phase, PDOK's products and services were further developed. Custom agreements were established with data providers, resulting in unique configurations, manual processing workflows, and dataset-specific processing. During this period, PDOK was funded by the consortium, and the number of datasets published by participating authorities steadily increased, while structural operational challenges also became apparent.

Growth Stage
In the customer-focused market introduction phase, the consortium was formally dissolved, and the Kadaster was assigned responsibility for operating and managing PDOK. From that point onward, all public authorities were able to publish their open geodata through PDOK. This phase was characterized by scaling up the team and services, as well as the active development of the platform, processing workflows, and infrastructure following agile/scrum principles. Data providers paid for making their open data available, while PDOK expanded and further strengthened its position as the central service provider.

Establishment Stage
The customer-focused market introduction phase continues, and the effects of prior growth became clear. Platform usage and the diversity of available geodata increased, resulting in higher costs and greater complexity in processing and management. This exposed risks to stability and performance, revealing the limits of the existing infrastructure. To address these challenges, the '3G program' was launched, emphasizing standardization, automated based on generic processes. Migration to a cloud infrastructure enabled robust, scalable processing and supported large-scale platform use. The focus shifted to operational excellence, with sustainable system and process design to support continued growth.

Expansion Stage
In the future proof operation-oriented phase, the stabilized platform allowed a renewed focus. Initial explorations of new standards and data products were conducted. The proven business model and now stable processing provided sufficient confidence for innovation. The '3G program' continued during this period, enabling the development and deployment of new data products.

Maturity Stage
In the innovation phase, the platform's maturity is clearly evident. Costs are monitored daily, staff operate according to the '3G program' principles, and data processing is standardized and uniform. Innovation continues: new data products can now be designed and deployed more efficiently and in an automated, standardized manner, serving both existing and new users. On the data provider side, costs are reduced and the turnaround time for new datasets is significantly shortened by applying a self-service approach. Having resolved its growing pains, a mature PDOK now has the capacity and flexibility to pursue further innovation.

3. Conditions for maturity and further innovation

The “open unless” mindset and agile-scrum methodology at PDOK were maintained, but a shift in focus from growth to stabilization necessitated a cultural change to enable further development. This led to the establishment of two internal programs: a cloud migration of all datasets and the 3G program. Both initiatives aimed to strengthen platform stability, laying the groundwork for the maturity phase while preserving room for innovation.

During the cloud migration, all existing dataset processing workflows were transferred to a cloud infrastructure without interrupting service. Processes were standardized and optimized to ensure uniformity and efficiency. Although standards had been in place, practical implementations varied, prompting a review of agreements with data providers and the adjustment of legacy configurations. The migration involved tighter implementation of standards across all technical components, updating open source software where necessary, and enhanced monitoring of changes. Upon completion, all new datasets were processed exclusively through the cloud infrastructure, significantly improving platform stability and performance. Simultaneously, updates to existing data, new product versions, and additional datasets continued to be delivered, maintaining service availability but adding operational complexity.

In parallel, the 3G program was launched, focusing on standardized and automated processing within the cloud environment. Submission formats were largely restricted to GeoPackages (GPKG), GeoTIFF, SLD, and GML, with limited exceptions. Validation processes were standardized, released as open source tools, and incorporated into the product policy. These changes required adjustments by data providers, which were supported through strengthened relationships and clear agreements.
Dashboards were also developed for monitoring cloud costs, in close coordination with the Kadaster’s finance teams. This standardization enabled automated processing, reduced the need for bespoke workflows, and resulted in a more stable, up-to-date, and cost-efficient platform.

4. Overwhelming success results in more customer requests

PDOK's strong success in recent years led to a significant increase in platform usage and a growing number of customer requests. Up to and during the growth phase, many of these requests were fulfilled with the aim of accelerating and strengthening the platform. These requests varied in nature and complexity, increasingly putting pressure on capacity, prioritization, and standardization. In practice, the focus on growth resulted in customized solutions for each data provider. Although PDOK continued to expand its role as a service provider during this period, it became clear that fulfilling further customer requests was no longer feasible.

4.1 More customer requests

During the stabilization phase, PDOK temporarily paused the fulfillment of all customer requests to focus on platform transformation. Requests with significant impact on the technical architecture, operational burden, or existing standards were particularly difficult to implement within the existing framework. Key areas of desired innovation included:

a. **Large-scale Topography Dataset (BGT):** As PDOK's largest dataset, BGT is available only via download API and WMTS due to its scale. A Web Feature Service (WFS) was previously offered but removed due to excessive platform load and associated stability risks. Despite technical limitations, the underlying demand for query services persisted, creating a need for an alternative solution.

b. **Enhanced Visualizations:** Over the years, PDOK received numerous requests from the community for additional and more specific visualizations within Web Mapping Services. Although some datasets were enhanced, manual implementation proved resource-intensive and unsustainable, highlighting the need for a scalable solution.

c. **3D Base Dataset for the Netherlands:** Developed jointly by Kadaster and TU Delft, the 3D base dataset required dissemination via PDOK. Its format and delivery method differed from existing standards, prompting a dedicated program to explore feasible implementation options.

d. **High Value and INSPIRE Datasets for Data Spaces:** Emerging European and national regulations, including the Green Deal, created a demand for PDOK to provide high-value datasets (based on the implementation regulation of the European Union 2024) alongside INSPIRE datasets (based on the INSPIRE directive of the European Union 2007), reinforcing its role as a national service provider.

4.2 Analysis and adopting new standards

The recently developed OGC API standards make open geodata more accessible, including for modern web developers, and offer numerous advantages. They are based on REST APIs and build upon existing OGC Web Service standards such as WMS, WMTS, WFS, and WCS. OGC APIs enhance the discoverability and accessibility of datasets, allowing geo-professionals to retain familiar benefits while enabling non-geo users to work with open geodata more easily.

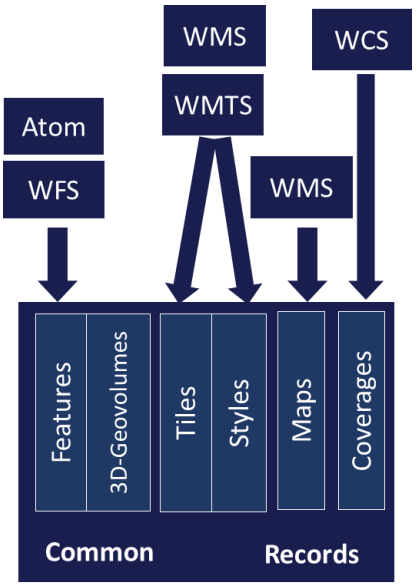
Internationally recognized OGC API standards align with broader global API standards, promoting interoperability and creating new opportunities for society. Following the introduction of OGC API Features, a consistent suite of API standards was developed, including an HTML landing page and OpenAPI specification for each dataset, enabling developers to get started immediately.

Geonovum, the advisory body for and on behalf of the Dutch government, participates in the international development of these standards as an OGC member and translates them for use in the Netherlands through consultations, guidelines, tooling initiatives, and knowledge sharing. In doing so, Geonovum supports the Dutch government and the wider geo-ecosystem in transitioning to the next generation of API standards.

At PDOK, some of the operational web services have existed for over ten years, whereas the underlying OGC standards date back even further. For optimal discoverability, OGC recommends that APIs describe their metadata uniformly and make it available in HTML, which at PDOK contributes to effective use of open geodata.

PDOK has therefore reviewed its web services and product portfolio and initiated a transition to OGC APIs.

OGC API Features and OGC API (Vector) Tiles have now been added to the Dutch “Comply or Explain” list, while the older WMTS and WFS standards have been moved to the recommended list.



5. Realization of desired innovations

With a stable cloud-based platform, built on new infrastructure and revised technical components, PDOK is now able to implement desired innovations and respond to customer requests, while taking into account national and international developments in the geospatial domain.

5.1 A first Minimal Valuable Product

To meet desired innovations and customer requests, PDOK assumed that implementing OGC APIs would provide a future-proof solution within its digital infrastructure. Users of the Web Mapping Tile Services (WMTS) reported that standard visualizations were difficult to integrate with their own map material, particularly regarding colors and labels. Adjustments are challenging because the current map material is pre-rendered as image tiles (PNG or JPEG) served online, making style modifications impossible.

By first implementing Vector Tiles and subsequently adding Features, PDOK anticipated being able to offer an integrated solution of data products with an API interface, rather than providing only Features as explored in other countries. The ambition remained to deliver replacement data products for web services on the existing platform. In 2019, PDOK formulated a research question and started a Proof of Concept: “Is it possible to make the largest dataset from the Key Registers, the Large Scale Topography, also available in a query service based on the latest OGC API standards, so that it can work alongside existing web services on the scalable platform?”

The exploratory project focused on (based on the Proof of Concept knowledge) realizing a Minimal Valuable Product in OGC API’s for the Key Register Large Scale Topografie (BGT), the largest and most complex dataset, with Vector Tiles identified as the main technical risk. The migration to OGC Tiles needed to be high-performing, stable, and of high quality, while fitting within the nightly processing window. Key considerations included on-the-fly tiling, zoom levels, projections, and HTML-based visualization.

In addition to the tiles, Dutch guidelines require accompanying visualizations. Using the existing map server style, manual transformations were performed and made available as styles in a Minimal Viable Product. Specifications for the Vector Tiles (OGC API Common Part 1, OGC API Tiles, and OGC API Styles) were identified and implemented, along with new technical components integrated into an automated workflow with daily updates.

After several iterations, the BGT Vector Tiles were successfully deployed to production on 12 September 2023.

5.2 All Key registers in Vectortiles (OGC API Tiles and Styles)

With the introduction of Vector Tiles, even non-geo experts can create custom map styles. Unlike static PNG or JPEG maps, Vector Tiles are smaller, data-dependent, and contain additional vector information that allows for flexible styling.

Following the successful realization of the Minimal Valuable Product, PDOK decided to implement Vector Tiles for all datasets from the Key Registers. The product specifications and criteria were clearly defined. In the Netherlands, and according to the Geonovum practice guidelines, Vector Tiles are realized through OGC API Tiles and OGC API Styles. For each dataset, available zoom levels are defined, and metadata indicates the implemented levels. The data is provided in three projections: NetherlandsRDNewQuad, EuropeanETRS89_LAEAQuad, and WebMercatorQuad.

PDOK and the data providers ensure a clear and recognizable default style for the OGC API Tiles, which can be further customized by end users. This provides a starting point for users creating their own styles without starting from scratch. In 2023, PDOK implemented Vector Tiles for all six open Key Register datasets and integrated them into the PDOK viewer. Additionally, an interactive temporary PDOK Vector Tile viewer was developed, allowing users to explore and modify styles, such as toggling layers or changing colors, demonstrating the flexibility and potential for developers.

5.3 All Key Registers in Features

Following the success of the Basisregistratie Grootschalige Topografie (BGT) in Vector Tiles and the implementation of the other Key Register open geodatasets, PDOK and the data providers decided in 2024 to make these datasets available via OGC API Features. OGC API Features offer greater stability than the traditional WFS, which was designed for internal organizational use and is difficult to scale for PDOK's large user base. Features are more manageable for the high volume of requests on the open geodata platform.

The second Proof of Concept again focused on the BGT due to its size, complexity, and historical data. Relevant specifications (OGC API Common Part 2, OGC API Features Part 1 and Part 2) were identified and implemented in technical components. The historical data raised new questions regarding filtering and usage, which led to updated architectural principles, after which the other Key Register datasets were rapidly implemented.

OGC API Features enable users to query geographic data via collections and simple queries, download subsets, and use them for analysis, visualization, or other applications. The APIs are self-describing via HTML and JSON, providing policymakers, data specialists, and developers with immediate insight into available data and usage options. Features consist of geometries and attributes, are individually accessible via deeplinks, and can be filtered where supported. Queries can be based on projection, reference date, or selection area, with up to

1,000 objects per request; pagination allows access to remaining data. Historical data enables spatiotemporal analysis.

Landing pages and metadata are optimized for search engines, with clear descriptions, images, and keywords. OGC API Features also provide map views with bounding box functionality to locate features and access all available information per item. Providers can add filters, while more advanced filtering will be part of future specifications (Part 3 and beyond).

On 21 May 2024, the OGC API Features query service for the BGT was deployed and added to the BGT landing page. This milestone marked the completion of the 2024 implementation of the Key Register datasets in OGC APIs and laid the foundation for broader platform-wide plans.

5.4 OGC API Features for all datasets and compliancy to High Value Datasets

With the introduction of High Value Datasets and their associated requirements, such as providing query services and schema information, PDOK decided to further scale and implement OGC API standards to strengthen and future-proof the platform. The initially experimental OGC API production pipelines for the Key Registers were fully automated and standardized, supported by additional innovation funding from the Dutch Ministry of the Interior and Kingdom Relations' Digital Government program.

The goal was to provide OGC API Features for all WFS-enabled datasets, enabling both platform evolution and compliance with High Value Dataset obligations. This led to improvements in technical components, further automation of the production process, and better insight into complexity, costs, and criteria for dataset self-service.

For the High Value Datasets, PDOK also implemented OGC API Features Part 5, making schema information available per collection. This functionality is comparable to WFS's DescribeFeatureType, including field types and optional functional descriptions. Schemas are available in HTML and JSON, usable in tools such as QGIS (version 3.44 and later), and included in the OpenAPI specification, providing developers with direct access to field definitions and data types. Part 5 also defines relationships between features, which, where present, can be navigated via hyperlinks or identifiers; currently, PDOK offers this functionality for two datasets.

The addition of more data sources and the standardization of processing pipelines has made the platform more robust and better aligned with performance and quality requirements. Since 2025, every WFS has been automatically accompanied by an OGC API Features, allowing datasets to be easily delivered via WMS, WFS, Atom, and OGC API Features. These developments establish a solid foundation for the future application of OGC APIs and the continued evolution of the PDOK platform.

6. PDOK as international example and the impact on the NSDI

The Netherlands, through PDOK, is one of the first countries in Europe to provide nationwide geodata according to the latest OGC API standards. PDOK achieved a world first by implementing the Large-scale Topography Database (BGT) in OGC API Vectortiles, thereby providing insight into the complexity of a national dataset and overcoming challenges in terms of processing, scalability and performance. This success has been internationally recognized and promoted by OGC as an example for other countries (OGC Tiles Showcase).

Subsequently, PDOK explored OGC API Features for the same dataset, enabling a robust query service that had previously been technically unfeasible. By implementing OGC API Common in conjunction with Features, BGT collections could now be queried in a consistent and standardized manner. This resulted in a second internationally recognized example (OGC Features Showcase) and earned PDOK the national API award.

The third international success concerns 3D geodata. PDOK was the first in the world to apply the OGC API 3D Geovolumes (draft) to nationwide datasets, including specific 3D standards. These datasets were made publicly available for societal use through sheet-level download functionality and an interactive 3D viewer, allowing users to visualize and analyze advanced 3D information.

Finally, PDOK is globally unique in offering integrated OGC API services for large-scale geodata use. Each dataset is available via both OGC API Vectortiles and OGC API Features, making PDOK a robust, future-proof, and internationally leading geodata platform.

The impact on the Dutch Spatial Data Infrastructure (NSDI) is significant. These innovations have strengthened the NSDI in terms of stability, continuity, and resilience, enabling broader innovation across a wider range of stakeholders, including non-geospatial parties. PDOK's open source policy promotes technological transparency, component reuse, and collaboration, ensuring that open geodata is efficiently, sustainably, and FAIR-compliant available to society. Additionally, PDOK supports the implementation of European directives such as INSPIRE, High Value Datasets, and the Green Deal, serving as a model for international best practices in OGC API implementation.

Through these developments, PDOK positions itself as a leading national and international service provider, offering both geospatial experts and a wider user community access to high-quality, nationwide open geodata, thereby making the NSDI future-proof.

7. PDOK and future ambitions

PDOK continuously optimizes its platform, services, and APIs, while actively engaging with stakeholders through communities, events, education, and social media to share knowledge and best practices.

Transition from Web Services

In the long term, OGC APIs will replace existing web services (WMS/WFS). PDOK drives this transition by implementing OGC APIs widely and promoting the reuse of open-source components, enabling new applications for citizens, businesses, and government. WMS and WFS support will remain available temporarily to ensure a smooth migration for GIS users and providers.

New Data Products and Enhancements

Existing products such as VectorTiles, Features, and 3D Geovolumes are being further automated and enhanced. Innovation is driven by user needs and emerging or concept standards, including relationships between collections and data schemas. Missing OGC API products are also being introduced, including Maps (replacing WMS), raster data via Coverages, and enhanced download functionality.

Metadata and Publication

PDOK is developing an integrated metadata catalog, in which the DCAT-AP-NL standard will be applied and extended with OGC API Records/STAC. Standardization and enhanced metadata improve proper usage and ensure better accessibility and discoverability.

Self-Service for Data Providers

A self-service platform enables data providers and PDOK staff to create and manage data products independently, largely automated and without IT intervention. This reduces costs, ensures consistent application of standards, and allows providers to take full ownership over time. Cybersecurity, authorization, and data delivery are integral to this process.

Geocoding via OGC API

The PDOK Location Server has been upgraded to the Location API, based on OGC API Features. This new data product is live and continues to be developed, with integration in both the PDOK viewer and the 3D viewer.

REFERENCES

PDOK is accessible via https://www.pdok.nl/. All OGC API's provided by PDOK are organized in https://api.pdok.nl/. All Dutch open geodata, including non-PDOK datasets, is published and searchable via het NGR https://nationaalgeoregister.nl/. For inquiries regarding specific datasets or to share knowledge, users can engage through the community at www.geoforum.nl or contact PDOK directly via the information provided on the website.

BIOGRAPHICAL NOTES

Anouk Povel-Michels is a Senior Advisor at PDOK (Public Services on the Map) within Kadaster Netherlands, specialising in geospatial information, open data, and digital public services. She provides strategic advice on the development of PDOK as the national geospatial data platform, integrating policy objectives, technical and business frameworks, and user needs. She also contributes to international initiatives through Kadaster International, including projects in Georgia, Albania, and Indonesia, and represents Kadaster International in knowledge-sharing and policy-oriented forums, promoting alignment of standards, best practices, and international cooperation in the global geospatial community.

Dorus Kruse is within Kadaster Netherlands manager within the Operations department. He is a leader in both managerial and international arenas. As a Permanent Correspondent for Eurogeographics and a delegate in UNGGIM Europe, he represents Kadaster Netherlands with distinction on the global stage. With a career spanning over two decades, he has excelled in roles such as Regional Director for the International Sybase User Group, managing impactful projects across Europe, Africa, and the Middle East. At Kadaster International, he has spearheaded transformative projects in Turkey, Croatia, Serbia, Kosovo, Montenegro and Rwanda, revolutionizing digital cadastre, land registry, and spatial data infrastructure (SDI).

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