

# THE DANISH WAY TO A NATIONAL SPATIAL DATA INFRASTRUCTURE

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### ABSTRACT:

In Denmark, location is a recognized gateway to eGovernment and public administration. The National Survey and Cadastre (KMS) participates in a range of public partnerships that work towards the generation of more effective public services. Recent developments in Denmark's public sector have placed new demands on KMS. The 2007 structural reform, in which Denmark's internal administrative boundaries were largely redrawn, has required the development of new cross-boundary solutions. This includes the sharing and merging of geographic information, which local and governmental authorities use in their administrative activities. Geodata are generated and maintained based on standardized, coordinated and cost-effective procedures. This yields a unique spatial data infrastructure for eGovernment and public administration in general. KMS is responsible for establishing national standards for the generation, storage and sharing of geodata. As Denmark's responsible authority for the implementation of the European directive INSPIRE, KMS has acquired new international obligations. This has required KMS to address the standardization of geodata as both a national and European activity. KMS' activities include the establishment and maintenance of the following geodata types:

1. National Geodetic Reference Systems and Networks
2. Digital Terrain Models
3. Place Names and Points of Interest
4. The Digital Map Supply - web service
5. Common/Shared Object Types - large and small scale map databases
6. Cadastre
7. Cadastral Archives
8. Nautical Charts
9. Administrative Boundaries

KMS is currently facing a transition from traditional mapping responsibilities to the development of a new infrastructure for sharing geodata in a wide range of contexts. This has required KMS to increasingly tailor its work to a rapidly changing national and international market.

## 1. INTRODUCTION

The National Survey and Cadastre (KMS) is an institution under the Danish Ministry of the Environment. KMS' vision is to provide Denmark's public sector, private companies and general public with accurate and updated geographic information about the territories and waters of Denmark, Greenland and the Faroe Islands. KMS is Denmark's public authority for maps and geodata, as well as the spatial infrastructure behind Denmark's growing eGovernment. The country is moving towards the implementation of a broad eGovernment strategy in which geodata will serve a central role in improving the efficiency of public administration. KMS ensures the development of the geodata required by civilian and military activities, but generates and produces very few paper maps or similar product. This production is tendered and outsourced to independent private contractors.

## 2. KMS' RESPONSIBILITIES AND TASKS



Figure 1. KMS' mapping responsibilities  
(Projection: LTP08)

### 2.1 eGovernment

Location is a gateway to eGovernment and public administration in Denmark. The national spatial data

infrastructure is increasingly supporting the needs of digital society by meeting national standards and fulfilling international obligations. The Danish SDI model (figure 2) recognises the central role that geographical data can play when used as a common foundation. Responsibility for data is distributed among the users who actively use the data and are therefore willing to pay for their generation and maintenance.

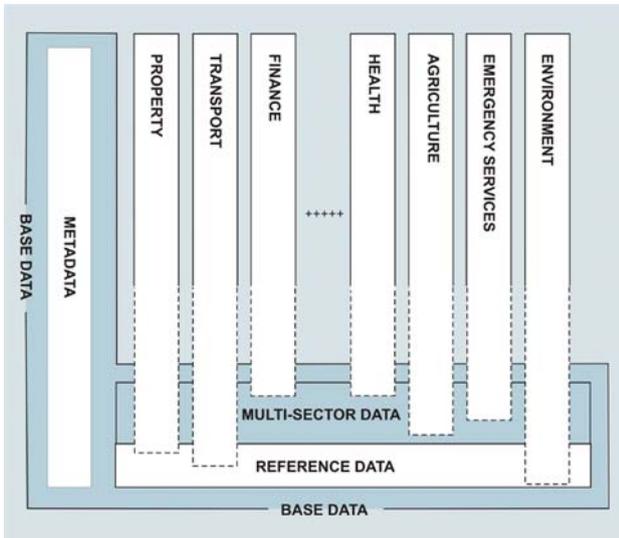


Figure 2. The Danish SDI model

In this model, KMS is responsible for the “base data” which consists of metadata, reference data and the multi-sector data that are shared and used in multiple sectors. Other public institutions maintain their own sector-specific data and provide for their compatibility with other institutions’ data. KMS ensures that the acquisition and management of geodata is standardised, coordinated and cost-effective. This facilitates the use of maps and geodata as an administrative basis for Danish eGovernment.

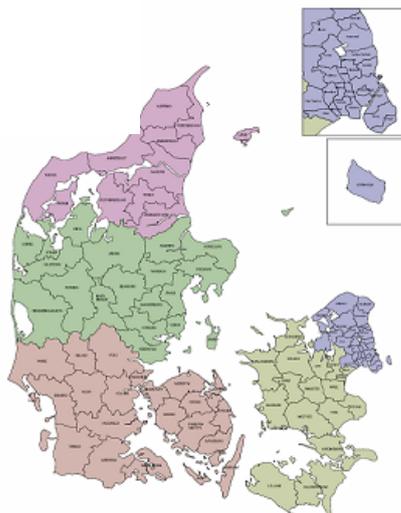


Figure 3. Administrative boundaries as of January 1, 2007: 5 Regions and 98 Municipalities

## 2.2 The 2007 Structural Reform

Recent developments in Denmark’s public sector have placed new demands on KMS. The 2007 structural reform, in which 13 counties were merged into 5 regions and 270 municipalities were consolidated into 98 new, larger units, required the development of new cross-boundary solutions. The new authorities met an immediate need to share and merge their geographic information, in order to fulfil their administrative responsibilities. In the coming years, KMS will continue to develop a modern and robust national spatial data infrastructure to reinforce data sharing among the municipal, regional and national authorities.

## 2.3 Spatial Data Infrastructure and INSPIRE

In many ways, the European INSPIRE Directive reflects Denmark’s recent initiatives to develop standardised geodata that can be shared across boundaries and sectors and in broad administrative contexts. The implementation of INSPIRE places additional demands on the Danish spatial data infrastructure in a number of areas, including metadata, access and licensing. KMS participates in a range of public partnerships that work towards the generation of more effective public services. Standardisation is a precondition for efficiently using geodata across boundaries and sectors.

Both the INSPIRE Directive and national stakeholders, including the growing national eGovernment project, place demands on the standards that Danish geodata must meet. Therefore, the Spatial Data Service Community (SDSC) was established in 2002 to coordinate public collaboration of geodata resources. The Community members include KMS, Local Government Denmark, Danish Regions, The National Agency of Enterprise and Construction, the Directorate for Food, Fisheries and Agribusiness, the Road Administration and the Ministry of Science, Technology and Innovation. Together, their goal is to establish digital solutions that support effective eGovernment. KMS holds chairmanship and secretarial responsibilities for the SDSC.

## 3. GEODATA - THE BACKBONE OF EFFECTIVE eGOVERNMENT

KMS’ activities include the establishment and maintenance of a wide range of geodata types. These include reference networks, a Digital Elevation Model (DEM), place name registers, topographic data, property registration records and archives, nautical charts and administrative boundary data.

### 3.1 National Geodetic Reference Systems and Networks

The development of GPS technology has revolutionized surveying methods in many ways, and has placed new requirements on KMS as Denmark’s surveying authority. The national spatial data infrastructure requires an updated version of the national network of reference points, 3D network and an expansion of the national network of permanent GNSS stations. Furthermore, KMS has developed new technical coordinate systems and projections in connection with the implementation of ETRS84 (WGS84). KMS has also assisted local and government offices with the shift from the outdated systems to the new one.



Figure 4. GPS measurements on the bridge that links Denmark and Sweden

The launch of the European satellite navigation system GALILEO will intensify the use of GNSS at all levels. Broader satellite availability will improve the prospects for a road pricing system. The registration of geographical data on a shared international basis and the uniform use of GPS throughout Denmark via national GPS services will be crucial.

### 3.2 Digital Elevation Model (DEM)

Digital elevation data is a necessary component of a spatial data infrastructure. Denmark's current digital elevation model is based on outdated terrain surveys and high altitude photogrammetry. There are growing demands for an accurate elevation model in applications such as climate change modelling, water management planning in accordance with the EU Water Framework Directive, shore protection, emergency management and defence. New techniques for gathering and processing precise elevation data have emerged in recent years.



Figure 5. LIDAR-based terrain model

**3.2.1 Technical Details of the DEM:** KMS is currently supervising the development of a new national digital elevation model on behalf of the public sector. In addition to the economic benefits of the joint procurement, the model will also ensure a common data foundation among its users.

The new DEM is based on laser scanning (LIDAR) and comprises 3 components; a digital terrain model (DTM), a surface model (DSM) and contours. The model is produced by a consortium of two private companies - BlomInfo and Scankort - and the contract was signed in spring 2007. The first deliverables were made available during the summer of 2007 and a full first draft of the dataset was delivered by January 1, 2008. The data, covering the entirety of Denmark, were acquired in the period 2005 – 2007 and are stored in more than 700.000 files.

A comprehensive specification for the 3 models was given in the tender material. The grid size of DTM and DSM should be 1.6 meters (data acquisition density 0.45 point pr. square meter on average) and a vertical accuracy between 0.1 and 0.5 meters, depending on the material and characteristics of the surface.

KMS is responsible for quality control of the model. The control is carried out in co-operation with national and international experts. The procedures have been divided into a delivery check and a final quality control. The delivery check ensures completeness and identifies possible gross errors such as peaks, areas with no data and artificially generated data from data processing. This check was carried out during the first months of 2008 and was focused on the terrain model.

Early in the quality control process, it became evident that further developments were necessary in order to achieve a reliable surface model. Standard filtering for the entire country was not satisfactory and a differentiated procedure that took the various surface types into account was necessary.

The basic topographic vector database of Denmark (TOP10DK with 52 surface and object types and a specified accuracy of 1 meter) was chosen as the reference for separating and identifying surface and object types. A raster version of the vector data base was introduced and its object information used to create specific filter and interpolation methods based on surface type. The result of a close co-operation between the supplier consortium and KMS on this matter has yielded quite successful results.

The contours are calculated from the 1.6 meter raster DTM with a contour interval of 0.5 metres. Depending on the use and the scale of graphical presentation, the contours will be recalculated in order to match the degree of cartographic details. Both the smoothness and the contour interval will be adjusted. This includes contours on printed maps at various scales for armed forces use and a number of web applications.

### 3.3 Place Names and Points of Interest in Denmark and

#### Greenland

There are approximately 25.000 authorised place names in Denmark. The standardisation of place names began in 1910, when the task was entrusted to the Place-Name Committee. The Committee is still the authority responsible for the orthography of Danish Place Names, and also distributes information about the official spelling of Danish place names.

KMS requires accurate information about place names in its data bases and on its digital maps. This includes spelling as well as correct positioning. KMS has developed a Place Name and Information Register that is linked to its topographic data bases.

More than 120.000 place names are included in the register – 25.000 of these are authorised – in addition to approximately 25.000 points of interest. These include camp grounds, museums, schools and the like.

As a result of the 2007 structural reform, many of the old place names related to the former 13 counties have been abolished. Naturally, some of the old names have been reused or modified in the new regional structure, but also many new names have been introduced.

As the Greenlandic nautical charts are currently being updated, there is a new need to translate a range of Greenland's place names. The registration of the nautical charts' sea and land place names has contributed to the revision of the gazetteer of Greenlandic toponyms. The gazetteer will likely be published in a generally accessible web application, where it will be edited and updated on a running basis. This process is being carried out in collaboration with Oqaasileriffik – the Greenland Language Council.

### 3.4 Common/Shared Object Types (FOT)

Together with the Spatial Data Service Community and Local Government Denmark, KMS has launched FOTdanmark to establish a national base map for use at all administrative levels. For example, the 2007 structural reforms redistributed responsibility for environmental administration in the public sector. FOTdanmark will ensure that geodata can be shared across the new administrative boundaries.

A number of municipalities have already joined FOTdanmark. It is crucial that FOT geodata is established nationwide in the coming years to ensure that FOT becomes an integral part of the national spatial data infrastructure and, further, the e-Government.

The establishment and maintenance of FOTgeodata is based on aerial photographs. Updating will be incorporated into the existing routine administrative updating. Updates will reflect administrative changes as soon as they have been registered by the local authority, and there will be integration between the shared geodata resources and the administrative realities.

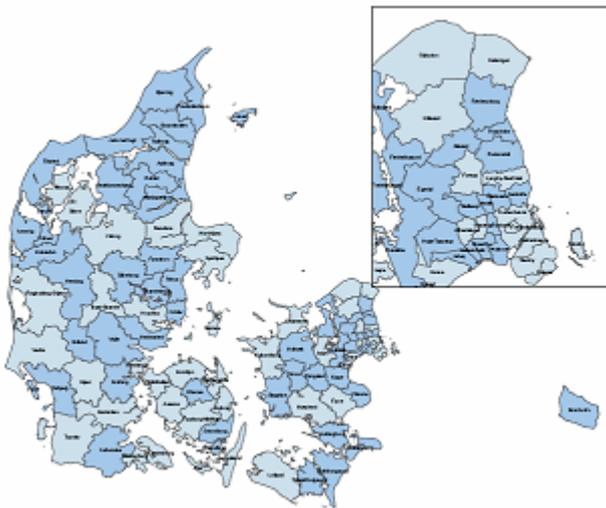


Figure 6. Members of FOTdanmark are shaded in darker blue

**3.4.1 The FOT Collaboration:** The FOT concept is based on a combination of the information from existing maps, including the nationwide topographical TOP10DK database, which has a specified accuracy of 1 meter in all three dimensions, and large scale "technical" maps with an accuracy requirement of 10-20 cm used by local government administrations.

The FOT object list comprises more than 60 object types; most of these are mandatory.

Three classes of photogrammetric registration (mapping) are defined for rural areas, built-up areas and city areas. The areas

and the corresponding object types and registration rules are named OP1, OP2 and OP3 respectively.

Data is acquired stereoscopically from digital aerial photos. Although the FOT specification identifies 3 image scales for the 3 different mapping classes, practise has shown that 2 ground sample distances in the photos are sufficient, i.e. 10 cm and 20 cm pixel size.

Seamless orthophoto maps have become an extremely popular product and several municipalities have decided that their respective administrative areas should be registered with 10 cm pixels, replacing a complete registration with 20 cm pixels and 10 cm registration of city areas. Utilizing modern photogrammetric software, digital orthophoto production is fast and cheap.

Orthophotos are an integral part of the FOT concept and the same digital photos are used for both stereo digitising and orthophoto production. In this way, complete consistency is achieved for vector data and orthophoto maps. In addition, the orthophotos are used in the quality assurance process for geometric completeness.

The production of FOT vector data is carried out through tendering by external contractors, in accordance with the FOT specification. The tendering is managed by the FOT networks, typically consisting of 6-8 municipalities and the national government, represented by KMS. The final check to ensure the data is harmonic countrywide and properly stored is a KMS responsibility.

So far it has been difficult for the contractors to meet the specification requirements and create a production line that can deliver data acceptable for the FOT networks. FOT is built on the idea that all the best of existing data should be reused and supplemented with the new registrations, in order to create an updated and complete geodatabase. However, the merging of existing data that is registered according to outdated specifications and data from new aerial photos is a very difficult task. Consequently, a more pragmatic solution has been agreed in some of the FOT networks. Most of the geometry is photogrammetrically registered from new aerial photos, while a significant percentage of attributes are reused from existing registers and databases.

### 3.5 Topographic data

Currently, the topographical databases and the various small scale map series are all based on the TOP10DK databases. Data for the various products are derived from the basic database by a complex set up of generalisation routines and links to place names and points of interest. Some of the map series can now be derived more or less automatically.

As FOT is implemented, the new FOT data will replace the existing TOP10DK data in the topographical databases. It will take a few years before all TOP10DK data is replaced, and in the meantime, a hybrid database is being used. Some areas are covered by TOP10DK data and some registered as more detailed FOT data. However, all topographic map series and data for KMS' web applications are derived from this basic database.

Figure 7 shows data from the hybrid database. The lower left part is detailed FOT data, while the upper right part represents TOP10DK data.



Figure 7. Merged FOT and TOP10DK data

### 3.6 Cadastre and Property management

A comprehensive property register is an important precondition for efficient economic development. The cadastre is the basis for property registration in Denmark.

An ambitious restructuring of the cadastral systems and procedures is underway, in order to improve the efficiency and quality of land administration and to support the land registration reforms.

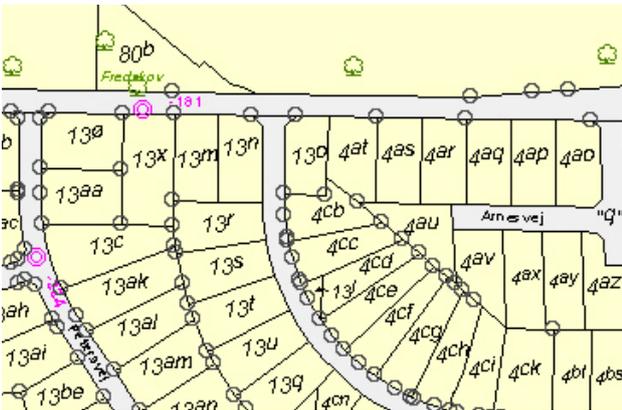


Figure 8. Part of Danish cadastral map

Once these reforms are complete, the cadastre and cadastral map will be a fully integrated component of the national spatial data infrastructure. It will also meet the criteria of a multi-functional cadastre. KMS takes responsibility for establishing models of cooperation for implementing this activity.

KMS continues to maintain the national cadastre at high standards, while simultaneously moving towards a paperless interface between chartered surveyors in private companies and KMS. This is being carried out in conjunction with the Danish

Association of Licensed Surveyors. In the future, both parties will contribute to establishing paperless processes in further areas of property administration.

Further development of the cadastre includes techniques for registering new types of property, including properties and infrastructure at elevation and depth. KMS will ensure that these needs are met.

### 3.7 Cadastral Archives

KMS has initiated a comprehensive digitisation of the Danish cadastral archives. The oldest records in the archive date back to 1844. The new digital records will be integrated into the national spatial data infrastructure, where they will complement e-Government services.



Figure 9. Old analogue cadastral archives

This digitisation project contributes to securing the objectives of the national eGovernment strategy, entitled *Towards Better Digital Service, Increased Efficiency and Stronger Collaboration 2007-2010*. The project also increases access to KMS' records for citizens, enterprises, researchers and others.

Digitisation of all cadastral archives constitutes a long-term process that is balanced against KMS' other strategic objectives. The most frequently used survey data and historical cadastral maps will be prioritised highest and digitised first.

### 3.8 Nautical Charts

KMS is responsible for nautical mapping of the Danish, Greenlandic and Faeroese waters, as well as for the quality assurance of the marine geodata of these regions.

A seamless interface between hydrographic and topographic geodata can be valuable, if not critical. This is the case in Armed Forces preparedness as well as emergency management and environmental administration. In the next few years, the need for greater integration between hydro- and topographic data is expected to grow.

**3.8.1 Revised Charts in Greenland:** Changes in navigation patterns, improvements in ships' navigation equipment and intensification of mineral resources prospecting around Greenland have created demands for higher quality nautical charts than those currently available. The geometrical accuracy varies, and calculations have shown the coastline to be several

nautical miles displaced in some areas. KMS is working with Greenland's authorities to improve and reissue a substantial number of the Greenlandic charts over the next four years.

Nautical charts in Greenland are mainly based on surveys from 1930-1988. Based on the need for nautical charts at a reasonable accuracy in a GPS-based datum, transformation of the existing data from the old chart to a new one based on datum WGS84, was investigated. WGS84 is realized as GR96 – the Greenland 1996 datum.

GR96 was developed on ITF94 observations in a few stations distributed across Greenland. The result of some older GPS, Transit and Doppler observations were datum shifted to GR96. The entire triangulation network with fairly few distance observations was adjusted.

From 1978 to 1986, KMS initiated a complete coverage of the ice-free parts of Greenland with super wide angle photogrammetric images. The scale is approximately 1:150.000. The black and white photos that cover the relevant charts were scanned and a new improved aerotriangulation was established based on the improved GR96 datum. A new coastline was registered photogrammetrically, a terrain model calculated by correlation and finally an orthophoto produced.

Since the original observations for the old charts were not available, the adjustment was based on a scanning and a subsequent vectorization. The photogrammetrically plotted coastline was used as the coastline in the new chart. Corresponding points, which were easy to recognize in both the *old* and in the *new* charts were chosen giving pairs of pixel in UTM zone 24 GR96 coordinates.

The differences between the charts were irregularly distributed, showing major differences over short distances. The most important data to be transformed were close to the coast, i.e. highest weight in the transformation. The farther away from the coast the information is, the more general the transformation should be. A collocation interpolation has such behaviour.

By the combination of geodetic observations, photogrammetric procedures and scanning/vector techniques, a cheap and efficient method has been developed to transform an old paper chart with substantial errors to a relatively geometrically correct GPS-based chart. Further, the charts are now in digital (vector) form, and can easily be updated when new information becomes available.



Figure 10. Securing the Maritime Highway

### 3.9 Administrative Boundaries

The 2007 structural reform affected municipal areas, jurisdictional districts, police districts and constituencies, and resulted in new administrative boundaries. This required the generation of a new official representation of Denmark's administrative units for statistical, planning and administrative purposes.

The INSPIRE Directive presents additional requirements for geodata on administrative boundaries. Together with Denmark's national authorities, KMS will ensure the establishment of a new independent dataset named *Administrative Boundaries of Denmark*. Once established, this dataset will be integrated into the national spatial data infrastructure.

## 4. APPLICATIONS

### 4.1 The Digital Map Supply

KMS' services are digital. Via the Digital Map Supply, the Internet has become the institution's most important channel for the distribution of geodata. The Digital Map Supply is thus an integral part of the national spatial data infrastructure and meets the INSPIRE requirements for geodata distribution services. The Digital Map Supply distributes geodata and spatial functionality based on a service-oriented architecture (SOA). It is not an end-user service, but feeds data into independent providers' own solutions. KMS' geodata is hereby simultaneously integrated into emergency services, environmental administration and other unique applications.

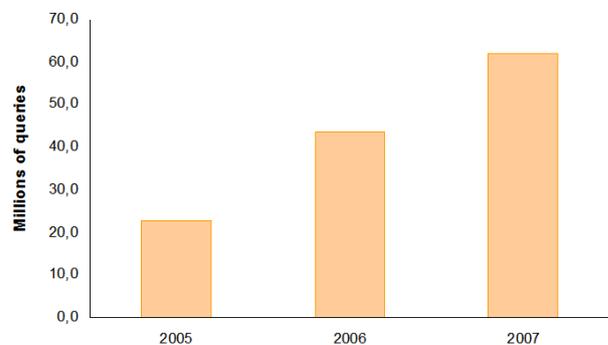


Figure 11. Queries to the Digital Map Supply

In the maritime sector, the distribution of electronic nautical charts is managed by Primar in Norway. The possibilities for parallel distribution through the Digital Map Supply are being examined.

### 4.2 Emergency data

In emergency situations, critical demands are placed on the ability to rapidly access and utilize geographical information.



Figure 12. An Emergency situation – with analogue map  
Foto: Uffe Kongsted, copyright (Politiken [www.pol.dk](http://www.pol.dk))

The growing threats of terror attacks, natural disasters, environmental pollution, epidemics, outbreaks of veterinary diseases, etc. demand emergency preparedness among national authorities.

Spatial data infrastructure can be a valuable element in the successful management and mitigation of emergency situations. KMS ensures that geodata is immediately accessible in emergency situations to provide a common operational picture for emergency management authorities.

KMS' activities in the emergency preparedness area will also reinforce the European initiative GMES, which fosters the development of environmental and safety information services linked to spatial data infrastructure.

#### 4.3 Armed Forces

KMS signed a new contract with the Danish Armed Forces at the end of 2006. The contract identified KMS as a consultant to the Armed Forces and as their centre of geodata expertise. KMS prioritizes the continued development of its cooperation with its military partners and will continue to respect their unique situations and responsibilities. The Danish Armed Forces have a strong focus on the development of their future spatial data resources. Their international engagements are also critical.



Figure 13. Military planning using analogue maps

A synergy between military and civil needs for spatial data infrastructure has become increasingly apparent. While implementing its contract with the Armed Forces, KMS will ensure that its efforts in the military sector are coordinated with

its work for the civil sector. This will ensure a more efficient and effective resource deployment in both sectors.

## 5. CHALLENGES AND PERSPECTIVES

Topicality in all KMS databases is a demand for today, as is immediate accessibility. Up-to-date data including comprehensive metadata is critical for almost any activity in modern society, and in many cases, it can be more important than geometrical accuracy.

The Digital Map Supply is a cornerstone in the distribution of data to partners in the public and private sectors. KMS focuses on well-tuned IT systems that support automatic and semi-automatic data quality assurance procedures, effective databases and rapid information dissemination.

KMS is currently facing a transition from its traditional responsibility of generating maps to fulfilling new demands for geographical data that can be shared and applied in a wide range of contexts. This has required KMS to increasingly tailor its work to a rapidly changing national and international market.

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