From spatial data infrastructure to geospatial knowledge infrastructure: The role of management and financing models

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Key words: GKI, SDI, IGIF

SUMMARY

With the introduction of new technology and advancements in how geospatial data is integrated, analyzed and visualized, there have been calls from multiple stakeholders to reject the spatial data infrastructure (SDI) paradigm, and make the transition towards Geospatial Knowledge Infrastructure (GKI), where the delivery of knowledge, and not data, is the primary focus (UN-GGIM 2020).

The infrastructure for sharing and using geospatial data in Norway falls within the former way of categorizing the infrastructure, as a spatial data infrastructure. It facilitates the use and sharing of geospatial information in both the public and private sector. In recent years, there has been an ambition to evolve and transform the Norwegian spatial data infrastructure into a geospatial knowledge infrastructure where the delivery of knowledge, based on geospatial data, is the aim. However, this transformation faces challenges due to shifts in the framework conditions that underpin it.

To meet these challenges and to help with the transformation, it is necessary to adopt new models for funding and managing the infrastructure. The Ministry of Local Government and Regional Development has over the past several years examined new models for funding of and collaboration in the infrastructure.

This paper will present the Geospatial knowledge infrastructure concept and key elements. The paper will also present the key components of the current SDI in Norway, and the changes in framework conditions. Lastly, the paper will describe the work of the Ministry of Local Government and Regional Development in exploring new alternative models for funding and management of the infrastructure, and how these can contribute to the transition towards GKI.

Sustainable financing and management of the geospatial knowledge infrastructure

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1. Introduction

Spatial data infrastructure (SDI) has long been regarded as the predominant concept for facilitating and organizing key components that enables the use and sharing geospatial data (UN-GGIM 2020). The spatial data infrastructure can be defined as a framework of policies, legislation, institutional arrangements, technologies, data, and organizations that enable the effective sharing and use of geographic information (Putra et al 2019, Bernard et.al 2005).

In recent years, there has been calls for a paradigm shift from a focus on data provision in the spatial data infrastructure to a knowledge infrastructure, or geospatial knowledge infrastructure (GKI), where the delivery of knowledge, based on the collection and modelling of geospatial data, is the main priority. The main arguments for this shift, is the technological limits of SDIs and the lack of results in ensuring standardized, up-to-date, and accurate data (UN-GGIM 2020, CRCSI 20217). The application of new technology such as artificial intelligence and Internet of things (IoT) is dependent on high computing and storage capacity, state- of-the art networking and security infrastructure and advanced analytics (Witkowski 2019, Kumaran 2019). These are prerequisites that many current SDIs are not adopted to nor can deliver on.

In Norway, the framework conditions that have been the foundation for spatial data infrastructure, are already under pressure from new, legislation, increased data usage and an increasing number of cyber-attacks, and the existing financing and management models are not able face these new developments. To ensure a transition from the spatial data infrastructure to a geospatial knowledge infrastructure, these and other challenges need to be solved to ensure that the GKI can be fully realized. This may necessitate adoption of new models for financing and management of the infrastructure.

This paper will start with an introduction of the geospatial knowledge infrastructure and how it can contribute to reach the Sustainable Development Goals. The author will then present the Norwegian spatial data infrastructure with a focus on changes in framework conditions in recent years, and the transition towards a Geospatial knowledge infrastructure. Adding on this, the paper will highlight the work of the Ministry of Local Government and Regional Development and Norwegian Mapping Authority in exploring new models for managing and financing key components in the infrastructure.

2. Geospatial Knowledge Infrastructure

The concept of a spatial knowledge infrastructure was first put forward by the Australian and New Zealand Cooperative Research Centre for Spatial Information (CRCSI) in 2017. CRCSI

proposed a transition from the SDI concept to a Spatial Knowledge Infrastructure which aims at automating the creation and sharing of, and using, knowledge (CRCSI 2017).

In a discussion paper from 2020, the term and concept of Geospatial Knowledge Infrastructure was introduced and described. GKI was presented as an infrastructure that "enables trusted understanding, knowledge, decisions and automation by integrating geospatial information, analytics and visualization into the knowledge and automation environments of our cooperative digital future" (Geospatial World & UN Statistics Division 2020, p.11). Within this concept, the geospatial infrastructure is seen as integrating and merging with the wider digital ecosystem, as the use of geospatial data has become a ubiquitous part of our lives and supports decision-making across multiple sectors (Geospatial World & UN Statistics Division 2021).

Building on this, the GKI represent a shift in focus from the provision of data, which has been the goal of SDIs, to the delivery of knowledge and foresight. As the complexity of understanding data rises, the need for non-domain experts to understand and create information and challenges with data duplication (CRCSI 2017), there is a growing demand for delivery of knowledge directly to end-users without the need for further processing or editing (Geospatial World & UN Statistics Division 2021). The GKI aims to achieve this by leveraging technological advancements, such as artificial intelligence, machine learning, Internet of Things etc. As shown in figure 1, the transition from SDI to GKI, also represent a shift in key stakeholders, systems and how data is distributed and presented.

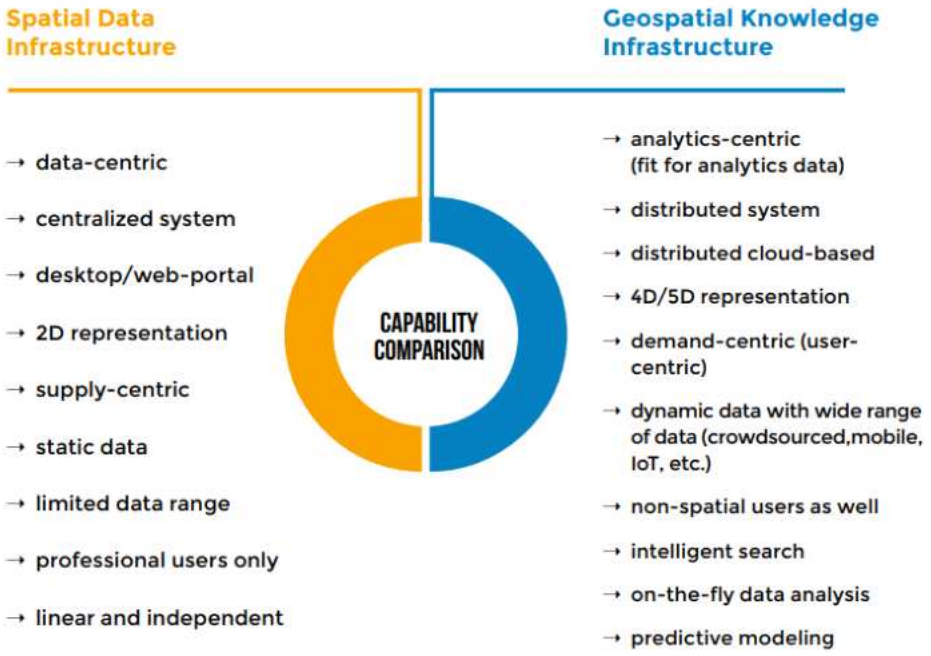

Figure 1: Comparision of characteristics for spatial data infrastructure and Geospatial Knowledge Infrastructure (Geospatial World 2020).

The GKI concept also proposes several goals. This includes that all data has attributes that enable geo-location and up-to-date foundation authoritative geospatial information is available for use. Policies and strategies should lay down framework conditions that contribute to realization of the value of location to multiple stakeholders. This is underpinned by principles asserting the importance of knowledge and foresight, which should be based on the needs of decision makers and users. Further, a core principle is that geospatial technology and infrastructure should emerge with the wider digital ecosystem to become one ecosystem (Geospatial World & UN Statistics Division 2021).

The geospatial knowledge infrastructure concept builds on six different elements that contribute and promote the key principles and goals of GKI, as described above. Through an integrated **policy framework (1)**, governments establish frameworks that ensure that spatial information can be utilized in the wider digital infrastructure across different sectors and society as a whole. Geospatial policies are developed to address the complex nature of geospatial data and to increase the use and value. **Foundation data (2)** is closely linked to the first element, as trusted and authoritative foundation data is a key element of the digital infrastructure and can through policies be defined, made accessible and open. It enables government bodies and businesses to retrieve essential information and unlock new insights (Geospatial World & UN Statistics Division 2021),

The elements of **partnership and collaboration (3)** and **industry leadership (4)** presents the key stakeholders in the GKI concept, and emphasize the need for government, public bodies, citizens, and the private sector to collaborate in order to unlock new knowledge from geospatial data. This also includes co-financing new infrastructure and data collection. The industry is seen as having a key leadership role as most new development and services will originate from within the industry, and not the government (Geospatial World & UN Statistics Division 2021).

As mentioned above, the primary objective of the GKI is to provide knowledge. Through **applications, analytics and modeling (5)** data is combined by the use of existing and new technology such as artificial intelligence, to deliver knowledge and to support decision making. Lastly, the sixth element puts forward the notion that GKI integrates a **geospatial dimension to the wider digital ecosystem.** Key elements such as geospatial data, xyz-position and geospatial analytics are viewed as an equal part of the digital infrastructure, and the infrastructure must be designed and built on these elements to enable the delivery of knowledge (Geospatial World & UN Statistics Division 2021).Within each of these elements,

as shown in figure 2, there are associated initiatives that contribute and promote the key principles and goals of the GKI.

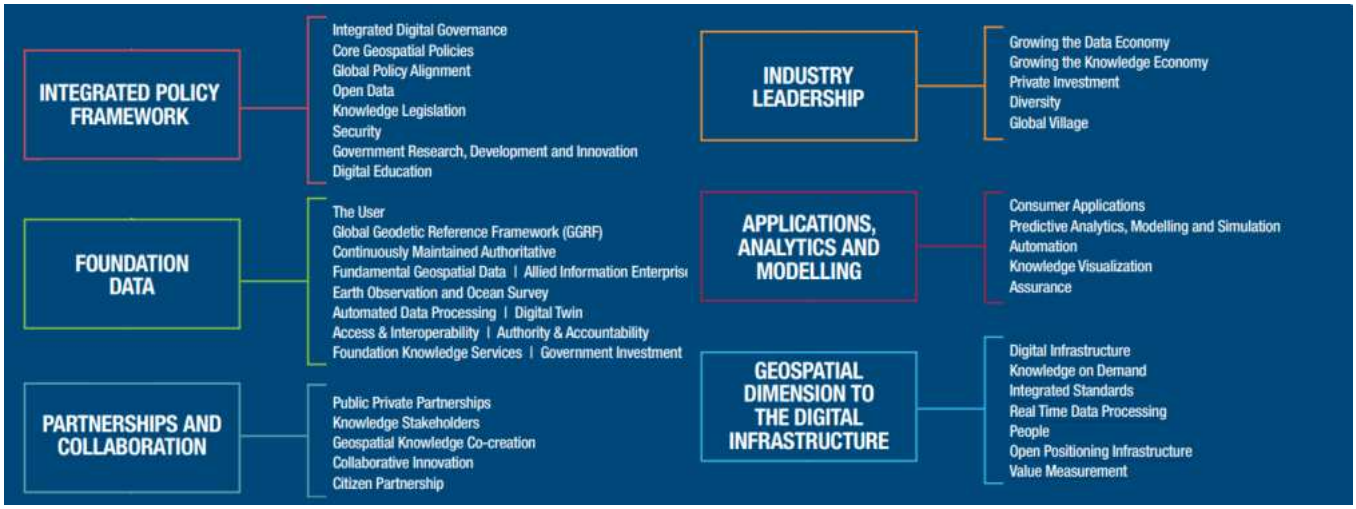

Figure 2: Initiatives associated with the seven principles of GKI. Adopted from Geospatial World & UN Statistics Division 2021

2.1 Geospatial knowledge infrastructure and the Sustainable Development Goals

By delivering ready-to-use knowledge, made possible using new technology, the geospatial knowledge infrastructure can be used to achieve and support the UN 2030 Agenda for Sustainable Development with its 17 sustainable development goals (SDGs) (Geospatial World & UN Statistics Division 2022). Information gathered from geospatial data, together with other types of data, is crucial to monitor progress and to make decisions that enable the achievement of the SDGs (UN-GGIM & WGGI 2022). It is estimates that 20 % of the SDG indicators can be interpreted and measured by using geospatial data by itself or coupled with statistical data (Arnold et. al. 2019).

However, geospatial data alone cannot support the achievement of the SDGs. All of the components that make up the geospatial knowledge infrastructure are needed to make sure that data is collected, funded, analyzed and delivered to users as knowledge. This is highlighted by the United Nations Integrated Geospatial Information Framework (IGIF). The IGIF provides a framework and guide for countries to develop, strengthen and manage geospatial information and related components. It focuses on the role geospatial data has for decision-making and how it plays an important part in the digital infrastructure and knowledge economy. The IGIF framework also emphasizes that nations need to strengthen and modernize all aspects related to geospatial management, such as policies, laws, infrastructure, usage and collaboration between public institutions, the industry, and citizens (UN-GGIM 2023a).

With all of the components of the GKI working together, the prerequisites are in place for acquiring new knowledge from geospatial data that can be used to both monitor and meet the

SDGs. Foundation data is especially important in this context, and the 14 global fundamental geospatial data themes defined by the UN-GGIM are shown to be relevant for all of the 17 SDGs (UN-GGIM 2019).

3. Norwegian Spatial data infrastructure

The Norwegian SDI facilitates the use and sharing of geospatial data to solve societal challenges and to reach the SDGs. A wide range of stakeholders across the public and private sector are involved in the development and maintenance of the infrastructure. It consists of data, metadata, digital services, and web mapping applications. It also encompasses legal, administrative, technical, and organizational prerequisites (Ministry of Local Government and Regional Development 2023a). In the following paragraphs, some of the key components of the infrastructure will be described.

3.1 Act on an infrastructure for geographical information (spatial data act)

The act on an infrastructure for geographical information, better known as the spatial data act, was put into motion in 2010. The purpose of the act is to promote access to geospatial data for use in the public and private sector. The act also defines which entities and organizations are mandated to participate in the infrastructure, and includes primarily public authorities such as state, municipal and county administrative bodies and other administrative and public advisory bodies. According to the act, these authorities must create and maintain a network of services that allows spatial data to be viewed, searched, transformed, and downloaded. Adding on this, the act also enforces that the involved bodies, shall share specified data through a common infrastructure (Ministry of Local Government and Regional Development 2010).

In 2012 a regulation to the spatial data act was adopted. This regulation presents detailed rules on how public bodies shall organize their services to provide spatial data, co-operation in the infrastructure, limitations in access to data and how data should be shared between participating actors.

3.2 Geovekst

Geovekst is a co-operation and collaborative effort between several public bodies, 351 municipalities, telecommunication company Telenor and several electric power companies to finance, establish, manage, collect, and use detailed spatial data and orthophotos. This co-operation, which was established in 1992, makes sure that data is collected once in an agreed standard, is maintained and is up to date, and can be used by a wide range of actors. Through co-financing by the above-mentioned stakeholders and through income from sale of data, a wide range of data can be collected and maintained at a low cost.

Through Geovekst, projects that involve aerial photography, map making, orthophoto, laser scanning, surveying, etc. are initiated. The costs of these projects for the involved

stakeholders, varies based on the cost/benefit principles, but the average distribution is set through a fixed rate. The revenue of Geovekst amounted to 165 million NOK in 2022.

3.3 Norway Digital

Norway Digital NSDI, is co-operation between organization and public bodies that collects and maintains spatial data or is a user of spatial data. Participants in the co-operation includes municipalities, counties, government agencies and other organizations that supplies and use spatial data. The cooperation involves over 600 partners as of 2024.

Members of Norway Digital get access to detailed spatial data, aerial photos, satellite images, cadastral and building information, positioning web services and zoning plans from municipalities. To gain access, members must pay an annual fee that is used to finance basic spatial data and agree to share their own spatial data in the infrastructure.

3.4 Ministry of Local Government and Regional Development

The ministry of Local Government and Regional Development in Norway is responsible for the Norwegian geospatial data policy. This includes the agency management of the Norwegian mapping authority, Kartverket. In 2018 the Norwegian government presented the National geospatial strategy towards 2025, and the ministry has the overall responsiblity for the action plan that follows the strategy.

3.5 The Norwegian Mapping Authority: Kartverket

Kartverket is the Norwegian mapping authority and is responsible for the management and coordination of the spatial data infrastructure. Kartverket establish, maintains, and shares detailed spatial data, cadastral information, land and sea maps and elevation data. Kartverket also manages several mapping services and solutions that enables viewing and downloading spatial data on behalf of a range of public bodies (Kartverket 2021, Ministry of Local Government and regional development 2023b).

3.6 Geonorge

Geonorge is the national web portal for spatial data and information in Norway. The portal gives public agencies, municipalities, and other government organizations the ability to register and make their data available for downloading. The portal also ensures that users can view geospatial data and download it. A wide range of data is accessible for downloading through Geonorge, such as basemaps, thematical spatial data and master and zoning plans. Geonorge is one of the most important components in Norwegian SDI and is managed by the Norwegian mapping authority Kartverket (Geonorge n.d.).

4. The Geospatial Knowledge Infrastructure Country Readiness Index

The Geospatial Knowledge Infrastructure Country Readiness Index assesses several parameters that are critical in the transformation from SDIs towards a Geospatial Knowledge Infrastructure and gives countries a score from 0 – 100 points. The purpose of the index assessment is to give stakeholders insights into the maturity of parameters that enables a geospatial knowledge infrastructure (UN Statistics Division & Geospatial World 2022)-

The six key elements of the GKI, which is described in section 2, is assessed and is the starting point for the summation in the index. Norway was ranked as number 15 of 50 countries in the 2022 GKI Country Readiness index with a total score of 70.21. Norway scores overall good on four of the six parameters, but compared to similar countries, has a low score on Industry leadership and Partnerships and Collaborations (UN Statistics Division & Geospatial World 2022).

5. Challenges to transform the spatial data infrastructure to a geospatial knowledge infrastructure

As indicated by the GKI Country Readiness index for 2022, there is still progress needed in the transformation of the Norwegian spatial data infrastructure towards a GKI. However, there is a clear ambition to evolve the SDI into a geospatial knowledge infrastructure where knowledge from geospatial data can be delivered directly to users. This is made evident in the geospatial data strategy for Norway: “Everything happens somewhere”. The strategy highlights that geospatial data must be analyzed and transformed into knowledge ready for the decision-making process and highlights the importance of using new technology to acquire knowledge (Ministry of Local Government and Regional development 2018). However, the transformation from SDI to GKI is challenged by changes in the framework conditions that lays the foundation for the transformation.

In recent years, the volume of spatial data and the use of mapping services in Norway has increased exponentially. Figure 3 shows the increase in the usage of mapping services provided by Kartverket, which has increased from 2 to 16 billion queries in 11 years. This has led to a significant increase in the costs associated with management and further development of the solutions and services. In addition to this, the demands of the users of the infrastructure are on the rise. There is an expectation from the users that more data should be made available, and that the infrastructure needs to be updated to handle new data sources and technology (Ministry of Local Government and Regional Development 2018). To meet the rising usage and demand in the future, further investments are needed. Adding on this, an increasing number of cyber-attacks and the need to safeguard data to ensure confidentiality, has necessitated considerable investments to ensure adequate security and control.

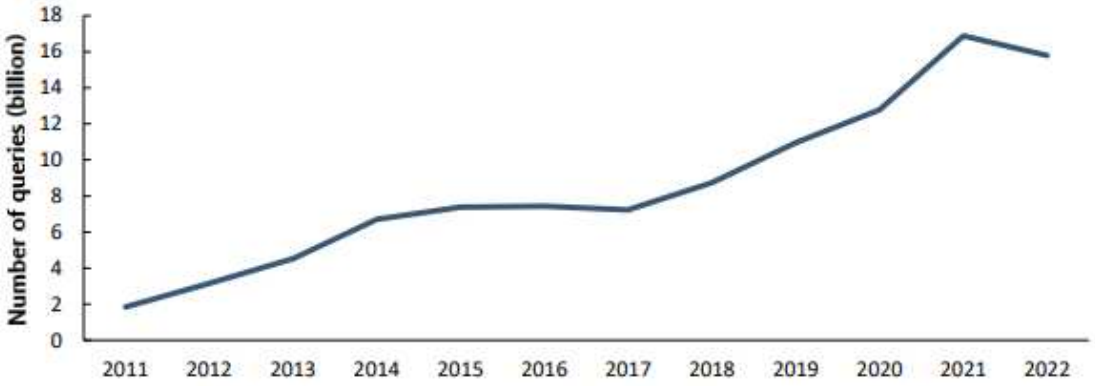

Figure 3: Number of queries in application run by the norwegian mapping Authority. Source: Menon Economics (2023).

New legal framework conditions also influence the ability for the Norwegian SDI to develop further and transform into a GKI. The European Open Data Directive (ODD) was adopted by the European Union in 2019 and lays the foundation for the reuse of public sector data, such as geographical information, in free and open formats for both commercial and non-commercial purposes. To comply with the directive, public agency and bodies must make information reusable and ensure that users can search and discover data. The directive also defines data under six different categories as high value datasets (HDV), including geospatial, which should be made freely available. In 2023, an implementing act for the directive was adopted, detailing specific datasets in each category that must adhere to the directive (EU 2023)

Since Norway is a part of the European Economic Area, the spatial data infrastructure must comply with the directive and implementing act. Currently some parts of the infrastructure comply with the new regulation. However, to meet all the requirements of the implementing act, new investments are needed to ensure that applications and data can be made available in machine readable formats through APIs. The implementing act might also affect the existing co-operation efforts in collecting and financing of geospatial data, such as Geovekst and Norway Digital (Agenda Kaupang 2019).

5.1 Assessment of new management and financing models

To meet the challenges described above, and to continue the transformation and improve the progress towards a GKI, new models for management and financing of the infrastructure are needed. The framework conditions for the infrastructure must also align with the challenges described above and provide predictability for stakeholders in both the public and private sector. Sustainable financing of the infrastructure that enables management and sharing of geospatial data, is a key component to drive this transformation. This supported by the IGIF framework, which highlights that financial governance and new investments are necessary to

achieve sustainable management of geospatial information. In countries where SDIs are already successful in providing users with the geospatial data they need, growing user demands for more data and new data types will require new and additional investments (UN-GGIM 2023b). As described above, this is in many ways indicative of the situation in the Norwegian SDI.

Giff and Coleman (2002) refer to the conclusion of Rhind (2000) that there are four different models for funding spatial data infrastructures; Government funding with funds derived from taxation; Private sector funding with funds derived from fees charged to customers; public sector funding with funds derived from fees charged to customers and lastly the indirect method, where funds are derived from multiple sources such as advertising, sponsorship etc. The funding of the Norwegian spatial data infrastructure consists of a mix of the first three models. Funding comes through budget allocation to the mapping authority, Kartverket. The government also generate funding by fees arising from public processes and applications and through the sale of data. Also, co-financing through Geovekst and Norway Digital is a source of funding the infrastructure. The different methods applied to fund the spatial data infrastructure has been effective to generate adequate income while maintaining the priority of key users and utilizing combined resources of multiple stakeholders. However, the challenges the infrastructure is facing today might indicate that the current funding regime in Norway is not predictable enough and sufficient (Ministry of Local Government and Regional development 2018).

The Ministry of Local Government and Regional development, together with Kartverket, therefore initiated in 2019 a process to assess current funding models, associated issues of new alternative models and to evaluate consequences of any potential restructuring. One of the models which was explored was making all the data in the infrastructure, free of charge. A large portion of the data in the infrastructure is already free and can be used without restrictions. However, this does not apply for the most detailed geospatial data which is collected and managed through the Geovekst co-operation. The release of restricted data may lead to a potential loss of revenue, and at the same time decrease available funding and potentially weaken the co-financing models such as Geovekst and Norway Digital (Ministry of Local Government and Regional development 2018). A study by Agenda Kaupang (2019), confirms that this is a possible scenario. The study highlights some of the positive consequences with the release of data, such as more innovation and efficient data collection by public bodies. At the same time, the release of data might necessitate that the government increase funding to compensate for loss of revenue and to ensure the continuation of collaborative efforts.

In the last two years, the work of the ministry has shifted from looking at the release of data to funding of map viewing services and APIs in the infrastructure. The Norwegian national geospatial data council has on several occasions expressed significant concern regarding the lack of funding for the applications and services in the infrastructure. There is a great need for accessible, up-to-date, and high-quality geospatial data for critical societal and operational tasks. This need cannot be met without adequate funding for the applications that manage and

distribute the geospatial data (Ministry of Local Government and Regional Development 2023c). The ministry has taken these concerns seriously and commenced efforts in 2023 to explore financing options for applications and solutions within the infrastructure. This initiative is ongoing, with further developments expected in 2024.

There is still work to be done to determine new funding models for geospatial data and applications that facilitate the sharing and viewing of such data in Norway. However, there is no doubt that this is an important prerequisite for the further development of and transition to a geospatial knowledge infrastructure. It is important to note, that new funding models will not solve all the challenges that the infrastructure is currently facing. As the GKI concept builds on and promotes several other elements, as indicated in section 2, there also needs to be action towards ensuring high quality foundation data, collaboration between public and private bodies and dialogue with stakeholders outside the geospatial industry to lessen the gap to the wider digital infrastructure.

6. Conclusion

This paper has introduced and presented the Geospatial Knowledge Infrastructure (GKI) concept, and its key components, principles and goals. The concept represents a shift from a traditional spatial data infrastructure, with a data-centric orientation, towards a focus on delivering knowledge to users. The GKI concept aims to bring the geospatial or spatial data domain closer to the wider digital ecosystem as geospatial data has become a key part of decision-making across several sectors.

The paper has described key components in the Norwegian spatial data infrastructure, and how the infrastructure scores on the Geospatial Knowledge Infrastructure Country Readiness Index. The process of transforming the infrastructure towards a GKI is challenged by changes in several framework conditions such as increasing use of data and applications, and new legislation.

The Ministry of Local Government and Regional development views new models for management and funding the infrastructure as potential solutions to address these challenges, and the paper highlights the work of the ministry into this matter.

There is need for further work within this area, but the paper underscores the importance of management and funding models to evolve the infrastructure into a Geospatial Knowledge Infrastructure.

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BIOGRAPHICAL NOTES

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