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IGIF-(M)SDI Maturity Roadmap

Towards Marine and Terrestrial IGIF Integration

Quick-Start Guide for undertaking an IGIF-aligned (M)SDI: The Foundation for an effective Digital Twin

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Maximising the value of location information

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Executive Summary

This IGIF-MSDI Maturity Framework structured by the UK Hydrographic Office and international partners, seeks to advance Marine and Terrestrial IGIF integration. One of the key messages therein is that an MSDI is a continual journey and not an end-state of expensive technological solutions. It asserts that nations are sovereign in what manner of MSDI they genuinely need for their national requirements, not by an externally imposed or presumed level of technological sophistication (unless otherwise chosen).

The IGIF-MSDI Maturity Framework is being jointly developed via the UKHO, IHO, OGC, and World Bank, with participation from the US National Oceanic and Atmospheric Administration (NOAA). As a straightforward and accessible document, its intent to provide a quantitative and prescriptive "Quick Start" or "Stepping Stone" for nations beginning an IGIF-aligned MSDI implementation. It supplements and does not replace any existing resource.

The World Bank SDI Diagnostic Toolkit with its Terrestrial heritage is augmented with IHO and OGC contributions to maximize its benefits to the Marine community, whilst being aligned with the UN IGIF principles (and UN SDGs as a result). As a guiding simplification, the involvement of the World Bank is crucial in providing answers towards the Financing question (incl. business cases), alongside Why (UN), What (IHO), and How (OGC). This aspect of measuring (socio-economic) return is commonly a key hurdle behind real-world progress.

When properly executed, the resulting MSDI Diagnostic Toolkit provides a quantitative assessment for nations or individual marine agencies to baseline their MSDI maturity, as aligned to the UN IGIF principles. The modular IHO and OGC additions ensures interoperability with the World Bank IGIF methodology, which can lead to the financing of approved MSDI development projects. Even as an independent tool, undertaking an MSDI assessment provides a clear reference point aligned with international Best Practice. Without such a starting point, progress towards any MSDI end state will be difficult to govern and manage.

Policy analysts and decision-makers are encouraged to focus on the context setting chapters, which are covered up to page 29. Experienced MSDI practitioners looking to implement the assessment can refer directly to page 29 onwards.

Six-Point Summary of the IGIF-MSDI Maturity Roadmap

1. Who?

For all stakeholders in the geospatial ecosystem working within the marine and/or terrestrial domains.

2. Why?

Cross-agency engagement is crucial for delivering sophisticated future capabilities such as Digital Twins.

3. What?

Alignment of an MSDI implementation with the IGIF, leveraging World Bank expertise in SDI assessment.

4. When?

Pre-implementation to the early and middle stages of an IGIF-aligned MSDI transformation programme.

5. Where?

As a stepping-stone to a fully integrated IGIF-MSDI ecosystem for national, regional, and port-specific MSDI solutions.

6. How?

Early alignment will reduce future costs of divergence by ensuring interoperability with an All-Domain NSDI[1].

1 All-domain: Air, land, sea, space, and cyberspace (if applicable). NSDI: National Spatial Data Infrastructure.

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IGIF-MSDI Assessment Questions

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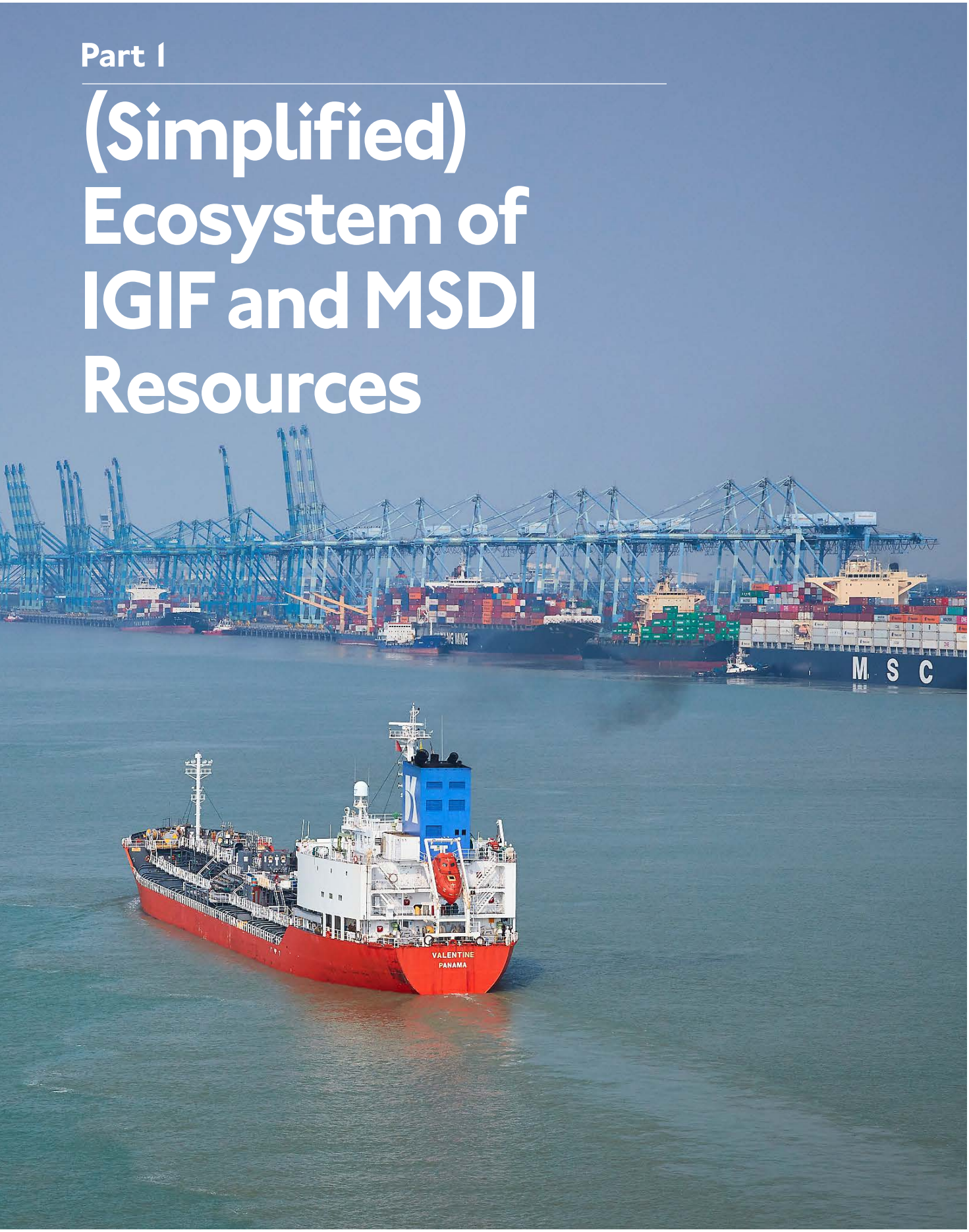
(Simplified) Ecosystem of IGIF and MSDI Resources



Introduction to this IGIF-MSDI Maturity Roadmap

Policy analysts and decision-makers are encouraged to focus on the context setting chapters, which are covered up to page 29. Experienced MSDI practitioners looking to implement the assessment can refer directly to page 29 onwards.

Who is this intended for?

This IGIF-MSDI Maturity Roadmap is intended to provide guidance for those within Governmental departments or agencies, who are actively planning an MSDI (Marine Spatial Data Infrastructure) implementation, which is independently aligned with the broader IGIF (Integrated Geospatial Information Framework) developed by the United Nations. Such stakeholders include all organisations who create or consume geospatial data. Typically, the coordination of such efforts is the responsibility of hydrographic offices or equivalent governing body, though this is not exclusively the case, and will likely vary depending on the national arrangements within a country.

Why it is useful?

The needs in respect of strengthening geospatial management will differ between stakeholders and very often each has an incomplete view of the current state of maturity of the MSDI. For national agencies beginning their IGIF-MSDI journey, this roadmap can assist in circumstances where familiarity is not at a level sufficient for enabling the coordinating marine and/or maritime body to pursue an IGIF-MSDI transformation programme. Depending on the arrangements within a country, increased engagement may be needed at the agency leadership level (delegated marine responsibilities), between governing agencies (split responsibilities) or at an Executive branch level (centralised responsibilities). This roadmap can be particularly useful as an executive summary, where full exposure to the ecosystem of separate IGIF and MSDI resources might create the basis for more questions than answers from decision-makers.

What is covered here?

This roadmap aims to cover the essential elements needed for an effective MSDI implementation, which is independently aligned with and supportive of the United Nation's IGIF initiative. It aims to distil IGIF-MSDI topics into a more digestible "quick-start" guide or "menu of options". As such, it is not intended to be complete, comprehensive or to replace any existing resource from either the IGIF or MSDI communities of interest – only to synergise and complement them.

When is it ideally applied?

Although it can be usefully applied at any point in development of an IGIF-compliant MSDI journey, it is especially well suited to nations who are beginning or have recently started their IGIF-MSDI journey. It is designed to align with government modernisation agendas, digital transformation, climate change and blue economy initiatives, helping to maximise the benefits of such undertakings. For hydrographic or maritime agencies having already started an IGIF and/or MSDI implementation, this Maturity Roadmap can help to ensure that current undertakings are adopting IGIF-MSDI global Best Practice.

Where is it applicable?

The focus of this IGIF-MSDI Maturity Roadmap is developing nations, but it has also been found to be useful in developed countries as it espouses generally applicable Good Practice. It need not only be applied at a national level but will work equally well at a regional and individual port level. It is especially suited where a "stepping-stone" is desired towards creating a fully featured ecosystem of IGIF and MSDI resources. It is not designed to replace the extensive materials published by the UN or IHO (or any industry, academic, or national-level resources), which provide the framework for aspiring nations undertaking an IGIF or MSDI initiative respectively. This roadmap is designed to complement and support any existing resources, where stakeholders should eventually progress onto using these in-depth resources, as/when they consider it appropriate to do so.

How will it help?

This IGIF-MSDI Maturity Roadmap is intended to enable early alignment of an MSDI implementation with the UN IGIF principles, thus reducing the risk of later divergence that would take significantly more effort and financial cost to correct (than that needed for early alignment). This is especially the case for mission critical technologies that have been implemented and effectively hardwired into an organisation, but that are not interoperable with end-users, data suppliers, stakeholders or MSDI partner agencies. One key benefit of early alignment is that a hydrographic office (or national equivalent) can remain relevant despite increasing competition from the private technology industry and open sources of data, which are not assured, verified, or validated for decision-making under time, safety, or security critical conditions.

Figure 1 provides some key examples where an IGIF-aligned MSDI could contribute to national interests.

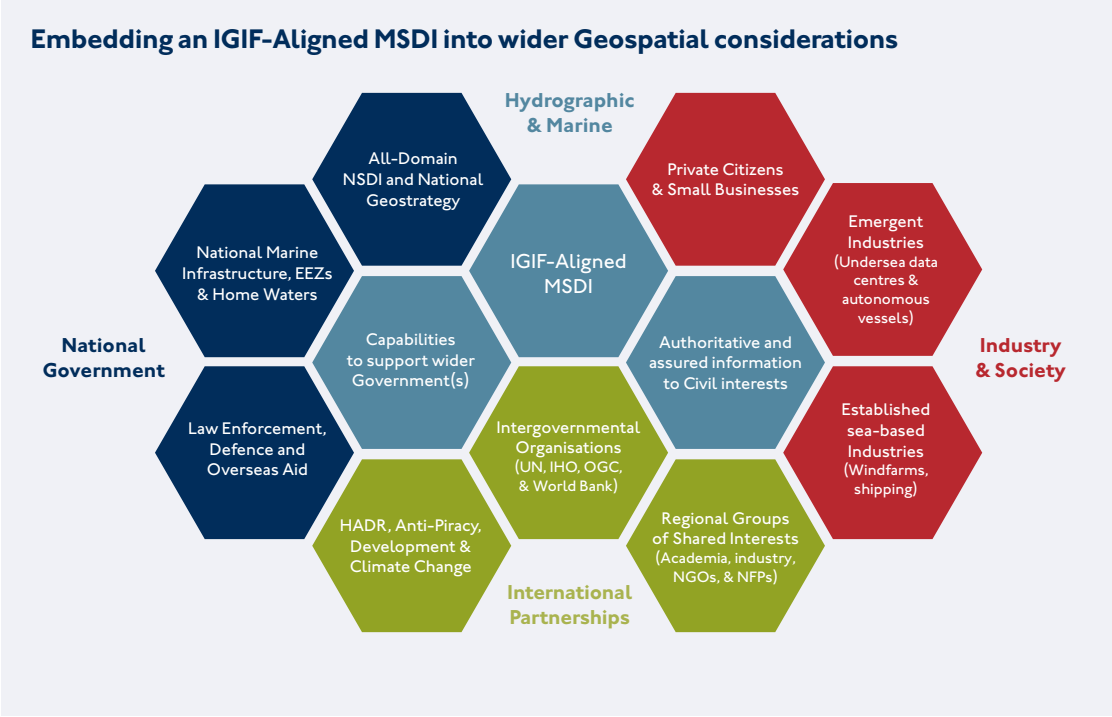


Figure 1: IGIF-MSDI contributions to Marine Spatial Planning, National SDI, wider Governmental decision-making, plus socio-economic activities by individuals, businesses, and industry sectors.

What is the IGIF and an MSDI?

It is important that this work builds on the existing work that has been done by pinnacle bodies – including the United Nations, World Bank, IHO, and the OGC in the field of strengthening geospatial information management. In this section we outline some of the key existing initiatives to show the crucial pillar of existing guidance and Good Practice upon which this work builds on.

UN Integrated Geospatial Information Framework (IGIF)

Developed and first released via the United Nations Statistics Division in 2018, the Integrated Geospatial Information Framework (IGIF) provides countries with a basis for developing, integrating, strengthening, and benefiting from geospatial information management. It will assist countries in bridging the geospatial digital divide and to secure socio-economic prosperity for all sectors of civil society.

The IGIF encompasses three connected documents: Part 1 is an Overarching Strategic Framework; Part 2 is an Implementation Guide; and Part 3 is a Country-level Action Plan (specific to a nation's goals). These three parts comprise a comprehensive framework that serve a nation's needs in addressing economic, social, and environmental factors, which depend upon location information that can be fast-changing.

The Implementation Guide describes what is needed to establish, maintain, and/or strengthen a nation's geospatial information management system and capability. The IGIF focuses on location information that is integrated with other meaningful data, acting as a catalyst for economic growth and opportunity, whilst aligning with a nation's development priorities and the UN Sustainable Development Goals.

The World Bank has developed an IGIF-aligned SDI implementation methodology for creating investment-focused Country Action Plans referred to as the "Four Tools". The first tool is an SDI Diagnostic Toolkit, followed by IGIF Alignment to Policy Drivers, that leads to an IGIF Socio-economic Plan, which ultimately results in an IGIF Action Plan at the Country-level. At all four stages, the World Bank's finance expertise ensures that all outputs are of investment-grade decision "quality".

The enhancement of the SDI Diagnostic Toolkit with its terrestrial origins and focus, is of key interest in this IGIF-MSDI Maturity Roadmap and is further developed with modular IHO and OGC input. This ensures interoperability with the original SDI model and hence an All-Domain NSDI approach (Air, Land, Sea, & Space). The analogy is the addition of "M" into (M)SDI with IHO insight and "Making it Real" with technology via OGC expertise.

The IGIF is sometimes referred to informally as the "Nine Strategic Pathways" that references the nine interrelated strategic pathways, which reflect the component parts of an integrated geospatial information system. It is key to note here that IGIF covers all types of geospatial information, not just the immediate context of marine data, building upon previous global efforts around National Spatial Data Infrastructures (NSDIs).

For completeness, IGIF has connections to other programmes that are also under the umbrella initiative of the UN-GGIM (UN Global Geospatial Information Management), which are developed and approved via the UN Statistics Division. These resources include the Implementation of Geospatial Standards (via ISO, IHO, and the OGC) and the White Paper on (Open) Marine Geospatial Information from the UN-GGIM Working Group on Marine Geospatial Information (WG-MGI).

Of note is the Operational Guide from the WG-MGI, also known as IGIF-H ("H" for Hydro) that contributes thematically towards IGIF Country-level Action Plans around marine and hydrographic data. One useful analogy is that IGIF-H is an operational lens or filter through which to view IGIF in the context of hydrographic offices (or their national equivalents).

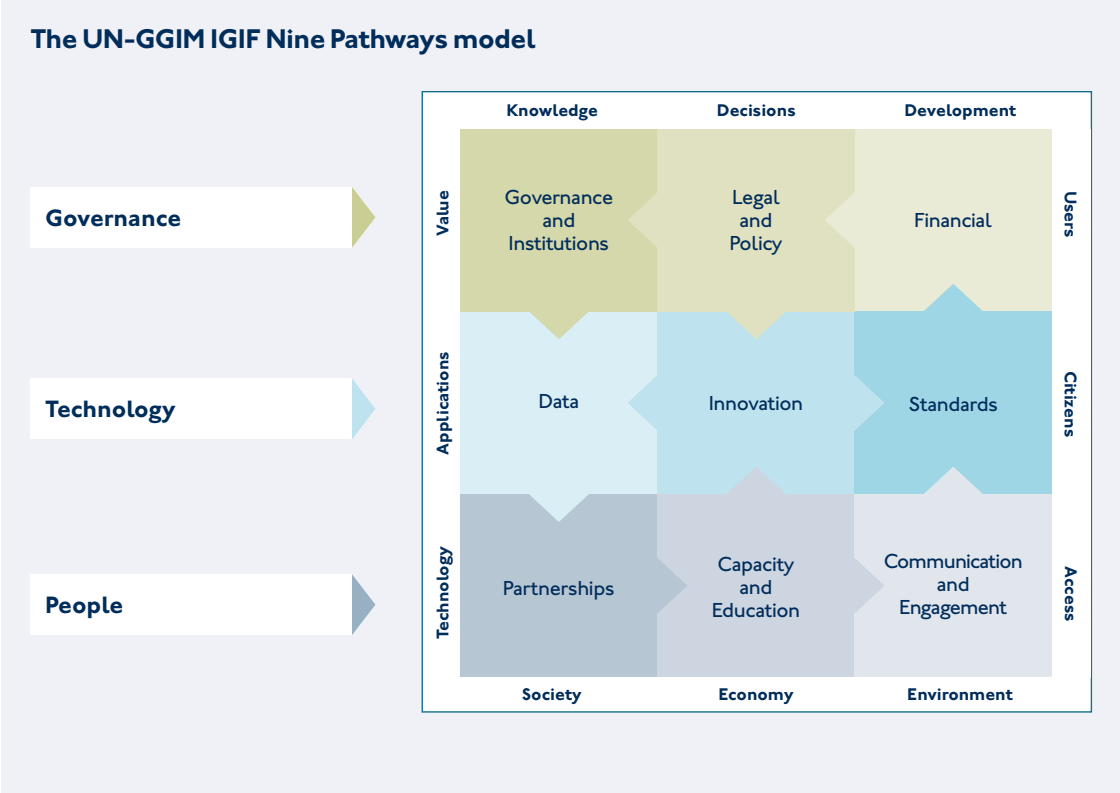


Figure 2: IGIF is anchored by nine strategic pathways and three main areas of influence.

Of note is the Operational Guide from the WG-MGI, also known as IGIF-H ("H" for Hydro) that contributes thematically towards IGIF Country-level Action Plans around marine and hydrographic data.

IHO Marine Spatial Data Infrastructure (MSDI)

The origins of the Marine Spatial Data Infrastructure (MSDI) concept can be traced back to the 2nd Edition (2005) of IHO Publication M-2, now released in its 3rd Edition (2015). This paper outlines the benefits and options for the development of a national hydrographic policy that ensures national knowledge of the physical seabed and coast, as well as the currents, tides, and certain physical properties of the sea, such that the needs of safety of navigation and protection of the marine environment can be met. In 2009, the IHO set an objective for a definitive procedural guide in establishing the role of a national hydrographic authority in creating an MSDI, which will not only meet the requirements of the mariner, but that can yield additional and often greater socio-economic benefits.

The Marine Spatial Data Infrastructure (MSDI) concept, as an essential component of a National Spatial Data Infrastructure (NSDI), is formally expressed in Publication C-17 from the International Hydrographic Organisation (IHO). This publication provides official guidance to national hydrographic offices around the world for developing an enterprise MSDI capability, defined as the relevant collection of governance, standards, technology, and content that facilitate the availability of and access to marine geospatial data. An MSDI can be summarised or referenced using the Four Pillars model within Publication C-17, which was developed by the IHO MSDI Working Group (MSDIWG) with input from participating IHO Member States. As outlined within Publication C-17, the MSDI Four Pillars outline the People, Standards, Technology and Data required for sharing and analysing marine geospatial information across government and commerce. These areas describe the hardware, software, and system components necessary to support the structure of working practices and relationships across data producers and end-users for access to marine geodata.

The IHO-MSDIWG is a subsidiary body of the IHO Inter-Regional Coordination Committee (IRCC) tasked with supporting the MSDI and Marine Spatial Planning (MSP) activities of the IHO. The IHO-MSDIWG also hosts an online Body of Knowledge (BoK) as a resource for countries seeking to develop and implement an MSDI for their national requirements. This BoK contains a range of in-depth resources, including MSDI training materials (in-kind contribution from the Kingdom of Denmark) and a joint MSDI Concept Development Study between the IHO and the Open Geospatial Consortium (OGC). Other resources of note for include White Papers on MSDI Capability Development and MSDI Benefits Realisation, alongside Hydrographic Data Policy Best Practice and (M)SDI Frequently Asked Questions.

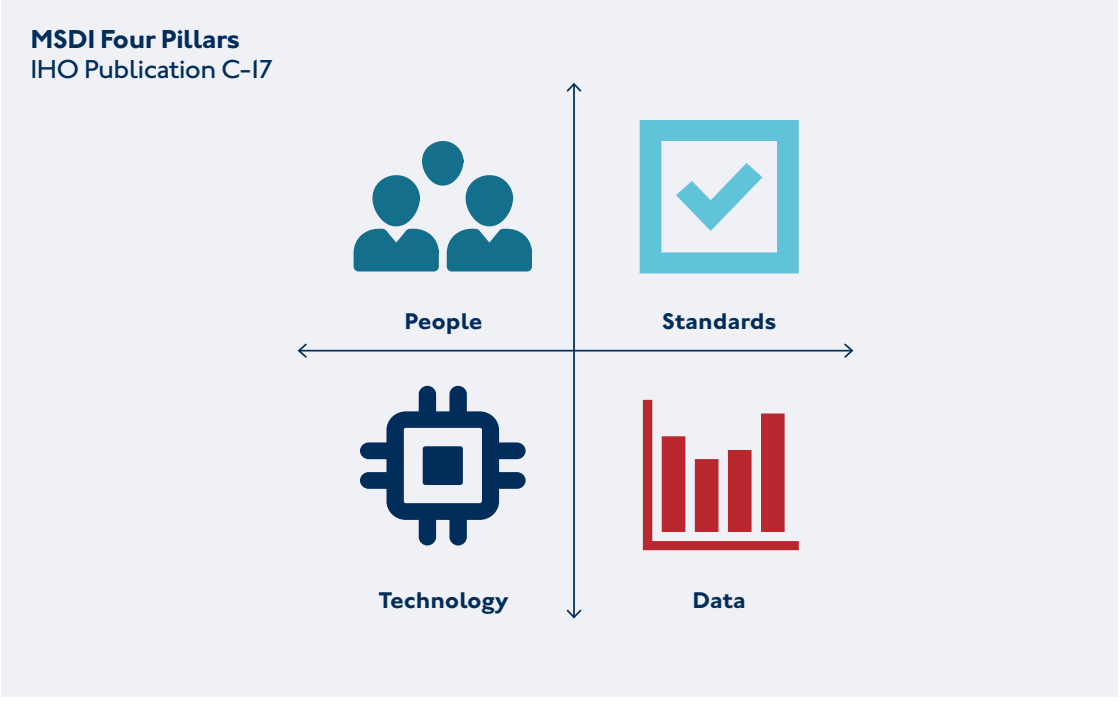


Figure 3: Visual summary of the MSDI Four Pillars, covering the key topics around marine geospatial data.

How do the IGIF and an MSDI relate to each other?

Sharing parallels with the Global SDI Cookbook initiative from 2005, the first version of IHO Publication C-17 (now Second Edition) was formally released in 2009, whilst the IGIF Overarching Strategic Framework was published in mid-2018, both after a lengthy period of international collaboration and consultation. Although the MSDI concept predated IGIF at the time of first release, the latest iteration of C-17 now refers to the UN-GGIM, the IHO, and their respective Member States as being "crucial to enabling the wider reach and use of hydrographic office data". Separately developed, both methodologies are increasingly seen as synergistic, with the successful exploitation of marine geospatial data relying upon leveraging IGIF and MSDI together for meeting a nation's objectives.

An imperfect but useful viewpoint is that IGIF offers a vision and strategy behind the "Why" of maximising geospatial information (of all types and domains) for inclusive socio-economic benefit, whilst the MSDI concept provides the "What" regarding the operational areas for developing improved use of marine data. Also included within this wider concept is the "How" of technological interoperability using industry open standards, via the Open Geospatial Consortium (OGC) that will be covered in the following chapters.

As briefly covered in their respective introductions, both IGIF and MSDI have significant "ecosystems" of resources, which together encompass around 800 pages of published materials hosted by the UN or IHO. There also exists numerous commercial, academic, and national-level resources outside of these bodies. This combined wealth of commentary and insight, which although necessary for empowering nations to eventually chart their own IGIF-MSDI journey, can occasionally be an encumbrance for stakeholders new to an IGIF-aligned MSDI – especially when attempting to build consensus outside of their organisations.

It is, however, possible to leverage those elements between the two frameworks, which can synergise well in the context of acting as a "quick-start guide", "menu of options" or "stepping-stone" towards full use of the IGIF and MSDI ecosystems of resources. This includes participation within UN and IHO groups that provide the opportunity to contribute and influence the future iterations of both geospatial frameworks. One area of synergy is a joint maturity roadmap that enables hydrographic offices to baseline their current readiness for an IGIF-aligned MSDI, plus the development opportunities available to them depending on their objectives and aspirations. Under regional collaboration initiatives, this joint IGIF-MSDI Maturity Roadmap, as described in the following chapters, can contribute to more efficient allocation of resources between countries, for realising shared benefits that are overall greater than if undertaken independently.

The Role of the OGC in IGIF and MSDI

The Open Geospatial Consortium (OGC) and Open Standards

The Open Geospatial Consortium (OGC) is an international consortium of more than 500 businesses, government agencies, research organisations, and universities motivated to make geospatial information and services FAIR – Findable, Accessible, Interoperable, and Reusable. The OGC's approach focuses upon the collaborative and agile development of consensus-based open standards, innovation projects, and partnership building amongst OGC members and other liked-minded groups (such as the UN and IHO).

Open standards support UN and IHO goals by promoting equal access to geospatial benefits for users of open source and proprietary systems, reducing the digital divide with regards to national development. Interoperability avoids "vendor lock-in" to a specific piece of technology or supplier community, thus reducing through-life costs for digital services via increased competition and the reuse of components. Open standards give better protection for datasets created on applications that implement them – which is crucial given the increased proliferation of digital services – preventing the risk of "too large to convert" when proprietary technology and/or standards are entrenched.

OGC Open Standards are formally expressed in the form of Abstract Specifications and Implementation Standards, with the former providing higher-level information to technology leaders and managers, since understanding the strategic context of an open standard can be as important as its technical details. OGC Implementation Standards are written for a more technical audience and detail the interface structure between software components. When implemented by two different software engineers in ignorance of each other, the resulting components are expected to "plug and play" with each other.

Also supporting OGC's goal of geospatial interoperability are the OGC API (Application Programming Interface) family of standards that are being developed to build upon the legacy of the OGC Web Service standards, through API "building blocks" taking advantage of modern web developments. Web services are standards for exchanging data between systems over a network, whereas APIs are software interfaces to allow two applications to interact with each other without any user involvement (including offline on the same system). All web services are APIs, but not all APIs are web services.

The OGC Community of Interest

Complementing the OGC ecosystem of open standards are OGC Best Practices the highlight the practical use of OGC standards within a specific domain or to address particular use cases. Meanwhile OGC Community Practices describe standards or specifications originating outside of the OGC, but which make an important contribution to addressing interoperability requirements within geospatial communities. Ensuring that open standards remain relevant and aligned to emerging technologies, the OGC also publishes Engineering Reports, Discussion Papers and Techpapers alongside its Compliance Testing services for organisations.

The core of OGC activities are its many Domain Working Groups (DWGs) and Standards Working Groups (SWG), which encompass numerous domains and applications of geospatial data – including Land, Sea, Air, Space and Cyberspace, covering applications from Disaster Response to Defence Intelligence. DWGs provide a forum for important interoperability needs and issues, debate and review of implementation specifications, and presentations on key technology areas relevant to solving geospatial interoperability issues. SWGs have a specific charter for working on a candidate standard prior to approval as an OGC standard or on revising an existing OGC standard.

How the OGC supports an IGIF-aligned MSDI implementation

The previous simplification of "Why", "What", and "How" is an effective view of how OGC resources can contribute to the strategic vision of *FAIR* [1] marine geospatial data, which is advocated by all three consensus bodies. This shared vision is important for demonstrating end-to-end evidence of strategy (UN), planning (IHO), and implementation (OGC), which is vital for organisational and inter-agency commitment. It can also contribute to national-level policy-setting by showing how an MSDI can contribute to an NSDI and a country's overall goals for socio-economic development. Outside of rare specific circumstances, an isolated and autonomous MSDI can be subject to unneeded risk if not connected or aligned with national governance, policy-setting, or strategy in the geospatial domain.

The OGC provides a practical toolbox of technological elements, supported by a wealth of community discussion and publications, for moving IGIF-MSDI considerations into real-world demonstrations. This is particularly crucial for short-term projects that provide the proof-of-concept, evidence, and realised benefits to support a longer-term programme of digital transformation. OGC resources provide the dual advantages of more immediate and practical results through smaller-scale interoperability (intra-agency and inter-agency), which by default of its consensus-based approval is automatically aligned with more strategic interoperability (national, international, vendor/supplier and futureproofing). The OGC offers the means and ways for organisations to govern the interoperability of new geospatial technologies, thus ensuring an IGIF-aligned MSDI can remain at the forefront of ICT capability (if/when this is a requirement).

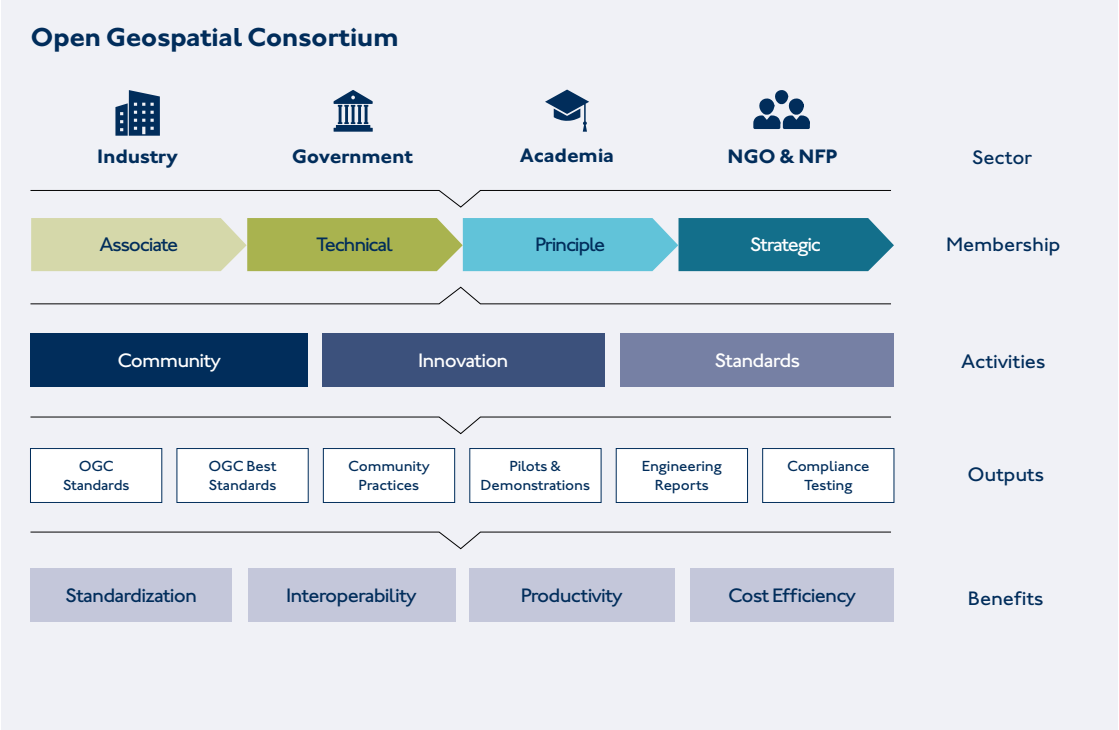


Figure 4: OGC activities, outputs, and benefits – the technical "ecosystem" for supporting IGIF and MSDI.

Government Policies and National Strategy

Although this chapter is one of the shortest due to the infeasibility of describing the structures, impacts and dependencies of all potential national arrangements around the world; the issues covered will have the most influence or potential constraints upon an IGIF-aligned MSDI and cannot be overlooked. On a general spectrum of governance, political officials approve laws, legislation, and/or statutes, which are then implemented as detailed regulations and directives upon national agencies or government departments. These tools of hard governance may be supported by a national geospatial vision or strategy, national ethics framework for the use of public data, and industry codes of conduct or best practice guidelines at the market level. The expected progression is from hard governance (national law) that is unequivocal, down towards soft governance (sector best practice) that gives room for interpretation and adjustment. Every country will have its own ways of working and divisions of responsibility, which will influence and guide any IGIF-MSDI development programme.

The most important consideration within this area is to identify national stakeholders and the landscape of governance, which would impact the development of an IGIF-aligned MSDI solution. This is increasingly described as a geospatial ecosystem, referring to the range of submarkets across the economy using geospatial data and/or services, including marketing, transport, and engineering. A range of organisations undertake a facilitating role within this ecosystem, including private and public sector organisations, academic institutions, and innovation hubs[2]. Where possible, a visually engaging and clear infographic that highlights the connections between stakeholders, groups, agencies, departments, and tools of national governance would help to ensure common understanding.

The goal of such a resource when actively maintained is to ensure that all IGIF-MSDI developments from agency strategy and policy-setting to technological implementation, are properly aligned from the start with national plans and priorities. This provides the positive outcome of potential national-level support for an IGIF-aligned MSDI, whilst mitigating the risks associated with divergence or perceived isolationism, which may lead to forced realignment of activities or a costly lack of technical and policy interoperability.

1 Findable, Accessible, Interoperable, and Reusable.

The World Bank has a comprehensive tool named the IGIF Geospatial Alignment to Policy Drivers (GAPD), as part of its IGIF Implementation Methodology. This tool is the next step beyond this IGIF-MSDI Maturity Roadmap and is shown in Figure 10, within that Chapter covering the World Bank's IGIF Implementation Toolkit, which provides the foundation for this paper. GAPD is used to identify the most relevant policies and frameworks where geospatial development can make the most significant impacts. It focuses on prioritised policy areas (themes) to make the subsequent IGIF Country Action Plan manageable, by avoiding attempts to satisfy all possible use cases that could be impacted by the (M)SDI. GAPD then aims to identify the key geospatial use cases that, from interactions with stakeholders and knowledge of the geospatial market, offer a pre-study assessment of the highest socio-economic impact. GAPD finally reports on the major stakeholders, both on the supply and demand side (end-users) and their influence on, and interest in, the likely success of the (M)SDI initiative.

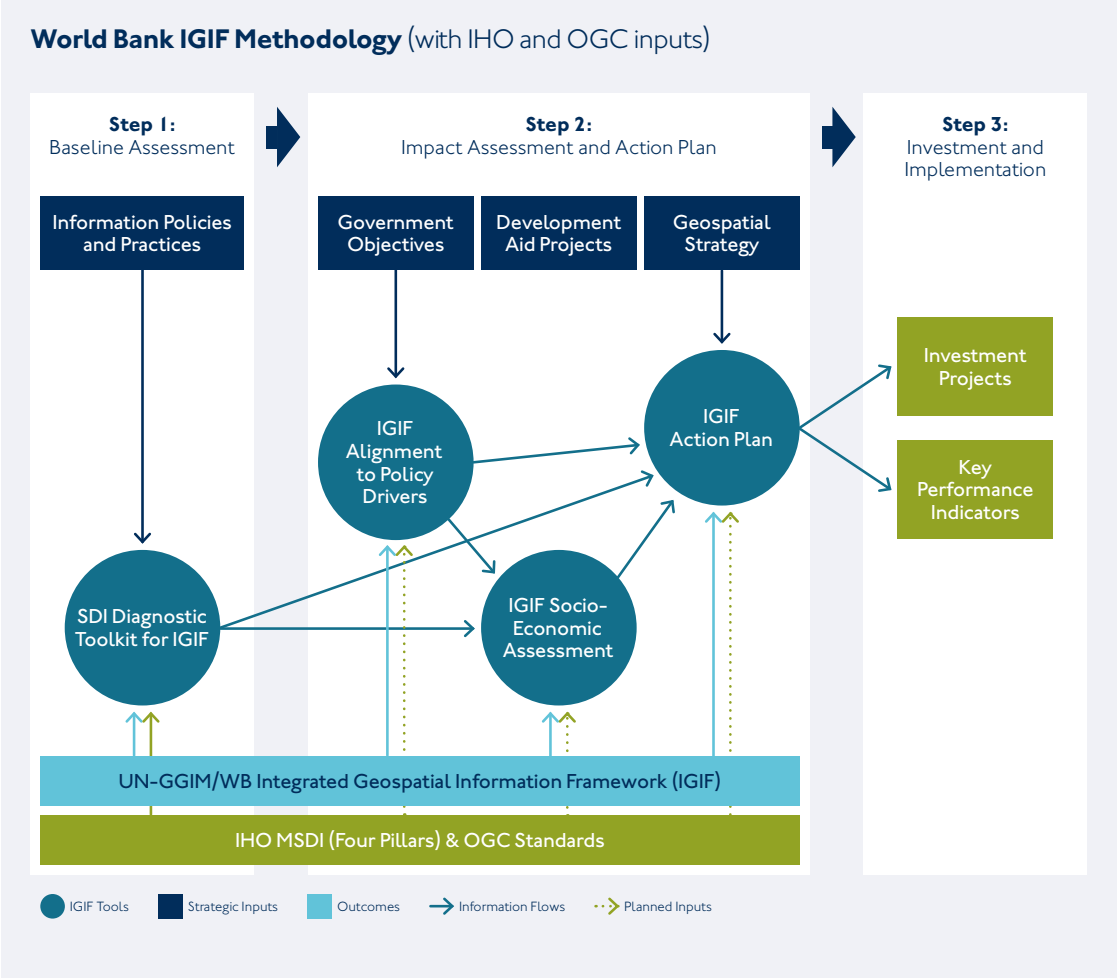


Figure 5: The World Bank IGIF Methodology relies on the SDI Diagnostic Toolkit for baselining, which unlocks the later steps towards investment and implementation. The addition of IHO and OGC inputs, adds the "M" into (M)SDI with assured interoperability whilst maintaining whole-of-nation NSDI alignment.

Later chapters of this IGIF-aligned Maturity Roadmap will highlight some "soft governance" good practice examples for building engagement and reaching consensus for driving practical progress, especially in situations where multiple marine and maritime agencies are essential for an effective MSDI. Within some national contexts (but not all), such agencies may have operated independently for a historically long period, developing unique ways of working and even legislative instruments that are specific to their responsibilities. Such contexts can create a tradition of "transactional" engagements

2 "Enhancing the UK's Geospatial Ecosystem" Geospatial Commission (November 2020).

with fellow agencies, reluctantly undertaken only when seen as unavoidable, alongside varying levels of agency and/or data protectionism. This is typically represented by comments such as "this is how our agency has traditionally managed X data for Y decades and it's the way it's always been done here".

These later chapters are intended to provide a starting point for overcoming the frictions preventing the committed and collective decision-making needed for developing an IGIF-aligned MSDI, which itself is an essential component of a wider NSDI that covers air, land, sea, plus (optionally) space and cyberspace. Every national context is unique, so these starting points require adjustment to the political environment at hand and may not solve every inter-agency source of friction. It is nonetheless crucial to address such issues to ensure effective MSDI progress, which one or even two agencies would struggle to deliver in isolation. In the absence of "hard governance" tools such as a National Geospatial legal mandate, the use of soft governance techniques will come to the fore as an alternative approach in the interim.

The following two images show the conceptual (simplified) ecosystem of IGIF and MSDI resources, from the national context covered in this section, to the OGC's resources for technological implementation. The key message is that this domain already possesses a significant amount of good collateral in the form of best practice, guidelines, standards, working papers, and that this document aims to build upon them.

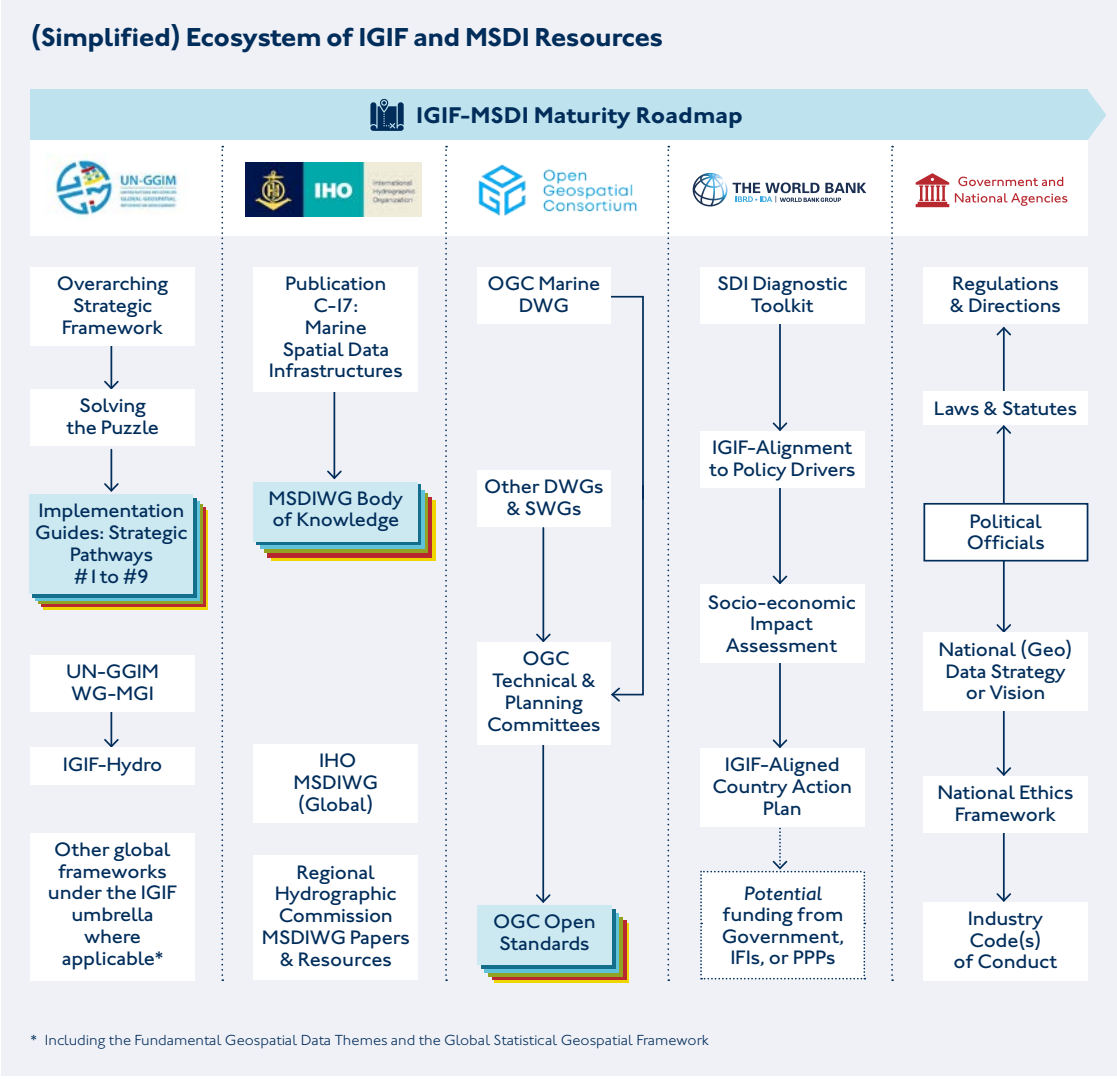


Figure 6: The (simplified) ecosystem of IGIF, MSDI and OGC resources. Not all connections are shown. The IGIF-MSDI Maturity Roadmap seeks to provide a "quick start" guide to aid nations in beginning their IGIF-aligned MSDI transformation programmes.

Figure 7: The context for the UN-GGIM, IHO, OGC, and World Bank, considering the "Why", "What" and "How" for charting a simplified narrative thread (or route) through the ecosystem of available resources.

Aligning an MSDI implementation with IGIF

IGIF-MSDI Overall Concept: Harmonising Governance with Technology

As is evident in the previous diagram, the ecosystem of IGIF and MSDI resources from both communities is extensive. Any harmonising between the two will necessarily be a simplification and there are likely many methods of aligning an MSDI to IGIF principles. The method adopted here is not intended to be complete, but only as a starting point or stepping-stone. Those benefiting from the approach taken here can chart their own path forwards when they choose to, tailored to specific national needs, and hopefully sharing their unique experiences and challenges with the global community (via the UN, IHO, and OGC).

The approach taken here is not to create a singular measure, metric, or pathway for an IGIF-aligned MSDI implementation, but a maturity roadmap that is "multi-dimensional" and gives opportunity for nations to interpret and manoeuvre. A single combined metric would be an oversimplification that would diminish the synergies that both an IGIF and MSDI approach can offer. "One size" does not fit all nations and such a reductionist approach would not do justice to either the IGIF or MSDI communities. It also incorrectly suggests that only one path forward exists for hydrographic offices to implement an IGIF-aligned MSDI.

Side Note: Balancing Governance with Technology

This "multi-dimensional" approach also captures the general principle of balancing governance for the socio-economic benefit of all stakeholders, with the exploitation of new technology being developed by private industry. This approach recognises that both areas have differing metrics of success, which need balancing where they overlap with occasional friction. One example is the ambition to maximise data access across a society competing with the need to respect the ownership rights of those that invested in creating data at time, effort, and cost. There are many others just as relevant, such as the emergence of autonomous shipping and the legal liabilities for accidents caused by inaccurate or incorrect use of spatial geodata by AI, leading to complexities around marine insurance, licensing, and compliance or assurance. The following diagram is a visual summary of balancing governance with technology for geospatial data.

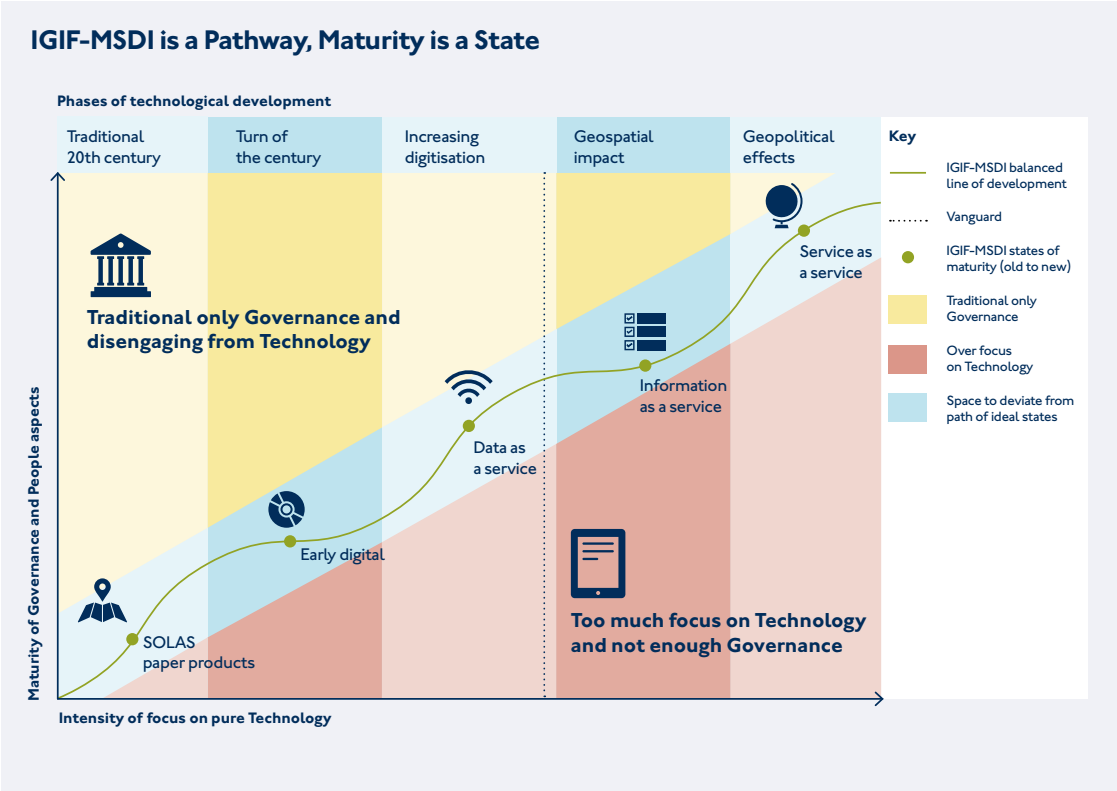


Figure 8: Balancing Governance with Technology – "2D" concept to aid general understanding.

› One axis is Governance – an approximation for the IGIF approach (for the purposes of this Side Note).

› Another is Technology – an approximation for the MSDI concept (for the purposes of this Side Note).

› It is entirely feasible to excel on one axis relative to the other and still have an effective IGIF-aligned MSDI, so long as this choice is deliberate, recognised, and any potential shortcomings mitigated.

› The optimal outcome is however ensuring adequate and sufficient Governance for the sophistication of Technology employed to ensure that net benefits are maximised for a given society and economy.

› Governance that is effective promotes inclusive and equitable outcomes across community groups, market sectors and national interests – thus supporting wider, sustainable economic development.

› Governance should be sufficient to minimise negative impacts, such as on community privacy, business intellectual property, national security/safety, and uncompetitive market practices.

› Governance should be adequate but not excessive, as new technology requires some level of risk tolerance to fully realise its applications, benefits, and limitations over time.

An effectively IGIF-aligned MSDI implementation should ideally "Drive Technology, rather than be Driven by Technology."

The outcomes of an IGIF-aligned MSDI implementation should ideally "Make the Data count, rather than just Counting the Data."

IGIF-MSDI Requirement: Standardised Assessment to inform Business Cases

Given the wealth of policies, concepts, models, and qualitative thinking across both the IGIF and MSDI communities, there is a clear benefit to be gained from standardised assessment with a quantitative focus. Such an approach is not for regional comparisons, but to enable developing nations to determine their starting point on an IGIF-aligned MSDI implementation journey. Measuring or baselining a starting point is an essential first step in charting a practical course towards a nation's desired end-state, which is ideally a balance between governance and the technology needed to achieve sovereign national requirements. An IGIF-aligned MSDI is not a "high-bar" threshold of cutting-edge technologies, unless a nation decides that it is genuinely required for their geospatial development goals. It is the sovereign choice of a nation if they judge that current (or even last generation) technologies are sufficient for their own aspirations.

Reaching that judgement and comparing it against a desired end-state, to chart a course between the two points requires a more quantitative and standardised approach. It also allows a "development trajectory" (generalised in Figure 8) to be plotted by reassessing at certain time intervals (annually or longer), so that political decision-makers can decide upon course corrections or adjusting final expectations. Without a known point of origin, it would be extremely challenging to plan a course/direction of development, let alone reach a desired end-state within reasonable time and cost.

One of the major drivers behind this IGIF-MSDI Maturity Roadmap is simplicity, which can be achieved by leveraging existing expertise from within the Terrestrial SDI community. The policy separation between terrestrial and marine is increasingly becoming a historical artefact or anomaly, especially as emerging technologies (via OGC Standards) are effectively "bridging the gap" between these two communities. The bulk of socio-economic activity is terrestrial in nature and an MSDI should ideally synergise with an SDI to form an encompassing NSDI (N for National – air, land, sea, space, and cyberspace). The World Bank offers such terrestrial expertise via their SDI Diagnostic Toolkit, which also meets the requirement for a standardized assessment to inform a true business case (the quantitative "development trajectory").

The SDI Diagnostic Toolkit from the World Bank

Since its establishment in 1944 to support post-war reconstruction, the World Bank has supported over 12,000 development projects since its first loan in 1947 and is part of the United Nations ecosystem. The World Bank goal of promoting shared prosperity is aligned with the 2015 UN Sustainable Development Goals, supported since 2016 by an SDI diagnostic toolkit to inform economic-business cases. Conducted in 11 countries to date, these SDI-related World Bank resources are fully aligned with the UN-GGIM IGIF Nine Pathways, meeting a requirement for the standardised assessment of investment needs. In August 2017, the UN-GGIM affirmed a collaborative agreement between the United Nations' Statistics Division and the World Bank's Global Practice on Social, Urban and Rural Development and Resilience.

Via a scored set of questions answered during interviews conducted by the World Bank, the resultant indicators across the nine assessed categories suggest an optimal "journey of SDI development". These indicators directly inform the standardised Assessment Report that sets an SDI baseline or starting point, from which funding can be assessed against via a subsequent geospatial business case. One notable example from this geospatial approach was the recent 5-year investment of the World Bank in Albania of over one billion USD into land infrastructure and NSDI development. Directly informed by the World Bank's SDI diagnostic toolkit, these geospatial business cases (when undertaken) can critically form the quantitative and socio-economic backbone of Country-level Action Plans within the IGIF approach.

One caveat and opportunity, hopefully realised by this IGIF-MSDI Maturity Roadmap, is that the current SDI diagnostic toolkit can be augmented with IHO MSDI domain knowledge, via its in-built flexibility to accommodate questions that are of particular importance to a given nation. As is the approach taken here (in later chapters), the inclusion of MSDI-specific aspects can make the already robustly IGIF-aligned SDI diagnostic toolkit even more useful to developing island nation states. Adapting the World Bank's SDI toolkit via the IHO's MSDI contribution is the quantitative counterpart of the IGIF-H Operational Guide, which itself seeks to qualitatively adapt IGIF for the hydrographic community. (Although IGIF could be applied "as-is" to the marine domain, its land-based origins provide ample opportunity for tailoring).

A useful analogy here is that the IGIF-H Operational Guide from the UN WG-MGI adds the "H" for Hydro to IGIF whilst the IHO MSDI Body of Knowledge appends the "M" for Marine to the existing resources from the UN-GGIM.

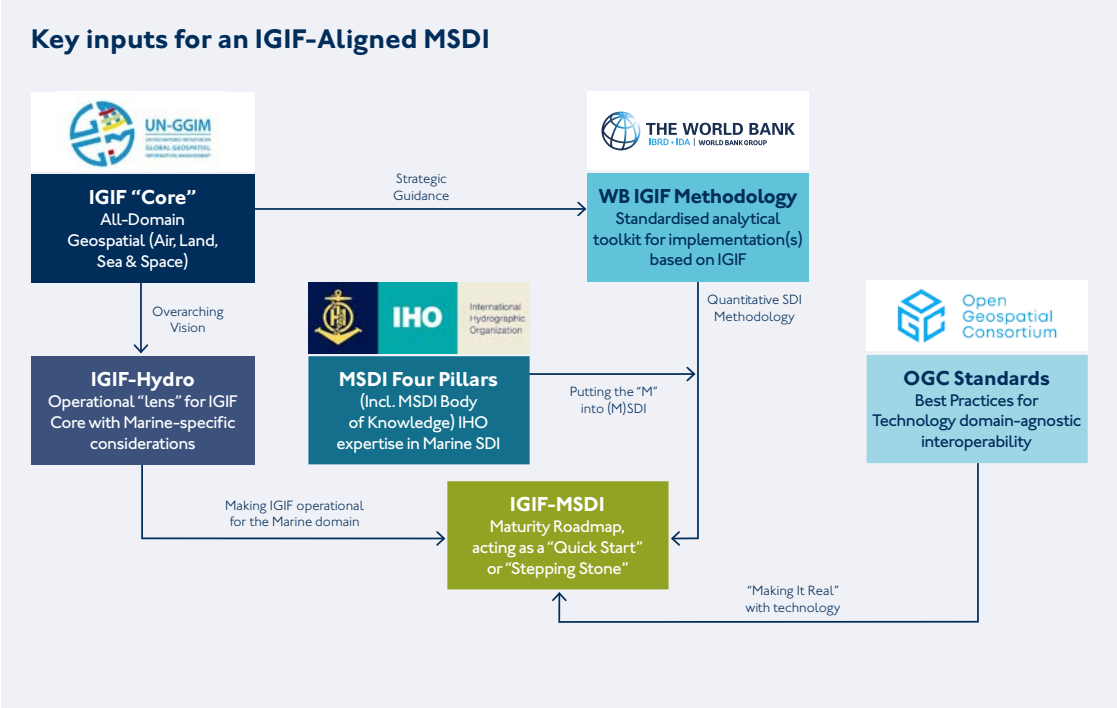


Figure 9: The relationship between the major influences and key contributions to the IGIF-MSDI Maturity Roadmap. For general awareness only and not a precise or formal mapping.

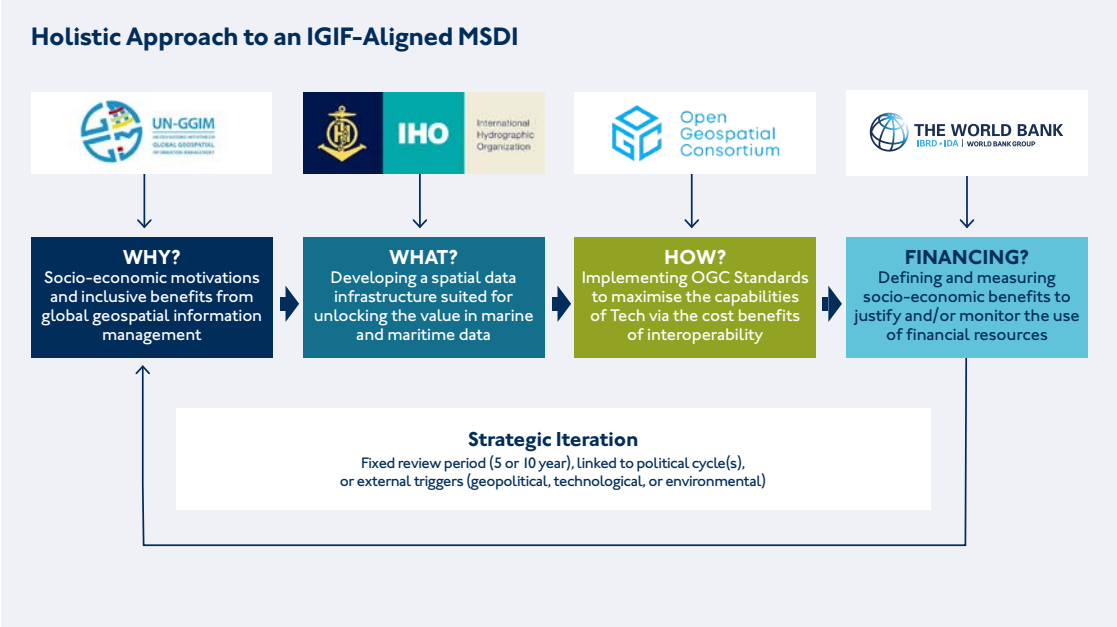


Figure 10: The IGIF-MSDI contributes to drawing together four key areas of consideration around an IGIF-aligned MSDI implementation – the "Why", "What", "How", and "Financing" aspects (with strategic iteration).

Augmenting the SDI Diagnostic Toolkit with IHO MSDI and OGC Contributions

The comprehensive version of the World Bank SDI Diagnostic Toolkit consists of 91 detailed questions, which are best applied via the expertise of the World Bank or its approved associates, to ensure a robust and credible outcome to support funding decisions. Significant thought and consultation were applied to the composition, wording and ordering of these 91 detailed questions across 9 categories, leading to a multi-dimensional "radar chart" that leads into the next stages of the World Bank SDI methodology. For the purposes of this IGIF-MSDI Maturity Roadmap, (M) SDI baselining is the primary focus here, although future versions in due course are likely to further reference, connect, or synergise with the World Bank. This includes the IGIF Geospatial Alignment to Policy Drivers (GAPD), as part of their IGIF Implementation Methodology and the next practical step beyond (M)SDI baselining – as shown in Figure 11 following, as a helpful repeat of Figure 5 previously.

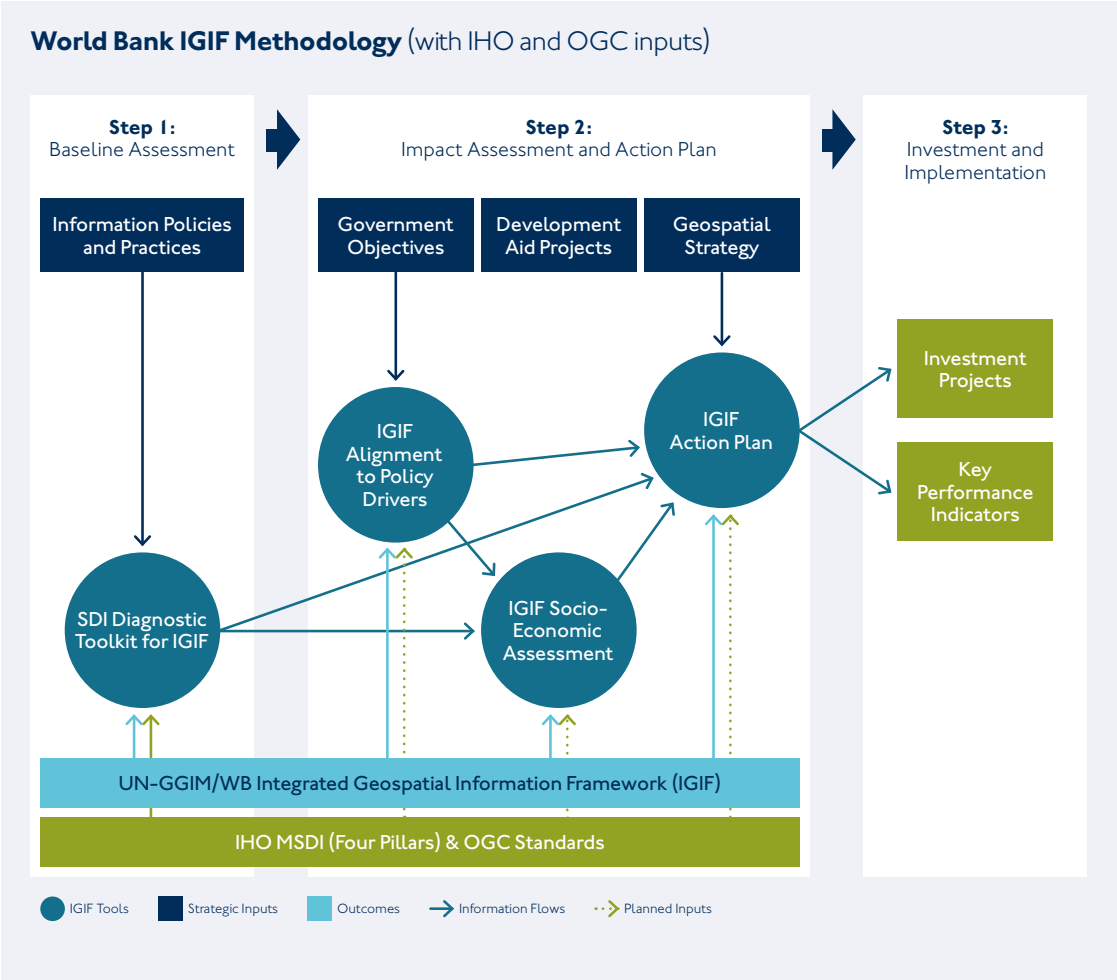


Figure 11: The World Bank IGIF Methodology relies on the SDI Diagnostic Toolkit for baselining, which unlocks the later steps towards investment and implementation. The addition of IHO and OGC inputs, adds the "M" into (M)SDI with assured interoperability whilst maintaining whole-of-nation NSDI alignment.

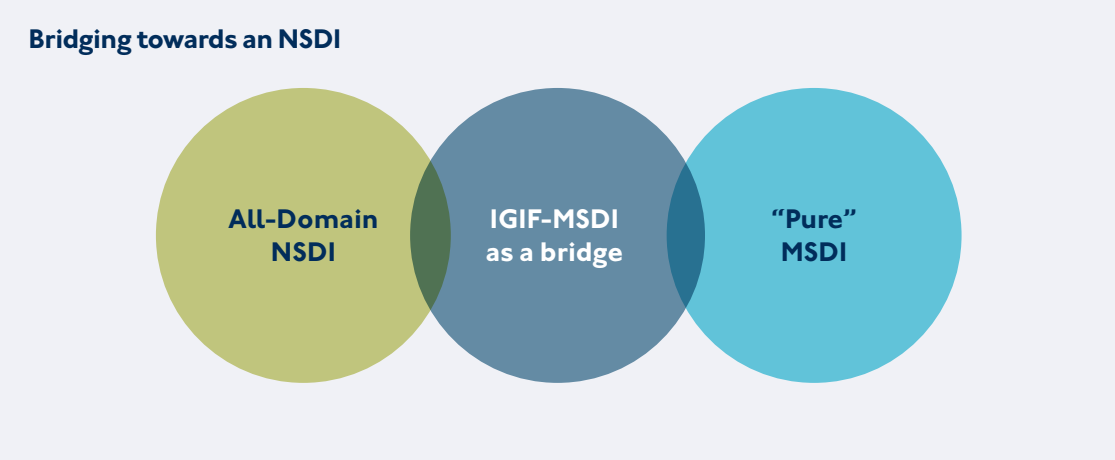


Figure 12: The IGIF-MSDI Maturity Roadmap enables the explicit connection of an MSDI to an all-domain (or whole-of-nation) NSDI, whilst preserving the unique marine considerations needed within an MSDI.

The SDI Diagnostic Toolkit is structured such that it can be applied on the national level or simplified for key stakeholder groups and/or individual geospatial agencies. The approach taken here is to combine the pre-existing "Decision Maker" and "End-User" versions of the SDI Diagnostic Toolkit, whose subset(s) of the full 91 question version have some simplifying overlap, followed by questions drawn from the IHO MSDIWG Body of Knowledge (incl. Publication C-17) and relevant resources from the OGC community. Combining these two subsets is justifiable, as hydrographic offices (or their national equivalents) are generally the facilitators between the "Decision Maker" (political/legal geospatial governance) and "End-User" (enforcing or subject to governance) communities. One example here is the legal creation of a Marine Protected Area by political officials ("Decision Maker") for environmental or economic reasons. This is then facilitated by a hydrographic office via authoritative geospatial data and information, which is then applied by marine enforcement bodies and/or used by shipping companies directly ("End-User").

Aside from simplifying the full 91 question version (best suited for a whole-of-nation baselining effort) to aid effective application within the marine domain, augmenting with IHO and OGC derived questions also provides additional benefits. By augmenting instead of replacing, this firstly ensures that responses to the "pure" SDI element can directly contribute to a whole-of-nation baselining effort, as the marine community input into an NSDI vision, thus highlighting the relevance of Marine affairs as essential to a true NSDI and not simply an adjunct to terrestrial affairs (the outmoded "Wet Land" perspective). The second benefit is related to the first, where the IHO and OGC specific elements can be recycled into plans, policies, and initiatives in those respective areas – such as Marine Spatial Planning or a Standards Implementation Strategy.

These two benefits provide the "upstream" and "downstream" connections for the IGIF-MSDI Maturity Roadmap, to national-level geospatial strategy (NSDI) and real-world technological implementation (in the marine domain) respectively. By being able to recycle "pure" SDI elements (whether air, sea, or land) and marine-domain specific elements, it helps to mitigate against duplicated effort in the medium-term. (It is reported that aligning with multiple models or approaches can create an overhead for hydrographic offices, in terms of their subject matter experts and their availability for business-as-usual priorities.)

Existing links between UN IGIF, World Bank SDI, IHO MSDI and OGC Resources

Although many initiatives and projects exist in a bilateral and multilateral manner between the UN, IHO, OGC, and World Bank, there are some existing links that are relevant for the purposes of this IGIF-MSDI Maturity Roadmap. To optimise the application of this Maturity Roadmap, it is highly recommended that these existing joint resources be referred to and understood within the context of an MSDI as a strategic input to a wider NSDI (air, land, sea, plus space and cyberspace if applicable).

"A Guide to the Role of Standards in Geospatial Information Management" (February 2022) – This joint publication between the OGC, ISO TC-211[3], IHO, and the UN addresses the role of open standards in geospatial information management. It defines what an open standard is, why they are valuable in use, and describes best practice around geospatial standards. It also introduces a goal-based approach to standards adoption and a multi-tiered "Geospatial Levels of Standards Use".

"Companion Document on Standards Recommendations by Tier" (August 2018) – This side document describes which OGC standards may be optimal to use for each tier as identified within "A Guide to the Role of Standards in Geospatial Information Management". Also outlined are the foundational standards generally required to implement any internet-based solution. No information technology standard exists in isolation and hence most OGC standards reference one or more of these foundational standards.

Both publications are crucial for the practical and operational implementation of an IGIF-aligned MSDI, by moving beyond strategy or policy considerations and towards "making it real". The first document provides the governance model and best practice around implementing standards for an organisation using a tiered approach. The second document provides the open and foundational standards that can be practically used by Data Architects (or similar role) for a prototype or operational IGIF-aligned MSDI.

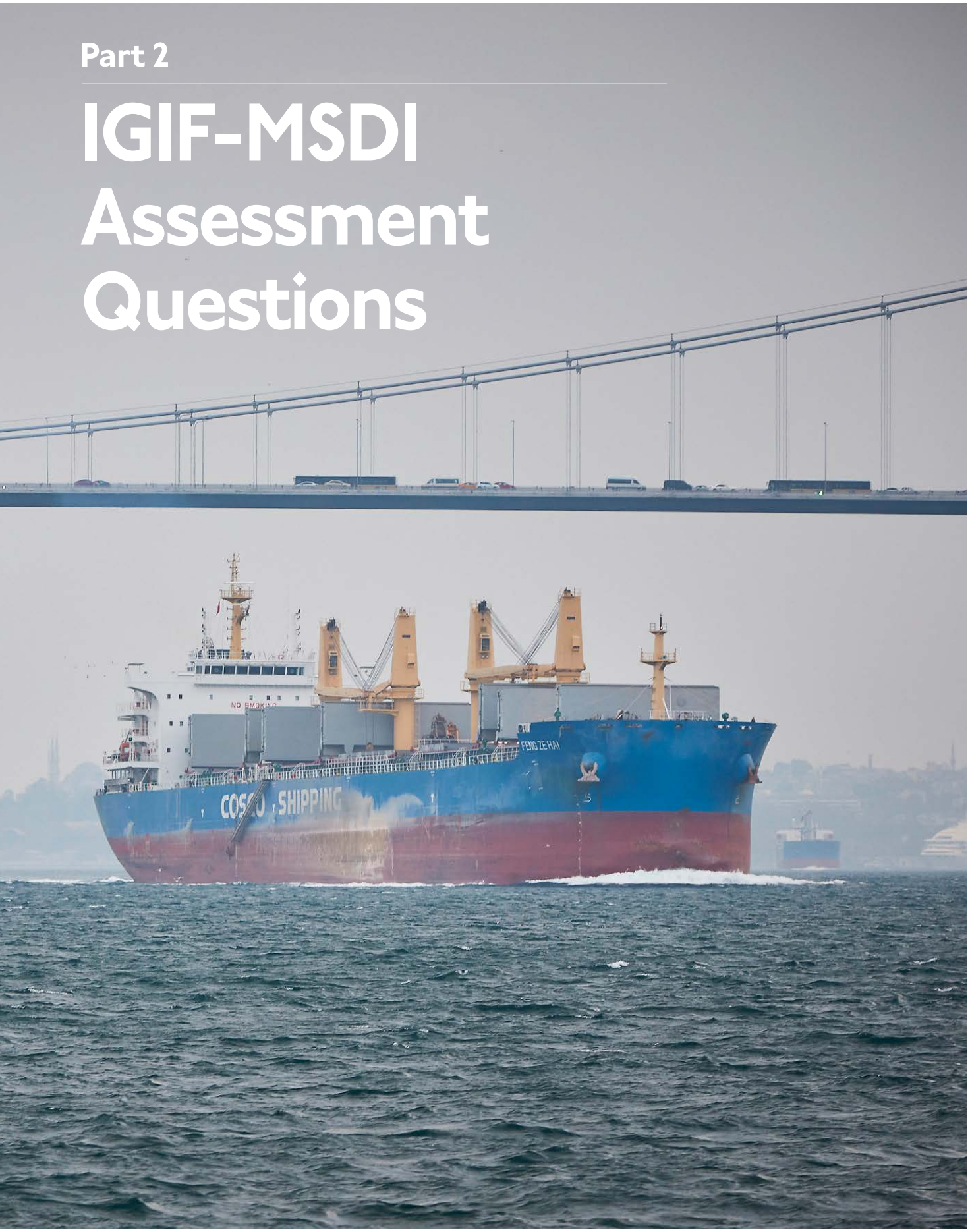
In cooperation with the OGC and Resource Data Inc, the IOGP (International Association of Oil & Gas Producers) and the IPIECA (International Petroleum Industry Environmental Conservation Association) issued the "OGC IOGP/IPIECA Recommended Practice for a Common Operating Picture for Oil Spill Response" in October 2015. This report provides recommended practice for GIS mapping in support of Oil Spill Response (OSR) and for the use of geospatial technology and information to form a Common Operating Picture (COP) for managing an OSR operation.

This report provides an excellent illustration of how an MSDI can directly contribute to emergency and disaster response, alongside the more frequently stated benefits for socio-economic growth and security. Whilst recognising the need for technical interoperability, this report also highlights the importance of interoperability around the coordination of organizational behaviour and the integration of information. Responding to an oil spill requires access to and understanding of many types of information. Effective, coordinated OSR operations require a COP, where interoperability provides shared situational awareness of the crisis and the response activities.

3 International Organization for Standards (ISO) Technical Committee 211 for Geographic information & Geomatics.

Part 2

IGIF-MSDI Assessment Questions



The IGIF-(M)SDI Diagnostic Toolkit

Structure and Format: Modular and Interoperable

The extensive 91 questions across all 9 categories of the SDI Diagnostic Toolkit from the World Bank are a significant undertaking, ideally executed with their independent advice to ensure an objective outcome. It includes interviews with a wide range of stakeholders and evidence reviews, which then cumulates in a baseline assessment result. This result is multidimensional across the nine pathways as no single metric can (or should) capture the nuances of a nation's geospatial maturity. The final report provides valuable independent insights, but also forms the crucial input into the later Impact Assessment and Action Plan tools, as part of the World Bank's SDI investment and finance methodology.

The full version of the SDI Diagnostic Toolkit is ideally suited for a "whole-of-nation" approach across all geospatial domains – including air, land, sea, plus space and cyberspace if applicable. Consequently, to maintain the "Stepping-Stone" or "Quick Start" of this IGIF-MSDI Maturity Roadmap, the combination of two smaller question subsets augmented with specific IHO and OGC related questions is the approach taken here. The two subsets of the full set of questions are tailored towards decision-makers and end-users and have been developed by the World Bank with extensive industry consultation.

These modular additions from the IHO and OGC ensure the interoperability of this IGIF-MSDI Maturity Roadmap with the full World Bank SDI version. Outlined via the existing collaboration with the United Nations[4], this also enables interoperability with an all-domain NSDI approach, as it is crucial that an MSDI contributes to national geospatial goals and is not unsustainably isolated as a "marine-only" endeavour.

Components of the IGIF-MSDI Diagnostic Toolkit

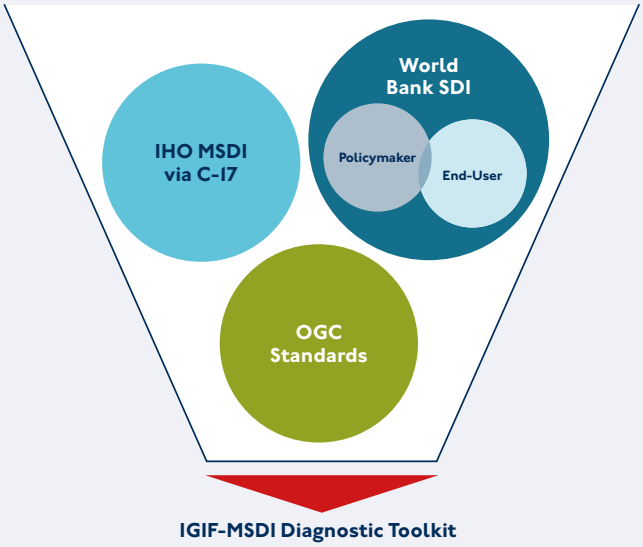


Figure 13: Composition of IGIF-MSDI assessment questions from the World Bank, IHO, and OGC.

4 K. Kelm et al; "SDI Diagnostic Tool – Partnerships for Implementation" The World Bank (March 2018).

As previously covered, the final output is in the form of a radar chart with nine dimensions, which better communicates a hydrographic agency's strengths and areas for development than a single metric value. Both within the full SDI Diagnostic Toolkit and the concentrated IGIF-MSDI version used here, question weightings are adjustable to take account of specific areas important to a nation's hydrographic interests. This functionality is contained within the World Bank's supporting spreadsheets and is best administered with their assistance, to ensure a consistent and dependable output, particularly as its integrity will be crucial for its proper application within the baseline assessment report. The questions themselves are openly outlined in the following chapter to enable early consideration, application, and the gathering of supporting evidence. This effort itself can yield useful insights when undertaken with committed effort, especially around the availability and accessibility of strategic, management, and technical information.

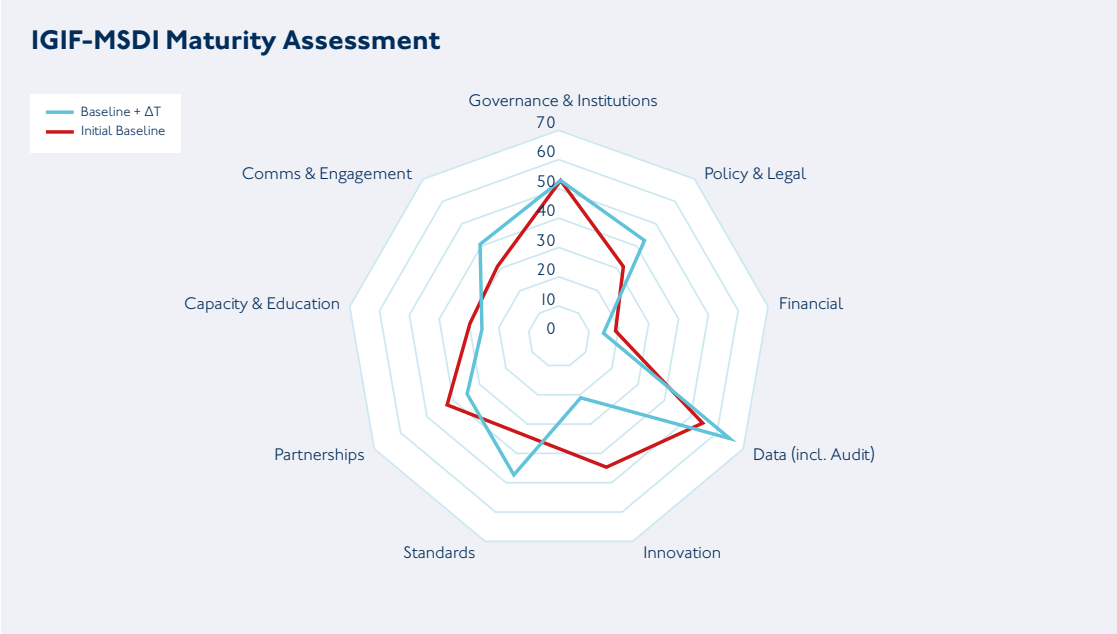


Figure 14: Example of radar chart output across 9 assessment categories, corresponding to the IGIF Nine Pathways, for an initial baseline and a subsequent baseline (two-years following). The underlying data is from real-world assessments taken under World Bank and partner oversight, which was openly published by the Agency for Land Relations and Cadastre of the Republic of Moldova.

Sub-National Application: Regional, Agency and Port-Specific Reinterpretation

What follows are the indicators designed to be used by those seeking to kickstart the creation of an MSDI implementation plan aligned with IGIF principles, particularly in small island and coastal nation states. As previously discussed, the following indicators have been carefully selected from the existing World Bank SDI Diagnostic Toolkit, with modular IHO and OGC additions that maintain interoperability with the World Bank's wider IGIF methodology, whilst imparting specific considerations for the marine domain.

To avoid divergence and ensure interoperability, the text for the following indicators have all been taken near verbatim, whether from the World Bank's resources or existing publications from the IHO and OGC. If and when the underlying source changes or new ones are published, revised versions of this document will reflect those changes or inclusions, thus maintaining UN, WB, IHO and OGC strategic alignment.

As such, the indicators are worded on a national level, but this can be reinterpreted for a regional, agency or even port-specific application. This however must be documented explicitly and unambiguously, so that all participating stakeholders can clearly understand this, whether they are contributing responses and evidence, or are receiving the final outputs and making decisions upon it. Documenting this is also crucial for an objective reassessment, so that the terms of reference remain consistent to allow progress to be properly compared over time.

Maintaining clear information on any reinterpretation of indicators will ensure interoperability between regions, agencies, and individual ports, allowing a higher government body to pool IGIF-MSDI baselines into a national resource. This may serve the purposes of geographic reallocation of resources to ensure regional equality, as an input into an all-domain NSDI development programme, or as a national-level submission into pinnacle bodies such as the UN-GGIM or the World Bank (for project financing).

Original wording	Suggested wording
National	Marine
National SDI	Marine SDI
Government (whole of …)	Agency (in question …)
Organisations, Departments, Institutions	Divisions (within an Agency)

Table 1: Example remapping of wording to reinterpret from National application to Agency application – this is only a starting point and likely requires adjustment for a country's unique national arrangements.

Maintaining clear information on any reinterpretation of indicators will ensure interoperability between regions, agencies, and individual ports, allowing a higher government body to pool IGIF-MSDI baselines into a national resource.

Instructions for Use

The underlying formulae for weighting and generating a baseline score is embedded within the associated templates made available online by the World Bank, but the following questions can either be answered in a qualitative or quantitative manner. A 5-point scale is used from "Attention" to "Best" that may be helpful for a first-time test run of the assessment questions in a qualitative manner, especially for testing internal capabilities for evidence gathering and the reporting of required management information. This 5-point scale maps to a quantitative rating system, which is the recognised World Bank methodology for proper assessment (requiring time, effort, and dedicated resourcing). In this case, "Attention" maps to a score of zero, whilst the other four grades increase in increments of 25 respectively, up to the maximum of 100. This allows for nuanced scores between grade levels, although reliably resolving a grade/score down to an increment of 10 or less is generally challenging.

› A complete glossary is not included for the sake of brevity. Users are referred to IGIF Part 2 for the latest definitive guidance on the technical use of terms. However, the terms geospatial and spatial are taken as equivalent here, although precise usage can vary from country to country.

› Marine SDI (MSDI) is used in preference to National SDI (NSDI) so that this diagnostic is orientated to the IHO C-17 MSDI Four Pillars model for the marine community. A similar case for preferring SDI over NSDI applies to regional, city, or port-specific contexts. An NSDI is the preferred term when the context is explicitly national and all-domain across air, land, sea, plus (cyber)space (if applicable).

› To recap, the Integrated Geospatial Information Framework (IGIF) is a framework of guidance for implementing an (N)SDI. It extends the concept from its former, largely technical focus, to a wider view encompassing consideration of governance, finance, and people perspectives.

› "Stakeholders" refers to all parties involved in developing or using an SDI in question (whether plain SDI, MSDI, or NSDI). This is not just within Government or data suppliers but also end-users, including NGOs, academia, individual citizens, small businesses, and multinational enterprises.

To recap, the Integrated Geospatial Information Framework (IGIF) is a framework of guidance for implementing an (N)SDI. It extends the concept from its former, largely technical focus, to a wider view encompassing consideration of governance, finance, and people perspectives.

› It is important that a wide range of organisations are involved in completing these assessment questions. The broader the group of stakeholders, the more perspectives can be considered. It is particularly important that the statistical, academic, and business communities are consulted.

› Different perspectives from government and private sector, data suppliers and end-users, decision-makers and community groups are important to produce a balanced and objective view of the current state.

› Interviewers should be impartial and not lead the interviewee(s) to a particular answer. Further, the comments should be kept anonymous, and this commitment must be made clear in advance of all interviews and to all interviewee(s). This is to ensure that full and objective assessments are obtained.

› The complete set of questions should, as far as is possible, be completed for each interview. It is unlikely that all answers will be available at the time of the interview, so follow-up discussions will be necessary and should be built into timetables for completion.

› For each question the interviewer should (based on the criteria), assign for scores of 0, 25, 50, 75, or 100 for each indicator. As previously discussed, any intermediate score up to 100 can be entered, as the observed current state may be between two of these values. Scores above 100 are not valid.

› Interview notes should be documented for each question as a narrative to explain the scoring – this is important for others to understand the scoring. It is helpful to include direct comments from the interviewees, but to avoid compromising confidentiality these should not be attributed.

› If any scores are "controversial", or it is difficult to align the situation neatly to the scoring options available, a provisional score can be entered that can be refined when further information is available. This may require canvassing other stakeholders' opinions. Where no information is available, score the indicator at zero and add appropriate comments in the interview notes.

› The interviewer should refer to guidance obtained directly from the IGIF Implementation Guide and its references to provide help to interviewee(s) for explaining what the question is trying to establish.

SP1 Governance and Institutions

Leadership

Is there an "advocate" in government that is leading, engaging, and promoting the benefits of a National SDI across all levels of government organizations, and with the private sector, academia, and the local community?

This indicator assesses the interest, understanding, and influence of the advocate promoting the National SDI initiative.

There should be a clearly identifiable individual(s), senior and influential, that is actively leading, engaging and promoting the National SDI vision and associated benefits across all stakeholder groups, resulting in tangible outcomes towards the design, development, and implementation of a National SDI within a government digital transformation agenda. This is essential for political buy-in and provides support at crisis points during the program.

Attention	None.
Minimal	Informal role.
Good	Defined role and person exists with vision.
Better	Actively driving change across government with tangible outcomes.
Best	Actively driving change across government, the private sector, academia, and the local community with tangible outcomes.

Governing Body

Has a governing body been established (or part of digital transformation governance) to provide leadership, direction and oversight for SDI-related activities and projects?

This indicator identifies the maturity of the governing body.

The governance model provides an environment for the strategic thinking, planning and decision-making necessary to modernize and sustain geospatial information management practices across all stakeholder groups. At the top level is the governing body that provides leadership, direction, and oversight. Different names may be used, such as council and steering committee, but the governing body must have the responsibility and powers to make the necessary changes to deliver the benefits. The SDI governance may also be an integral part of the digital transformation governance arrangements. (See IGIF Strategic Pathway 1: Governance and Institutions – Appendix "Steering Committee Charter Example").

Attention	None.
Minimal	Leader and institution appointed to establish governing body and governance model.
Good	Terms of reference of governing body agreed.
Better	Members appointed to governing body.
Best	Governing body active and starting to deliver elements of the SDI.

Geospatial Strategy

Is there a National SDI Strategy that identifies the vision, mission, goals, and objectives of the geospatial information management initiative to create a National SDI?

This indicator assesses the maturity of formulating and agreeing a strategically aligned National SDI strategy.

This is a strategy to achieve the long-term and overall aim of implementing the National SDI through using the IGIF. The strategic formulation process must be inclusive, and the implementation of the strategy will usually be incrementally achieved across specific sectors, for example. The strategy should connect to and aligned with other broader strategic and policy objectives of government (government digital transformation, environmental policies, financial policies, health policies, etc.) to provide direction on where to focus and apply most effort.

Attention	None.
Minimal	The governing body has formed a committee with terms of reference to formulate the strategy.
Good	A partial strategy, such as regional or sectoral strategy, has been created and signed off by all stakeholders.
Better	A national strategy has been agreed by all stakeholder groups and signed off by government but does not integrate with broader government strategies.
Best	A national strategy has been agreed by all stakeholder groups and signed off by government and is strategically aligned and fully integrates with broader government strategies.

Value Proposition Statement

Is there a simple statement that summarizes why stakeholders should engage with and use geospatial information and why the government needs a National SDI and how the investment is aligned with the strategic priorities of government?

This indicator assesses the process and maturity of creating a value proposition.

The value proposition, initially derived from the outline socio-economics impact analysis, is a clear and concise statement that addresses strategic priority problems (social and economic development, SDGs, regulatory, public safety, and emergency response, etc.) that would benefit from having integrated geospatial information and analytical capabilities of a National SDI. It explains how geospatial information can address these problems, the impact and benefits that can be realized, and what makes these benefits valuable. It is key to achieving political and management buy-in, financial support, human resources, and sustainability. The value proposition will be refined after a full socio-economics impact analysis is completed.

Attention	None.
Minimal	Anecdotal evidence exists about the value of a National SDI.
Good	A strategic alignment has been carried out to identify key, government priorities to be supported.
Better	A value proposition has been created from an outline socio-economic impact analysis, but it is not widely accepted and has not triggered significant change.
Best	The decision-makers are fully convinced about the value proposition, derived from a full socio-economic impact analysis, and the importance of integrated geospatial information and are actively investing.

Monitoring and Reporting (IHO Publication C-17)

Is there a consistent process of monitoring and effective reporting to international coordination bodies that primarily includes the IHO and United Nations?

This indicator identifies the extent that transparent and effective reporting is undertaken to support international awareness and information sharing.

Every Hydrographic Office (or national equivalent) should provide update reports, regarding their status in respect of building, engaging and/or contributing to an SDI in their country or region, to their respective IHO Regional Hydrographic Commission (RHC) meetings. Such update reports should also be leveraged to inform relevant UN communities of interest and should include at a minimum:

› What types of data are being disseminated (through web-based access or manual dissemination).

› Identification of which datasets, complete with metadata, are provided into an MSDI and reporting progress on preparation (for pending datasets).

› Monitoring and report on feedback from end-users and stakeholders.

› Defining the type of data services and products being offered by the Hydrographic Office.

Attention	None.
Minimal	Need identified.
Good	Sporadically undertaken with inconsistent breadth and/or depth of detail.
Better	Regularly undertaken with inconsistent breadth and/or depth of detail.
Best	Constantly maintained (and reported) with consistent breadth and depth of detail.

SP2 Policy & Legal

Policy & Legal Review, Needs Assessment, & Gap Analysis

Has the Legal & Policy Working Group conducted a needs assessment for the policy and legal framework to support the SDI and then identified gaps in the existing policy and legal framework to be implemented?

This indicator assesses the maturity of reviewing existing policies and legal frameworks.

The review of the existing policy and legal framework will be carried out by the Legal & Policy Working Group and will identify strengths and weaknesses. It is important to note that there are many other equivalent terms to legislation and laws that are used that have essentially the same meaning. These include decrees, orders, codes, and ordinances. Laws may be created specifically for geospatial information (such as legislation on geospatial data sharing) or directly use extant, closely related laws (including privacy, liability, and intellectual property rights management). Regulations are not enshrined in laws but are more flexible to modify and a faster to implement. (See IGIF Strategic Pathway 2: Policy and Legal – Appendix "Review and Assessment – Considerations").

Attention	None.
Minimal	The working group has terms of reference to conduct a needs assessment and gap analysis.
Good	The working group has completed the needs assessment of the existing policy and legal framework.
Better	The working group has completed the gap analysis of the existing policy and legal framework.
Best	The working group has completed the needs assessment and gap analysis of the existing policy and legal framework and the results have been agreed by the governing body.

Licensing Geospatial Information

Are geospatial data licensing agreements (data use rights) supported between providers and users of the data?

This indicator assesses the scope and impact of data licensing agreements.

A geospatial information license agreement is a legal arrangement in which one party (the 'licensor') grants another party (the 'licensee') certain use rights in geospatial information that the licensor either owns or has rights to license or sub-license. In a license agreement the licensor retains the rights it does not grant to the licensee, including ownership. License templates can be adapted to accelerate the creation of license agreements. The most important characteristic of a license is to keep it simple and adopt international standard wording where at all possible, this will keep costs to a minimum for supplier and user. These data licensing agreements ensure that geospatial information is not illegally used, is not used outside the conditions of use, and supports a revenue stream from licenses.

Attention	None.
Minimal	Geospatial data licensing agreements are offered by a few central government institutions.
Good	Geospatial data licensing agreements are offered by the majority of central and local government institutions.
Better	Geospatial data licensing agreements exist for all uses but are limiting the use of geospatial information because of complexities and restrictions.
Best	Widespread data sharing takes place across all stakeholders within and outside government under the restrictions of security and data protection.

Data Sharing

Are there effective policy and legal arrangements with official guidance for agencies to ensure that geospatial data sharing, or data release is encouraged, promoted, and fully enabled?

This indicator assesses the scope and impact of data sharing arrangements, plus whether data sharing is hindered by a lack of guidance for agencies.

Data sharing arrangements can take several forms – such as a national policy, a set of sectoral guidelines, a memorandum of understanding, a data sharing agreement or contract, a license agreement, or a piece of legislation. Importantly, the chosen arrangement must be able to adequately address the concerns by balancing the needs of the data provider with those of the data user. Sharing should embrace modernised FAIR-Plus variants such as FAIR-TLC (legacy/traditional FAIR plus Traceable, Licensed, and Connected).

Data custodians are accountable for the release of information, and this responsibility is often mandated under a custodianship policy. However, custodians often need additional guidance on how and what can be lawfully released in the national interest. This is usually achieved by assigning a government approved access category, data license, and following a standard process. The question is do they also consider an environment where data privacy, sensitivity, 3rd party rights, license fees, and warrantability are required.

Attention	None.
Minimal	Data sharing exists between a few central government institutions, with the need for common guidelines for releasing data recognized but not implemented.
Good	Data sharing exists amongst all central government institutions, with 25% of agencies currently complying with data release guidance.
Better	Data sharing exists amongst all central and local government institutions, with 50% of agencies currently complying with data release guidance.
Best	Data sharing exists across all stakeholders within and outside government (under security or data protection restrictions). All agencies consistently comply with release guidelines.

[6] Findable, Accessible, Interoperable, and Reusable data sharing principles, as used within the academic community.

Open Data Policy

Is there a policy or legislation that supports the dissemination of geospatial data through 'Open Data'?

This indicator assesses the maturity of an Open Data policy.

Governments are increasingly adopting 'Open Data' policies to encourage the sharing and ease of access to their data assets. Geospatial data is normally covered under these 'Open Data' policies – openly accessible, but not necessarily free of charge (see https://theodi.org/article/what-makes-data-open/). Geospatial data can sometimes be accessed free of charge where countries embrace the concept of 'common good' benefits associated with geospatial data, such as "key registers". However, many countries will still restrict access to high-value geospatial datasets, such as large-scale topographic data and land administration data, through charging for access and use (such as licensing). This depends on the business model adopted to support the (M)SDI.

Attention	None.
Minimal	Government has recognized the need for an 'Open Data' policy.
Good	Data sharing exists amongst all central government institutions, with 25% of agencies A draft 'Open Data' policy that includes geospatial data has been created.
Better	The 'Open Data' policy has been adopted, is active and is implemented by a small number of government institutions.
Best	All major stakeholders have embraced the 'Open Data' policy and are disseminating the majority of their geospatial data through 'Open Data'.

SP3 Financial

Business Model

Has a sustainable business model for a functional (M)SDI been defined?

This indicator assesses the extent to which a sustainable business model for the (M)SDI exists.

The SDI business model defines how the (M)SDI will be made economically successful and sustainable. See IGIF Part 2 Appendix 3.4 titled "Example of a business model canvas" for further details. To be sustainable in the long-term the costs must be understood and financial management in place to keep costs within agreed limits. It is recognized that financial management can be fragmented across different agencies and different levels of government making it difficult to build sustainable business cases.

Attention	Not defined.
Minimal	Organizational business models are in place for principal (M)SDI supply agencies, but (M)SDI component not defined.
Good	Governing body understanding of need to define sustainable (M)SDI business model is a work in progress.
Better	Sustainable (M)SDI business model defined and agreed.
Best	Sustainable (M)SDI business model documented and regularly reviewed and update.

Funding Sources

Does the (M)SDI governing body have a full understanding of the possible sources of financial partnerships for investment funding, including international sources, and what is required to secure them?

This indicator assesses the understanding of (M)SDI funding options.

Finance to develop (M)SDI can come from multiple sources including government funding, public sector cost sharing schemes, loans, or grants from International Financial Institutions (IFIs) and from public-private partnerships (PPPs). The SDI governing body will need to develop a full understanding of the possible sources of funding and what financial information each will require to obtain investment approval. This importantly requires an understanding of the concept of public good, namely a commodity or service that is provided without profit to all members of a society, usually funded by government.

Attention	No understanding.
Minimal	Some understanding but no direct engagement.
Good	Understanding of all options and initial engagement with most promising.
Better	Full engagement and justification in preparation.
Best	Plans fully developed, approved by government and financial partners.

Socio-Economic Impact Assessment

Has a socio-economic impact assessment of the value of investment in the SDI been fully developed?

This indicator assesses the state of development of a socio-economic impact assessment of (M)SDI investment.

The investment in substantial programmes of work, such as developing an (M)SDI requires a justification, often referred to as business case. It describes the strategic, economic, commercial, financial and management reasons for investment. This is referred to as socio-economic impact assessment because some benefits cannot be assessed in purely financial terms. IGIF Part 2 Appendix 3.7 titled "An example of a socio-economic impact assessment approach" and Appendix 3.8 "Components of a business case – five key perspectives" provide further guidance.

Attention	No development.
Minimal	There is an understanding of the need for a socio-economic benefits assessment to support investment in SDI development.
Good	Work to construct a socio-economic impact assessment for SDI investment has been started.
Better	A socio-economic impact assessment outline has been completed and approved by the national financial authority.
Best	The socio-economic impact assessment is regularly updated and reviewed.

Geospatial Product and Services Pricing

Has a coherent and sustainable pricing policy (including open data) for (M)SDI datasets and services been established?

This indicator assesses the degree to which a geospatial marketplace exists for products and services.

Various approaches to pricing may be appropriate and will often be determined by overall government policy towards public data. Data may be free of charge to all users, or public sector only. Alternatively, it may require partial or complete recovery of production and maintenance cost. Some countries have adopted a "freemium" model where certain basic data products are free but premium products are chargeable. Pricing policy must be aligned to licensing which controls the type of access and usage associated with the price paid.

Attention	No pricing structure exists.
Minimal	Need for coherent policy recognized.
Good	Being developed with major stakeholders involved.
Better	Draft policy agreed.
Best	Implemented and under regular review.

Benefits Realisation

Are the benefits of (M)SDI implementation being measured and compared to predicted levels identified in the socio-economic impact assessment?

This indicator assesses the measurement maturity of (M)SDI benefits of that are realized because of its implementation.

To justify ongoing investment in an (M)SDI, a series of financial Key Performance Indicators (KPIs) that can be measured in a repeatable manner need to be defined. These should be designed to be simple to implement and easy to understand. These indicators are derived from the results of the socio-economic impact assessment.

Attention	No measures.
Minimal	The need for measures is recognized.
Good	Measures are defined.
Better	Measures are implemented and regularly reported.
Best	Measures are used by decision makers to make changes in priorities if required.

SP4 Data (incl. separate Data Audit)

Data Inventory and Data Profiles

Has a set of fundamental datasets been identified for each data theme, and do they have a data profile (such as descriptive and administrative metadata)?

This indicator assesses the level of awareness of what data exists.

Fundamental datasets (and others) are identified through a data inventory. The data inventory should record as a minimum the spatial data format, currency, accuracy, ownership, extent/coverage, datum coordinate reference system, and the purpose for which the data is primarily used. Descriptive metadata should provide sufficient information for discovery and identification, whilst the administrative metadata enables data asset management (by data type, access permissions, creation time, location, and method).

IHO commentary from Publication C-17 (2017) – Hydrographic data which should be part of an MSDI includes any navigational (or other water body data) and comprises at least:

› "Source" data (such as dense bathymetric data) and/or

› Derived data (such as ENC data, digital nautical publications, Digital Elevation Model), plus

› Essential supporting metadata (data that provides other information about other data).

It is critical to identify those categories of data that would support an MSDI as "core or base reference" information (such as bathymetry, seabed characterization, and coastline). Note that the inclusion of other water body data will depend upon the constitution and remit of a given Hydrographic Office (or national equivalent) with respect to its fellow Government Agencies. In some rare cases, the only data that could be offered is bathymetry, particularly if other data falls under the responsibility of other Departments or Agencies, who may have genuine reasons for not releasing that information.

Attention	None.
Minimal	The need for a data inventory is recognized as there is no clear understanding of what exists.
Good	A data inventory has been completed and datasets categorized according to each theme.
Better	There is a data profile (descriptive metadata) for each dataset identified in the data framework.
Best	All fundamental datasets are actively managed and maintained.

Data Gap Analysis

Have all critical fundamental geospatial datasets been created to an agreed quality level?

This indicator assesses the current progress towards the completion of each fundamental dataset; which ones are identified as crucial to national needs, and those to be prioritized for creation or quality improvement.

A Data Gap Analysis is required to organize information so that it is simpler to identify the strategies required to address the gaps in geospatial information capability. The report should reference the standard list of UN-GGIM fundamental data themes where appropriate.

Attention	None.
Minimal	The need for a gap analysis to identify critical datasets is recognized.
Good	Discussions indicate that more than 25% of critical datasets have been created but no formal gap analysis has been undertaken.
Better	A gap analysis reveals more than 50% of the critical datasets have been created.
Best	All identified critical fundamental datasets have been created.

Data Acquisition Program

Is there a centrally coordinated Data Acquisition Program, where organisations (including project teams) can register their data requirements at agreed intervals and where centralised purchasing reduces duplication?

This indicator assesses the level of cooperation through a central Data Acquisition Program to reduce the amount of data duplication, with a view to understanding the potential for savings and productivity gains.

Each year government agencies purchase or collect a wide range of data and geospatial information products, such as aerial photography, satellite imagery, and hydrographic and topographic mapping surveys. The procurement of this information is often not coordinated or centralized, resulting in significant potential for the same information to be purchased, digitized and/or duplicated. Coordination through a centralized Data Acquisition Program can reduce duplication.

IHO commentary from Publication C-17 (2017) – For the (re)acquisition of digital information from legacy physical sources, the "5-Star Deployment Scheme" should ideally be referenced, where generally:

› Scan manuscript documents into raster formats, ensuring the scan density is such that it can be used without resorting to the hard copy for resolving readability; and/or . . .

› Capture data in vector format wherever possible. This could be done using optical character recognition methods or using double digitization to ensure the quality and completeness of data capture (such as from hand-drawn soundings).

› Ensure rigorous verification and validation is in place, mitigating against the propagation of errors.

› Capture data as close to source scale or at highest possible resolution (not at product scale).

Attention	None.
Minimal	The need for a data acquisition program has been identified but currently there is a high degree of duplication in data acquisition across all sectors.
Good	Duplicated datasets exist and there is a plan to resolve this costly overhead.
Better	Aerial photography and satellite imagery is managed through a national acquisition program, but duplication still exists for other geospatial data.
Best	The planning, recording and acquisition of geospatial data is channelled through one governance conduit that has oversight of national needs and priorities.

Data Ownership (IHO Publication C-17)

Are the datasets required for populating an (M)SDI under beneficial ownership or have rights been granted for onward exploitation within an (M)SDI?

This indicator assesses the extent of ownership or assured rights for exploitation of the required data, as needed for an effective and functioning (M)SDI.

An organisation which provides data into an (M)SDI must take steps to ensure that it possesses ownership or the rights to populate an (M)SDI. Hydrographic Offices (or national equivalents) are often dependent on the provision of bathymetric survey data from other parties such as port authorities, the offshore industry, and other marine agencies. In this case, the Hydrographic Office is not the "owner" of the data but rather a "custodian". When considering what data may contribute to an MSDI, a Hydrographic Office should be aware that it may not have authority to include source data for which it is not the owner. Permission to provide such data should always be sought although, in general terms, the Hydrographic Office would be able under its agreements with the data suppliers to include product level data.

Some categories of data might be held by other authorities who are also providing inputs to an (M) SDI. Ideally, the HO should discuss with other data providers where potential overlaps exist in data holdings. Part of this discussion would involve the need to deconflict data where overlap occurs. Source data should prevail over derived and generalized product data.

Attention	None.
Minimal	Beneficial ownership and exploitation rights are recognized as integral for an (M)SDI but is not implemented at a material or significant level.
Good	Some datasets (25%) are under beneficial ownership or with rights acquired and there is a plan to increase this.
Better	Most datasets (50%) are under beneficial ownership or with rights acquired and the plan to consistently increase this is under active management and execution.
Best	All datasets are under beneficial ownership or with rights acquired and there is a plan to maintain this for new data, which is under active management and execution.

Data Quality

Are the fundamental datasets being checked for data quality to ensure that the data (and its metadata) are fit-for-purpose?

This indicator assesses whether the fundamental datasets are fit-for-purpose and whether data quality is checked.

Under the fit for purpose approach, each dataset will have a different minimum data quality threshold. It is essential that each fundamental dataset is regularly checked to ensure compliance with this defined data quality around the quality dimensions of currency, timeliness, accuracy, completeness, coverage, integrity, and interoperability. Data quality improvement plans should be implemented to improve the data quality to the agreed level for each dataset,

where required. Quality requirements of data users may change over time, so quality checks must be regularly implemented. This includes structural metadata on the characteristics of the dataset (and its digital container), alongside legal metadata (if provided) on the creator, copyright holder, and applicable licensing or rights.

IHO commentary from Publication C-17 (2017) – The minimum set of metadata required for data discovery should describe information about the type of data, the extent of data, the quality of the data, and the spatial/temporal reference system(s) used. Metadata should enable data characterization so that end-users can exploit data efficiently by knowing its basic characteristics. Optional metadata elements should allow for more detailed description of data, with ISO 19115 used as the standard to ensure full interoperability. An essential part of metadata includes information on the Coordinate Reference System used, including horizontal/vertical datums and projections – such as EPSG (European Petroleum Survey Group) codes and Coordinates, whether XYZ, WGS84 datum, or Vertical Datum (local and regional).

Attention	None.
Minimal	Quality dimensions are recognized as integral to managing data reliability but there are no checks in place.
Good	Some agencies (25%) have agreed quality dimensions for their data (including metadata) and are only inconsistently checked.
Better	A common set of quality dimensions (applied at different threshold levels for different data) is applied across all fundamental data themes and these are adopted and checked by 50% of agencies.
Best	All fundamental datasets have associated quality dimensions based around fit for purpose and are checked on a regular basis in compliance with international best practice.

Data Interoperability

Is data interoperable with multiple systems and services?

This indicator assesses whether data are interoperable with multiple systems and services, and how easily they can be used to conduct geospatial analysis.

Data interoperability is crucial to achieving integrated data supply chains. Having data that are interoperable means that systems and services that create, exchange, and consume data have clear, shared expectations for the contents, contexts and meaning of the data. To be interoperable data will need to use community agreed formats, language, and vocabularies, and follow (at a minimum) FAIR data principles (Findable, Accessible, Interoperable, and Reusable) or modernised variants such as **FAIR-TLC** (legacy/traditional FAIR plus Traceable, Licensed, and Connected).

Attention	None, common data standards are not in evidence.
Minimal	The need for common data standards is recognized but not implemented.
Good	Data models comply with a national standard and are curated and aggregated at the national level but only 25% of available data sets are integrated and used.
Better	Integrated geospatial data are available nationally, but integration with marine and statistical data is limited.
Best	All geospatial and statistical data is integrated at the feature level and is used widely for complex data analysis.

SP5 Innovation

Geospatial Innovation Strategy

Is there an innovation strategy to drive transformational change, invigorate the geospatial marketplace, and trigger investment in innovation?

This indicator assesses if the need for technological innovation and the use of new technologies is both recognized and supported, and to what degree geospatial data and technology are involved.

An innovation strategy identifies the opportunities for geospatial digital innovation and sets transformation goals aligned with government strategic needs and priorities, being important for stakeholder buy-in and participation. It may be part of the Digital Transformation Strategy.

Attention	None.
Minimal	The need for a strategy is recognized.
Good	A government innovation strategy exists but geospatial technologies are not well-considered.
Better	A geospatial innovation strategy is under development.
Best	A geospatial innovation strategy exists and approved.

Core ICT Infrastructure

Is the fundamental ICT infrastructure (Internet, electricity, and digital geospatial technologies) available, accessible, and easily leveraged?

This indicator assesses the level of the core ICT infrastructure and whether leapfrog opportunities are plausible and/or being embraced.

Effective geospatial information management is only effective when the underlying core ICT infrastructure is available to all, robust and scalable. Without investments in electricity, internet, cloud technologies, and geospatial technologies, a comprehensive SDI will be very difficult to achieve.

Attention	None.
Minimal	The need to address gaps in the fundamental ICT infrastructure is recognized.
Good	Plans are underway to modernize the ICT sector and leapfrog opportunities have been identified.
Better	There are examples demonstrating increasing digital access, adoption, and use of the internet and geospatial technologies.
Best	The Internet and digital geospatial technologies are widely adopted and do not impede development of an (M)SDI.

Data Products and Services

Are geospatial technologies being used to deliver new services and insights to the broader community of users (beyond specialist/expert users), and as a catalyst for innovation in areas of strategic need?

This indicator assesses if geospatial data products and services are being used in an innovative way to deliver strategic decision-making and new insights.

Having access to data is one part of the IGIF journey, being able to use these data for decision-making is equally important. Data services such as web services, data-as-a-service, and APIs, provide flexibility in how and where data are stored and accessed – making it easy to find and use data from anywhere – leading to innovation. Ideally, this innovation should be prioritized to meet strategic needs, which may include economic growth through the use of APIs in commercial applications.

Attention	None.
Minimal	The need to stimulate wider use of geospatial data to deliver new services and insights is recognized.
Good	Plans are underway to deliver new services and decision-making tools and applications.
Better	Geospatial services, tools and applications and are used widely across the professional geospatial sector for strategic decision-making.
Best	Geospatial services, tools and applications are used widely and innovatively across both the professional and broader community of users for strategic decision-making.

Modernising Data Assets

Are state-of-the-art methods, such as machine-learning and the latest GIS software, being used widely for data creation?

This indicator assesses the level of maturity in data creation to understand where there is scope for new methods and thus opportunities.

State-of-the-art data creation methods include using earth observation technologies and aerial imagery for feature extraction, web services (such as APIs), IoT devices (such as sensors), Artificial Intelligence driven solutions (such as deep-learning models), crowdsourced data, and data harvesting.

Attention	None.
Minimal	The need for improved data creation methods is recognized.
Good	Plans are underway to modernize data creation methods.
Better	There are examples of state-of-the-art data creation methods in use.
Best	State-of-the-art methods for data creation are frequently used.

Enabling Geospatial Infrastructure

Is there an SDI enabling infrastructure and geoportal in operation that supports sharing, viewing, accessing, and using geospatial information?

This indicator assesses the capability of government to share, access, view and use data between government agencies and with the private sector and citizens.

An enabling infrastructure, is an integrated environment where data and products from multiple agencies can be uploaded, discovered, viewed, queried, and downloaded. These platforms are typically deployed within the framework of the National SDI and provide governments with a solid foundation towards transitioning to online citizen-centric whole-of-government services.

Attention	None.
Minimal	The need is recognized, and design agreed.
Good	The SDI enabling infrastructure and geoportal is under development.
Better	SDI enabling infrastructure and geoportal is partly in operation but needs enhancement.
Best	A state-of-the-art scalable, enabling infrastructure and geoportal is in operation and used widely.

National Innovation System

Does the government have an organization responsible for innovation? Is geospatial data and technology included in the government's innovation efforts?

This indicator assesses how well the government recognizes the need for technological innovation and the use of new technologies, and to what degree geospatial data and technology are involved.

A key component of the innovation process is the flow of technology and information among people, enterprises, businesses, and institutions. This flow is referred to as the National Innovation System. An organization is usually established to provide oversight and direct the National Innovation System or responsibility is delegated to an existing authority.

Attention	None.
Minimal	The need is recognized, and design agreed.
Good	The SDI enabling infrastructure and geoportal is under development.
Better	SDI enabling infrastructure and geoportal is partly in operation but needs enhancement.
Best	A state-of-the-art scalable, enabling infrastructure and geoportal is in operation and used widely.

Geospatial Innovation Program

Is there an investment program for geospatial information and technology innovation?

This indicator assesses whether there is a commitment by government to invest in geospatial innovation through a formal innovation program.

Innovation programs are a subset of a National Innovation System. The objective of an innovation program is to take new ideas or new ways of doing business and make them viable. This can include geospatial innovation hubs that provide small business incubation centres.

Attention	None.
Minimal	The need for a funded innovation program is recognized.
Good	The framework for an innovation program is under development.
Better	There is no formal innovation program, but geospatial-related innovation projects are funded on an individual basis.
Best	A fully funded Innovation Program exists for geospatial information and related technologies.

SP6 Standards

Standards Strategy or Plan

Is there a National Standards Strategy and a process to review or develop (as necessary), and endorse a common framework of national data and technology standards?

This indicator identifies the level of maturity of a standards strategy.

There should be national-level policy that encourages the adoption of a common framework of standards. and the benefits the successful implementation will deliver. In the absence of other factors, national standards should be developed and applied only when international standards do not meet national needs. Where national standards are deemed to be required, they should strive to either profile existing international standards or use defined international standards as a framework.

OGC commentary from the Role of Standards in Geospatial Information Management (2022) – Standards are a critical element of geospatial information management, with a National Standards Strategy ideally referencing the trajectory for increasing levels of capability and collaboration over four Tiers:

› Tier 1 – Share maps internally and over the Web.

› Tier 2 – Geospatial Information partnerships to share, integrate and use geospatial data from different providers.

› Tier 3 – Spatially enabling large scale (typically national) efforts to develop a comprehensive (M)SDI that provides access to multiple themes of information, applications for using the shared information, and access via a variety of environments (mobile, desktop, etc).

› Tier 4 – Towards spatially enabled IT infrastructure, delivering geospatial information into the Web of Data, and bridging between an (M)SDI and broader ecosystems of information technology.

Experience has shown that lack of consensus, leadership commitment, and a clear governance structure are the key factors limiting the full achievement of the benefits of open standards. As consensus builds, understanding improves and the willingness of stakeholders to commit resources and coordinate activities in an open fashion grows. This facilitates a continuing, self-sustainable, and self-governed expansion of open standards. Single agency portrayal of basic information develops into collaborative multi-agency standards implementations that take full advantage of emerging technology. Recognizing the complexity and constraints, it can be worthwhile to implement standards in an incremental fashion. Full interoperability can take time as an organization or institution matures in technical and policy terms.

Attention	None.
Minimal	The need for a common framework of data and technology standards is recognized.
Good	Work on developing a standards strategy with necessary financial support is underway.
Better	A strategy or plan has been developed and approved.
Best	The Standards strategy or plan has been implemented with cross-government and community coordination including an on-going revision.

Standards Awareness

Is there an active awareness program that raises, advocates, and promotes the principles, values, needs and benefits of geospatial data and technology standards?

This indicator identifies the extent of the standards awareness program.

A key element of implementing standards is to raise awareness of the benefits of moving towards a standards-based approach for geospatial data management at all levels of government and with the private sector and academia. A heightened understanding and awareness of the relevance of standards, as an information sharing enabler, is crucial to strengthening capability.

Stakeholders need to be made aware of the costs of initially defining standards and then the costs of migrating their data and ICT solutions to be compliant with the standards. This is not insignificant, but the benefits will be considerable. There are also costs associated with OGC membership.

Attention	None.
Minimal	Awareness has been raised across the stakeholders involved in using the standards.
Good	An engagement strategy for active interaction with community stakeholders and users to raise awareness has been created.
Better	Broad public/private sector stakeholder dialogues and forums to raise awareness and to promote the alignment is actively being promoted.
Best	Awareness of standards to a level necessary to apply them is universal amongst stakeholders in the geospatial information sector.

Understanding Organizational Needs (OGC's "Role of Standards …")

Is there an active program for understanding which open standards are available for addressing an organization's needs?

This indicator identifies the extent of understanding around organisational needs for open standards.

Understanding the standards landscape for supporting organizational needs is complex and commonly requires expert knowledge and advice. To understand organizational needs, it is helpful to look at user requirements from three different perspectives: the user, the data, and the organizational perspective.

A user must have the ability to easily discover new knowledge, information, or data to address their needs. Users are increasingly diverse beyond the established communities of researchers and navigators, now including non-expert decision-makers and the web developers that support them. Web developers may be unfamiliar with domain-specific content data and need to find relevant standards for exploitation.

From the data perspective, many considerations around data needs exist and should be accounted for. These include the ability to access and use data subject to Legal and Security requirements, Data Format needs, and Data Volume constraints. From the organizational perspective, there should be a process for capturing needs and gaps, which should become part of a future information policy and annual plan for integration into existing practices.

"A Guide to the Role of Standards in Geospatial Information Management" (February 2022) contains advice around the adoption of metadata, data, and technical standards applicable to an MSDI. This OGC resource contains a Five Point Plan that heavily draws upon the IGIF Strategic Pathway on Standards (SP6).

Attention	None.
Minimal	The need for understanding organizational requirements for standards is recognized.
Good	The organisational program for standards requirements is under development.
Better	There is no formal organisational program, but the discovery of standards requirements is undertaken on an individual project, discipline, or divisional basis.
Best	An active organisational program for standards requirements exists for geospatial data and related technologies.

Implementation

Have technology and data standards been endorsed or mandated to support interoperability and enable different systems and diverse data types to work together seamlessly?

This indicator identifies the level of maturity in specifying, adopting, and implementing standards.

Technology standards, such as for Application Programming Interfaces (API), are used to specify how software components interact with each other through standard interfaces to enable different systems and services to work together. Geospatial data standards provide a digital encoding and support the management of geographic features as coverages (including fundamental data themes), attributes and imagery, and are integral to the reuse and repurposing of information. These standards should also support the agreed meaning for terms, referred to as achieving "semantic interoperability".

Attention	None.
Minimal	A few technology and data standards have been informally agreed and adopted by some stakeholders in the geospatial domain.
Good	National data standards and technical specifications have been defined for the geospatial domain.
Better	A national action plan has been agreed for rolling out data standards and technical specifications.
Best	Comprehensive adoption and implementation of data standards and technical specifications has been achieved across the geospatial domain.

Standards Compliance (OGC's "Role of Standards …")

Is there a system of compliance for ensuring the implementation of (inter)nationally endorsed standards for data interoperability, and to verify that procured technology solutions properly implement the standards required?

This indicator identifies the level of assessing standards compliance.

The OGC Compliance Interoperability Test Engine and ISO 19105 test scripts are available as open source technology for implementation by government organizations for the testing of internal systems which use, or may have been modified to use OGC and ISO standards.

The ISO 19105 standard specifies the framework, concepts and methodology for conformance testing and criteria to be achieved for claiming conformance to the family of applicable standards documents regarding geographic information and relevant application domains. It provides a framework for specifying Abstract Test Suites (ATS) composed of abstract test cases grouped in conformance classes and for defining the procedures to be followed during conformance testing.

IHO has a long history of supporting international testing frameworks for certification against global standards supporting the SOLAS convention. These testing and compliance regimes are the result of global harmonization efforts by many national agencies via IHO's "Standards in Force" online resource.

Attention	None.
Minimal	Occasional assessment and validation of organisational compliance in implementing endorsed geospatial standards that align with agency, regional and national policies.
Good	Inclusion of nationally endorsed standards as a requirement for all geospatial tenders or procurements, with a preference for certification by an appropriate compliance authority.
Better	Policies include the facilitation of testing and certification functions to provide formal certification nationally, as well as certification recognition under international standards.
Best	Mandated use of available technology compliance testing resources to confirm proper implementation of standards related to any government developed technologies.

SP7 Partnerships

Culture of Cooperation

Are the SDI stakeholders across the city, region, or country moving towards a culture based on inclusion, trusted partnerships and strategic alliances that recognize common needs, aspirations, and goals, towards achieving national priorities and outcomes?

This indicator assesses the adoption of a collaboration culture.

Multi-stakeholder partnerships and collaboration leverage a range of resources. These may include knowledge, technology, information, expertise, and financial capabilities. They have the potential for creative and innovative approaches, leveraging the diversity of partners and their respective contributions. Partnerships and collaborations can be amongst government institutions, community and civil society, private sector, academia, regional or international organizations. The adoption of the partnership and collaboration paradigm can require significant cultural change in many countries and therefore can take time to evolve. It is normally recommended that the level of collaboration starts at a basic level and is increased over time to build trust and implement capacity development to support this new way of working.

Attention	None.
Minimal	A very few ad hoc, informal collaborations exist between the public sector institutions.
Good	Formal cross-sectoral collaborations have started to be created amongst public sector institutions.
Better	Successful Public Private Partnerships (PPPs) are being established.
Best	The creation of partnerships and collaborations across all stakeholders in the geospatial information community has become the norm.

Public Private Partnerships

Are strategic partnerships and joint ventures between the public and private sectors, Public Private Partnerships (PPPs), being successfully implemented and delivering new or improved innovative geospatial products and services?

This indicator assesses the type and scope of Public-Private Partnerships (PPPs) established.

PPPs can be seen as an activity or project, or a form of delivery mechanism. It can also be a stated intent in a government policy statement, and generally involves the sharing of risk, a way of financing and joint development. Types of PPPs can be formal joint venture or collaborative development (CRADA), for example. This can apply to infrastructure development, such as that of geodetic infrastructure, including a continuously operating reference stations (CORS) network, and geospatial product and service delivery. Partnerships with the private sector can facilitate win-win collaborative outcomes for governments and stakeholders but may require significant cultural change within government. (See IGIF Strategic Pathway 7: Partnerships – Appendix "Evaluation of Potential Partners".)

Attention	None.
Minimal	There is a policy statement supporting and encouraging the creation of PPPs in the geospatial information domain.
Good	Initial, experimental PPPs have been initiated.
Better	A few, significant PPPs have been successfully established and are delivering new, innovative products and services.
Best	A wide range of PPPs are delivering new, innovative products and services.

Academic Cooperation

Is there cooperation between the public sector and academia to benefit from the scientific, technical, research and learning capacity available?

This indicator assesses the scope and maturity of cooperation established with between public sector and academia.

When the public sector cooperates with educational and research institutions, there should be the ability to benefit from the scientific, technical, research and learning capacity available. Benefits include greater access to knowledge, mitigating risk and reducing potential mistakes through greater understanding, being able to draw from a wider pool of technical expertise, cost sharing, increased innovation potential, and the ability to overcome challenges more readily.

Attention	None.
Minimal	There is a policy statement supporting and encouraging collaboration between the public sector institutions and academia.
Good	Initial, tentative collaborations between public sector institutions and academia have started.
Better	A few collaborations between public sector institutions and academia have been successfully established and are delivering benefits.
Best	A wide range of collaborations between public sector institutions and academia have been successfully established and are delivering significant benefits.

International and Regional Collaboration

Are there international and regional collaborations on geospatial information management issues where the interaction between organizations, representing various nations, pursue common goals or interests?

This indicator assesses the maturity of collaboration established at the regional and international levels.

International and regional collaboration refers to the interaction between organizations representing various nations in the pursuit of common goals or interests and to build consensus and support transboundary solutions. A good example is UN-GGIM. The collaboration can include partnerships with international aid agencies, philanthropic foundations, and official development agencies. Typically, this cooperation involves technical support, knowledge exchange, funding as well as affording access to regional and global networks and at times also to levels of government and politics.

Attention	None.
Minimal	There is a policy statement supporting and encouraging international and regional collaborations on geospatial information management.
Good	A governance structure has been established to support international and regional collaborations on geospatial information management.
Better	Regional collaborations on geospatial information management have been initiated.
Best	International collaborations on geospatial information management have been initiated and are active and on-going.

Citizen Engagement

Is there civil society participation in geospatial information management where individuals and community groups are involved in geospatial information projects to either solve their own problems or contribute geospatial data through crowdsourcing?

This indicator assesses the level of engagement with citizens and community groups.

Community participation using geospatial information has increased significantly through the rapid expansion of the sharing economy. Now acquiring, providing, and sharing access to geospatial information through community based on-line platforms is giving rise to a new economic model – collaborative consumption. Businesses are developing goods and services that rely on regularly contributed and updated geospatial information. In addition, crowdsourcing is being used to maintain geospatial information products in the public and private sectors. Community participation is especially important in emergency services programs where people contribute local knowledge about their location and surroundings to improve emergency preparedness, mitigation, response, and recovery.

Attention	None.
Minimal	Citizens engage with global corporations and provide geospatial information.
Good	Citizens also engage with community-based platforms and provide geospatial information.
Better	Citizens also engage with public sector services and provide geospatial information.
Best	Citizens regularly provide geospatial information to a wide range of community, public sector, private sector, and global platforms.

SP8 Capacity & Education

Assessment and Analysis

Has an assessment been conducted to understand the priority areas for capacity development so that geospatial information management can be strengthened and sustained in the longer term?

This indicator identifies the priority areas for capacity development in geospatial information management.

The needs assessment and gap analysis created the inventory and baseline of existing capacity development and education policies, programs, and resources in geospatial information management. This indicator determines if the needs have been prioritized to support the government's policy direction and the priorities of the geospatial sector.

Attention	None.
Minimal	There is an awareness that priorities are required, but there is no consensus.
Good	A Working Group has been established to identify the priority areas for capacity development.
Better	The Working Group has identified and agreed the priority areas for capacity development.
Best	Priority investments and interventions in capacity development are being implemented across the geospatial sector.

Strategy and Implementation Plan

Is there a Capacity Development and Education Strategy and associated action plan that sets out how capacity development and education programs will support the strengthening of integrated geospatial information management?

This indicator identifies the maturity level of the strategy.

The strategy sets the stage for the desired transformations that will empower individuals, leaders, organizations, and societies. The strategy must be country-driven, address specific needs and conditions of the country, and reflect national sustainable development strategies and priorities. The strategy must be accompanied by an implementation plan and budget. (See IGIF Strategic Pathway 8: Capacity and Education – Appendix "An example of the typical components of a capacity development and education strategy").

Attention	None.
Minimal	The terms of reference for producing the strategy have been created by the Working Group on Capacity and Education and agreed.
Good	The strategy has been established and agreed by the Governing Board.
Better	The implementation plan to implement the strategy has been agreed with the corresponding financial resources.
Best	Capacity Development and Education Strategy is being implemented across the geospatial information domain.

Professional Development Approaches

Are the necessary human resource elements of professional training, lifelong learning, internship opportunities and/or continual technical and professional development available to the workforce to sustain geospatial information management capabilities?

This indicator identifies the extent of these opportunities to gain new knowledge and skills.

Knowledge and know-how can be developed and shared within an organization, such as through on-the-job training, study and exchange visits, and fellowship programs. Workplace training can be conducted internally or be obtained from external providers, including international partners or donors. These opportunities also apply to related professions, such as planning, disaster management and agriculture, that utilize geospatial information.

Attention	None.
Minimal	A few professional development opportunities in geospatial information management are initially being provided by professional associations / bodies or more informal groups.
Good	Knowledge and know-how are being developed and shared within organizations through on-the-job training, study and exchange visits, and fellowship programs.
Better	A range of professional development opportunities in geospatial information management are being provided by an increasing range of external providers, but not meeting demand.
Best	Comprehensive range of professional development opportunities in geospatial information management courses are being delivered by a range of external, specialist, commercial providers. Demand by the geospatial information sector is being met.

Entrepreneurship

Is government supporting and stimulating entrepreneurship through innovation programs and geospatial challenges that grow the capabilities of the business sector to develop products and services that are underpinned by geospatial information?

This indicator identifies the range and availability of this support to stimulate entrepreneurship.

Governments can support and stimulate entrepreneurship through innovation hub and incubator programs that grow the capabilities of the business sector to develop products and services that are underpinned by geospatial information. This support includes capacity development, public private partnerships, learning programs, mentoring opportunities, industry challenges through GeoHackathons, innovation hubs and small business incubators, for example.

Attention	None.
Minimal	A few, embryonic innovation programs are available to stimulate entrepreneurship, but with mixed results.
Good	A few, targeted innovation programs are available to stimulate entrepreneurship and are delivering successful new business ventures.
Better	A range of support through innovation programs is available, is stimulating entrepreneurship and delivering success, but not meeting demand.
Best	Comprehensive range of support to stimulate entrepreneurship through innovation programs is available and delivering successful new business ventures. Demand by the geospatial information sector is being met.

SP9 Comms & Engagement

Engagement Strategy

Is there is an agreed engagement strategy for all types of stakeholders?

This indicator identifies the stage of engagement strategy development

The development of an engagement strategy involves segmentation and targeted activities/ channels aimed at reaching and interacting with the various stakeholder types. IGIF Part 2 Appendix "Stakeholder Analysis Matrix" provides a template for categorizing stakeholders by interest and influence. It is particularly important to design engagements approaches and channels to suit each type of stakeholder.

Attention	None.
Minimal	No strategy.
Good	The need is recognized.
Better	Strategy drafted.
Best	Consultation on strategy completed and agreed.

Communication Team

Is a dedicated team to support communications within the engagement strategy formed, fully resourced and operational?

This indicator identifies whether a communication team has been formed and is operational.

Without dedicated resources to support the formulation and delivery of engagement and communication strategies it is difficult to secure wide buy-in to the (M)SDI. The resources may sit within a government function that controls communication of policy but does need to be dedicated to geospatial activities to create credible marketing and engagement materials.

Attention	No team in place.
Minimal	Need for team recognized.
Good	Budget for team allocated and recruitment commenced.
Better	Team is operational and involved in Communication Strategy and Plan definition.
Best	Team is effectively supporting both engagement and communication of an (M)SDI.

Key Messages

Have the messages that convey the economic and societal value of an (M)SDI been agreed?

This indicator identifies the state of development of key messages about the value of an SDI.

Strategic messaging involves developing the narrative of clear, succinct, and compelling messages to all audiences to create on-going understanding and buy-in to the (M)SDI concept and its socio-economic value. Clear messaging is part of building brand recognition for the (M)SDI across all stakeholders from decision makers to citizens.

Attention	Not discussed.
Minimal	Some limited discussion at organizational level.
Good	Wider discussion including all stakeholders.
Better	Key messages defined.
Best	Agreed and widely used set of key messages in regular use.

Communications Plan

Has a plan for the methods of communication, to be used for each stakeholder type, been defined, agreed, and being followed?

This indicator identifies the stage of development of a communication plan.

The communication plan uses strategic messages to effectively build sustained two-way communication with different stakeholder groups. The strategy should define the communication channels to be used for each audience type. The IGIF Part 2 appendices titled "Communication Methods" and "Communication Methods – Advantages and Disadvantages of Commonly Used Methods" provide further guidance.

Attention	None.
Minimal	The need is recognized.
Good	Plan drafted.
Better	Consultation on plan completed and agreed.
Best	Plan implemented and subject to regular updating.

Stakeholder Engagement

Is active and ongoing engagement with key stakeholders implemented, being reviewed, and working effectively?

This indicator assesses the extent to which the engagement is being working effectively with all key stakeholders.

Active and on-going engagement of all key stakeholders is essential to the success of the SDI initiative. The nature of the engagement will evolve over time and with increasing levels of awareness and acceptance.

Attention	No engagement.
Minimal	An engagement strategy for all key stakeholder groups has been established.
Good	Some engagement but it is not continuous and limited in coverage.
Better	Engagement is continuous but does not cover all key stakeholder groups.
Best	Regular exchanges take place with all key stakeholder groups.

Link to SDGs

Is there is a fully established link between the National or Marine SDI and the UN Sustainable Development goals in engagement and communication materials?

This indicator identifies the extent that (M)SDI communications explicitly references SDGs.

The purpose of the IGIF is to support the achievement of the SDGs. The National or Marine SDI should be assessed to see how it can help with achieving SDGs and this should be included in communications materials. Each country will have a coordination mechanism for SDG monitoring and reporting with which National or Marine SDI communications need to be integrated.

Attention	No.
Minimal	Need identified.
Good	Sporadically included in communication materials.
Better	Included in most communications.
Best	Fully integrated into National SDG Reporting.

Data Audit

Part 1: Fundamental Data Themes

A data audit in this context refers to the auditing of data to assess its quality and/or utility for geospatial exploitation. Auditing data, unlike auditing finances, involves looking at key metrics, other than purely quantity, to create conclusions about the properties of a dataset and its strategic value to an organisation. The full World Bank SDI Diagnostic Toolkit includes a spreadsheet to facilitate an effective Data Audit, but all its structure and content is covered here for completeness of this IGIF-MSDI Maturity Roadmap.

The Data Audit is divided into three parts: Part 1 focuses on the 14 Fundamental Geospatial Themes as agreed by the UN-GGIM and is suitable for all-domain global use (across air, land, sea, and space). Although a dedicated Water theme exists, marine and maritime interests are not confined to this data theme – the official UN publication on these Data Themes should be consulted for exhaustive detail. As an example, the Land Parcels (Cadastral) data theme encompasses seabed access and easement rights, which are important for pipelines, fibre optic cables, and underwater data centres.

Figure 15: The 14 Fundamental Geospatial Data Themes developed to support UN initiatives such as the UN Sustainable Development Goals (SDGs) and the Integrated Geospatial Information Framework (IGIF).

There may be multiple datasets per theme and so all datasets should be listed, along with the Custodian and Producer of the data. Also, it is not unusual to find several institutions creating the same type of data. If this is the case, list the duplicate dataset(s) and the producer(s), even if the duplicate is not considered the authoritative source. This is valuable information, as it highlights where efficiencies can be made by sharing data. In the case of geodetic reference frames, it is key to note the reference frame used, whether it is an agreed standard, and whether multiple reference frames are employed. This information highlights potential interoperability issues that can be addressed more effectively at an earlier stage.

Part 2 provides the opportunity to document datasets that exist or are currently being produced but fall outside of the fundamental data theme classification, such as health or cyber-related data. Part 3 requires the documentation of details about data producing organizations, which will form part of the stakeholder list that is important for multiagency IGIF-MSDI Umbrella Governance (fully discussed in the Appendix).

A. Identification of Data Theme

In reference to Figure 14 above and the official UN publication on the 14 Fundamental Geospatial Data Themes – as an example "Geographical Names" is applicable to both land, sea, and subsurface domains.

B. Datasets Currently Available

As part of this example, the "Official Geographic Names Dataset" includes approved road names, and land/sea geographical features such as hills, monuments, waterways, ocean features (inlets), localities, and administrative boundaries (including Law of the Sea).

C. Responsible Organisation

This may be an institution such as the Geographic Names Office, Survey Department, Ministry of Lands, Department of the Oceans, or the National Hydrographic Office.

D. Resourcing for Updates

This entry for a dataset considers if the responsible organisation adequately resources the maintenance and updating for the dataset in question. Given the example here, a possible response could be: "The annual budget supports 4 full time staff, with a typical 3-month lag between the request for the approval of a name and its gazettal."

E. Data Format and Technology

Continuing the example and for the remainder of this section: The "Official Geographic Names Dataset" is held in Microsoft Excel with structured fields. Two other geographic names datasets are (i) "Cadastre" (with Road Names) – MicroStation; and (ii) "Topographic Database and Census Bureau Data" – ArcGIS.

F. Geospatial Standards used and their Interoperability

"There are national geographical naming guidelines standards in use, with the UNGEGN Toponymic guidelines adopted for the placement of names on published topographic maps."

G. Percentage of Country Coverage

"Approved Road Names exist mostly in urban areas and for all major highways. The Official Geographic Names Dataset covers the whole country, but it is thought that only 20% of features are named in rural regions and townships."

H. Description of Data Quality

"The location of a named feature is manually recorded in an Excel spreadsheet and a geographic coordinate (latitude-longitude) is assigned. Coordinate values are subject to a high degree of human error. There is currently no funded improvement program."

I. Latest Released Version

"The Official Geographic Names Dataset is made available on a quarterly basis."

J. Revision Cycle

"The data is updated on a daily basis."

K. Access Category, Pricing, and Licensing

"The Official Geographic Names Dataset is publicly provided as an open access dataset under CC-BY-NC licensing. There are no privacy or security restrictions and no restrictions on its use. There is however a fee required for commercial use with a special license required, although revenue is currently minimal."

L. Access Methods (incl. via OGC APIs)

"The Official Geographic Names Dataset is available on the Survey Department website as an Excel document. Number of downloads per annum ranges from 75 to 100. The data is not viewable online."

M. Duplication by other Agencies

"Road names are also captured and maintained in the cadastral and topographic datasets. The Census Bureau also records and updates geographic names, plus administrative boundary names. The Census Bureau validates names against the Survey Department's geographic names dataset on an annual basis."

N. Links to other Datasets

"There is no linkage between the Official Geographic Names Dataset, and the cadastre, topographic and census datasets. Consequently, there is some duplication of effort occurring in relation to data capture, management, updating, and publishing. It is difficult to keep the datasets synchronized, current, and consistent."

O. Primary User Base

"The majority of departments refer to geographic names within official business. However, because the Official Geographic Names Dataset is only tabular (as opposed to map form), many departments are not realizing the full value of this information for decision-making."

P. Existing Themes – Additional Notes

"There is a heightened awareness that geographic names should be integrated within a Geographic Information System (GIS) environment. However, the coordinate location of each feature is not accurate meaning that the Excel dataset, while holding the official gazetted names and their description, is not necessarily spatially accurate. Data enhancement is required."

Part 2: Non-Fundamental Data

This section is more unstructured and freeform to allow the nuanced capture of organisational data on non-fundamental datasets and/or themes not captured above, such as health related data that may have indirect geospatial dependencies or mappings. If it is feasible to use the classification and/or categories in Part 1, then it is greatly preferable and will enable data audit interoperability with other agencies in the nation's IGIF-MSDI ecosystem. Another benefit of doing so is future proofing, where an otherwise non-fundamental dataset (or theme) eventually becomes "fundamental" to the agency at a future point.

Part 3: Data Producing Organisations

This section is also unstructured and freeform to allow the nuanced capture of organisational knowledge regarding the sources of its data. The registered addresses and formal (or legal) names of the institutions providing geospatial information should be accurately recorded along with verified contact details of the responsible Information Asset Owner (IAO). The IAO must provide a point of contact to that institution's Agency Information Risk Owner (AIRO) for strategic concerns, and to the relevant Data Custodians (DCs) for technical queries and error reporting. Please refer to the Appendix on Governance Best Practice for information on these roles and responsibilities.

Another crucial aspect to record (for some contexts), is when the supplying institution does not legally own the supplied datasets but possesses "pass-through" or 3rd party rights for onward supply, subject to some type of restriction (such as intra-Government only or for the provision of Public Services). This may particularly be the case in the marine domain, where many Hydrographic Offices rely upon contracted surveys, or even data collection that is contracted to another legally separate marine body. This may include the Navy, Coastguard, Department of Ports, Ministry of Surveys, or Subsea Resources Authority.

Onwards Steps: Charting an Implementation Course

Once an IGIF-MSDI baseline is generated, it can also be used to determine the target state for each indicator once an agency's (or nation's) IGIF-MSDI Action Plan has been implemented. A further use is described as "in flight", that is during the implementation of any Action Plan, to assess progress as part of a mid-point review. The measurement of a reference (or origin) point for IGIF-MSDI maturity will enable organisations to manage a course of implementation or improvement, which should be fully aligned to national policy drivers. This is best covered by the World Bank's IGIF methodology as previously outlined within Figure 10, although future revisions of this IGIF-MSDI Maturity Roadmap will expand into this area.

The decision on what areas to improve, strengths to leverage, and the strategic direction of an IGIF-MSDI implementation is dependent upon national geopolitical objectives, along with the current ecosystem of marine geospatial responsibilities and resourcing amongst government agencies. Each nation embarking upon an IGIF-MSDI transformation programme will face unique challenges in this respect, particularly due to established "Ways of Working" due to long-established conventions that can hinder collaboration. The following appendix provides starting points for the best practice of multiagency governance, which can be augmented or adapted to suit the unique national ecosystem that marine agencies operate within.

Appendix: Best Practice for Multiagency Governance

Umbrella Governance Model for Established Agency "Ways of Working"

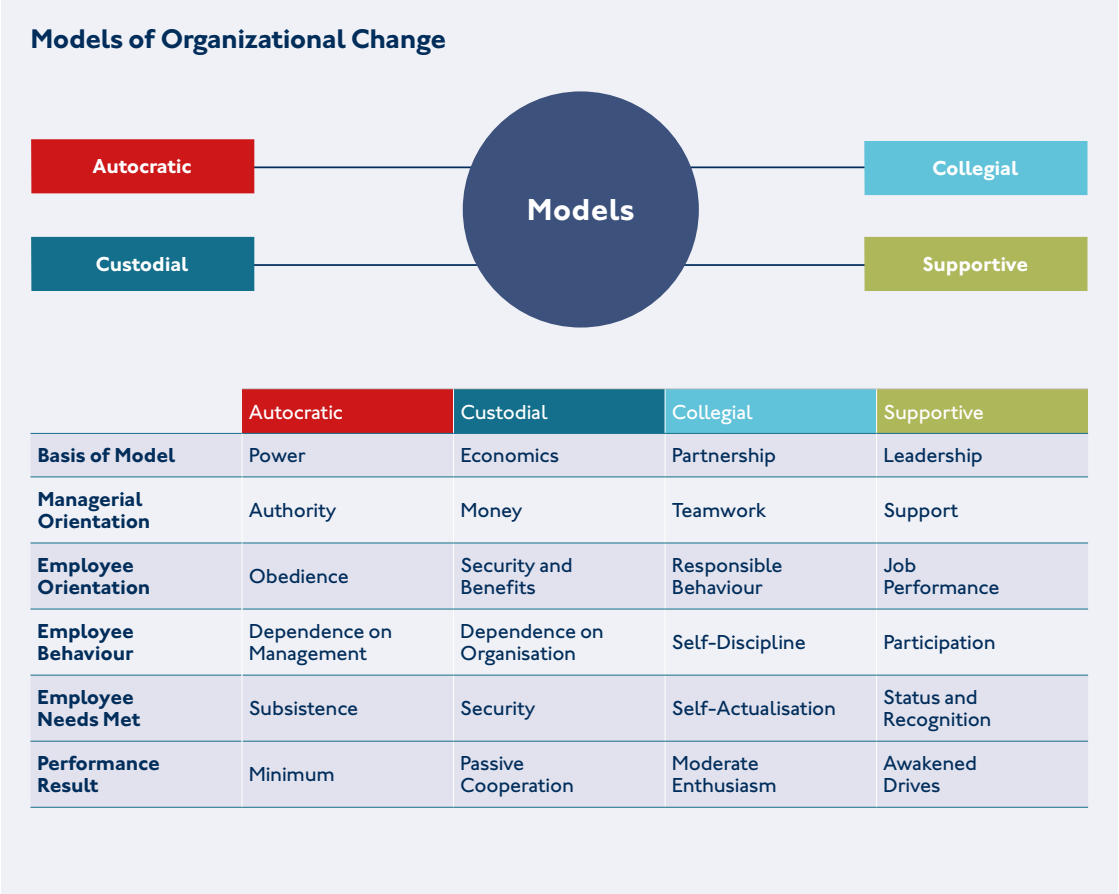
This appendix seeks to provide best practice starting points regarding effective IGIF-MSDI governance amongst independent agencies who may not have a historical record of close, operational integration. This may be useful in situations where long-standing traditions and conventions may have created a culture that is not conducive to the tight-knit cooperation needed to develop complex IGIF-MSDI solutions. Such solutions require the pooling of expertise, resources, and capabilities that not one or even sometimes two agencies could or should provide alone.

The model proposed here is "Umbrella Governance" that sits above each participating agency and leaves them sovereign in their own internal affairs, mitigating the potential obstacles to effective cross-agency working and avoiding a lengthy period of (perhaps unnecessary) disruption before progress is achievable. This approach of leveraging an existing situation (where feasible) to nudge behaviours and outcomes is known as Soft Governance, which seeks to work with the grain of human behaviour and not despite it. It is an adjunct and not a replacement to traditional Hard Governance, which is more commonly associated with prescriptive rules, regulations, and checklists with centralised "command and control".

This Umbrella Governance model is entirely voluntary and relies upon institutional commitment in the absence of a Hard Governance alternative, though that may be required at some point if agencies do not self-organise and cooperate, especially if national government signals that it expects self-organisation. Consequently, enterprise risk is far lower for early voluntary cooperation than "waiting until it is too late", whereby central government legally mandates "forced cooperation". In some cases where an external trigger such as a natural disaster (incl. climate impacts) or a regional geopolitical event occurs, such a mandate may be drafted at pace and (relatively) independently of agency consultation to their detriment.

Recognising this enterprise risk, the senior leadership of those agencies required for forming an effective IGIF-aligned MSDI implementation will need to make a strategic commitment to common goals. Such voluntary goals should be transparently published and ideally supported by central government, taking the form of "one fails, all fail" to prevent agencies withdrawing when challenges or difficult changes arise. One of the major issues behind failures of inter-agency cooperation is "fair weather participation" where agencies are risk-adverse and only engage when progress is consistently fast, easy, and publicity-friendly. The step-change needed in institutional understanding, for enabling effective change via common goals, will have to result from enlightened negotiation and discussion between agencies at the highest levels.

Using the language of corporate strategy, the desired outcome for participating agencies is "playing to win together" the socio-economic benefits from better geospatial capabilities, via a risk-tolerant approach where the precise outcome is not always known. ("Privatising the risks within the agency, socialising the benefits to their nation.") Contrast this to the traditional approach of "play not to lose individually" in a risk-adverse manner to protect the position of individual agencies, with its subtle but far-reaching outcomes. ("Privatising the benefits to the agency, socialising the risks to their nation.")



	Autocratic	Custodial	Collegial	Supportive
Basis of Model	Power	Economics	Partnership	Leadership
Managerial Orientation	Authority	Money	Teamwork	Support
Employee Orientation	Obedience	Security and Benefits	Responsible Behaviour	Job Performance
Employee Behaviour	Dependence on Management	Dependence on Organisation	Self-Discipline	Participation
Employee Needs Met	Subsistence	Security	Self-Actualisation	Status and Recognition
Performance Result	Minimum	Passive Cooperation	Moderate Enthusiasm	Awakened Drives

Figure 16: Models of Organisational Change. Formally speaking, the desired outcome is to elicit Collegial-Supportive behaviours aligned with national goals, whilst concurrently minimising Autocratic-Custodial behaviours between individual agencies.

Umbrella Governance: Scalable for Agency and Regional IGIF-MSDI Practice

Figure 15 shows the idealised structure for multiagency IGIF-MSDI Governance, which can and should be adapted depending on unique national needs or established "Ways of Working" that cannot be readily changed without time-consuming disruption. The most important elements are not the precise names, structures, or relationships, but those characteristics of the overall ecosystem that follow Figure 15. This model is scalable for agency and regional practice using a fractal approach, where a smaller mirrored or duplicate version operates within agencies, to unite different divisions towards a common approach.

These smaller fractal versions can then report as needed into a larger regional version on the same basis, which in turn reports into a national IGIF-MSDI structure, including any created for all-domain IGIF-NSDI governance. (Unless political-technical decisions require an intermediate layer, such as one for national air, terrestrial, and marine respectively – although this entails governance risk.) The potential ultimately exists for a federated IGIF-MSDI governance body along these same principles (outlined as follows), for neighbouring coastal and island nations to collaborate in organising a multinational IGIF-MSDI solution.

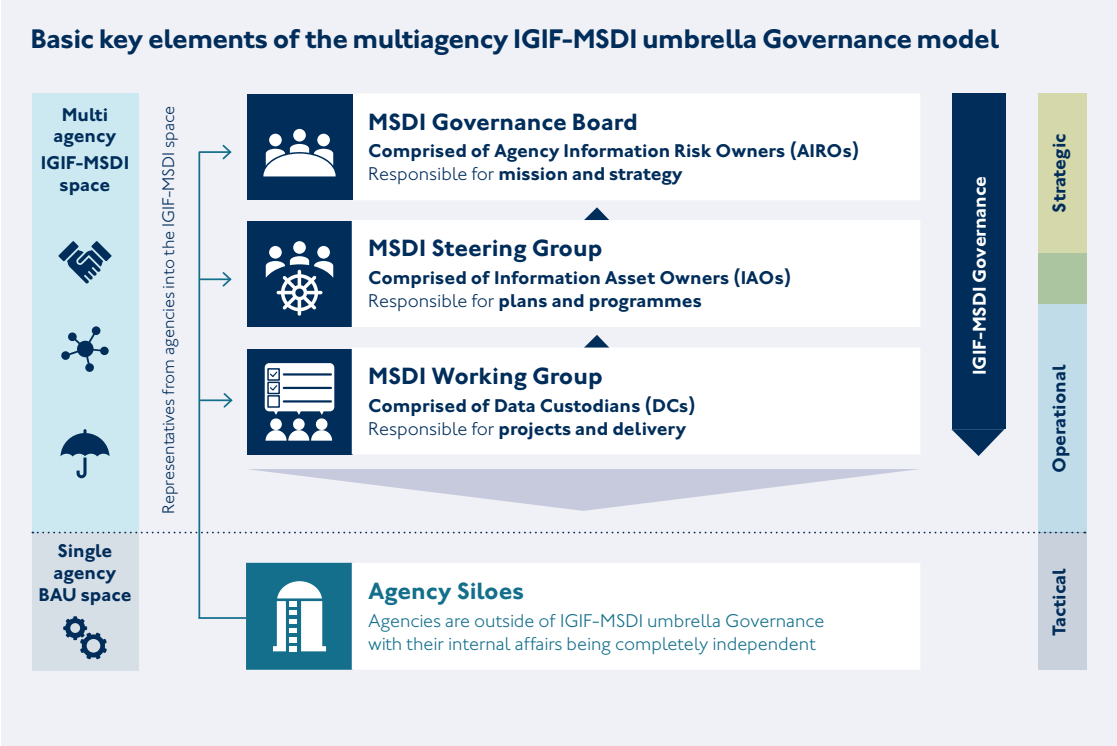


Figure 17: The idealised structure for multiagency IGIF-MSDI Governance, which will likely require adaption for a particular national or agency setting – an agency specific variant of this model is already in operation at the United Kingdom Hydrographic Office (UKHO).

› The multiagency IGIF-MSDI "space" above agency siloes is a cooperative space that does not belong to any one agency. Where administration and organisation are required, this should be undertaken in a joint manner and/or rotated between participating agencies to ensure equality and objectivity.

› The ideal situation would be the political support and organisation of central government, using a voluntary Soft Governance approach to participation, but it is acknowledged that may not always be possible or may entail Hard Governance aspects that could reduce agency motivations to engage.

› As far as feasible and sustainable, this multiagency IGIF-MSDI space should develop its own unique identity and branding, both for publicity and communication, in addition to ensuring longevity should (for whatever reason) a major participant withdraw in whole or in part.

› Although three bodies are suggested in the form of a Working Group (projects and delivery), Steering Group (plans and programmes), plus a Governance Board (mission and strategy); it is not necessary to commission all three should the practical reality suggest that the merger of two bodies is expedient.

› The bodies directly report to each other as shown to ensure cohesion and integrity of the shared IGIF-MSDI space, mitigating against conflicts of interest that could pull apart the shared space. This does not prevent participants involving their home agencies indirectly, but upholding collaboration is key.

The names and terminology used are descriptive, but do not need to be exactly copied. It is far more important that terms are standardised and well understood amongst all participants. Mirroring the drive for data interoperability, the goal here is interoperability between agencies and their key decision-makers at peer level.

› For the roles outlined as follows[5], the key factor is the representation of agencies by those with the right balance of accountability, responsibility, and expertise with respect to their peers within a given IGIF-MSDI body – refer to Figure 16. (Issuing clear Terms of Reference will facilitate this.)

› Since participating agencies can greatly vary in size and scope, they may likely have different management hierarchies and job titles, so standardised roles ensure the right representatives are present, independent of formal role titles whose practical responsibilities can greatly vary.

› It prevents situations such as requesting (as an example) that only "Heads of Digital" attend the Steering Group, where one-half of representatives from smaller agencies are technically expert but not empowered to make strategic decisions – "I know exactly how this can be done, but I need management approval, let me get back to you next month".

› Whilst the other half of Steering Group representatives (for this example) from relatively larger agencies are empowered to make key decisions but may be technically unfamiliar with the exact details at hand – "I could sign this off for our Agency today, but I need to consult with our technical experts, let me get back to you next month."

› The goal is effective and efficient decision-making, minimising where feasible, unnecessary layers of consultation and approval-seeking, creating risks of miscommunication and delays in progress. Brining the right balance of accountability, responsibility, and expertise "into the room" is crucial.

5 The comprehensive description behind these Data Governance roles is not covered here due to space limitations, but is available upon request and consultation, subject to the Lead Author's availability and scheduling at UKHO.

Agency Information Risk Owners (AIROs)

AIROs have the responsibility for understanding how the strategic business goals of their Agency may be impacted by any information risks, and for formulating an organisational response to mitigate them. They own their organisation's strategic information risk policy and risk assessment processes, ensuring they are implemented consistently by the IAOs who manage information assets on a regular basis. The role of an AIRO is to act as an advocate for information risk to their Board (or equivalent) and provide written advice to the Accounting Officer (or equivalent) on the governance of information asset risk.

› **Typical role titles (not exhaustive) – Director of Operations, Chief Data Officer, or Chief Ops Officer.**

Information Asset Owners (IAOs)

Within their area of responsibility, IAOs establish a corporate culture that values, protects and provides information to its users to meet defined needs, driving commercial growth and maximising information asset value to their organisation. An IAO has a shared accountability to deliver upon corporate objectives and their organisation's strategy through asset protection, exploitation, management, and data sharing. They are "owners" of the information assets assigned to them, which are usually entire categories, types, or themes of datasets, but within the context of the organisation's strategy, requirements, and objectives.

› **Typical role titles (not exhaustive) – Head of Data, Head of Operations, or Data Group Manager.**

Data Custodians (DCs)

Data Custodians (DCs) support their Information Asset Owners (IAOs) in achieving their responsibilities. Under those delegated responsibilities agreed with their IAO, they may lead activities that contribute to the operational delivery of corporate objectives through the protection, management, sharing, usage, and exploitation of information (data) assets. DCs play a leading role in managing processes and systems that generate the information assets within their business area, contributing to decisions regarding the use and release of that information. They have custody of those datasets delegated to them by their division IAO.

› **Typical role titles (not exhaustive) – Data Manager, Data Team Leader, or Geospatial Technical Lead.**

Crucially for effective Soft Governance, representatives are to be considered as "Ambassadors" and the sovereign or free choice of their respective home agencies, regardless of any perceived disparity in formal job titles. Equitable representation and fair treatment of agencies and their "Ambassadors" is crucial for progress, independent of an agency's size, budget, scope, remit, or historical prestige. Relatively larger agencies should not try to dominate their smaller peers.

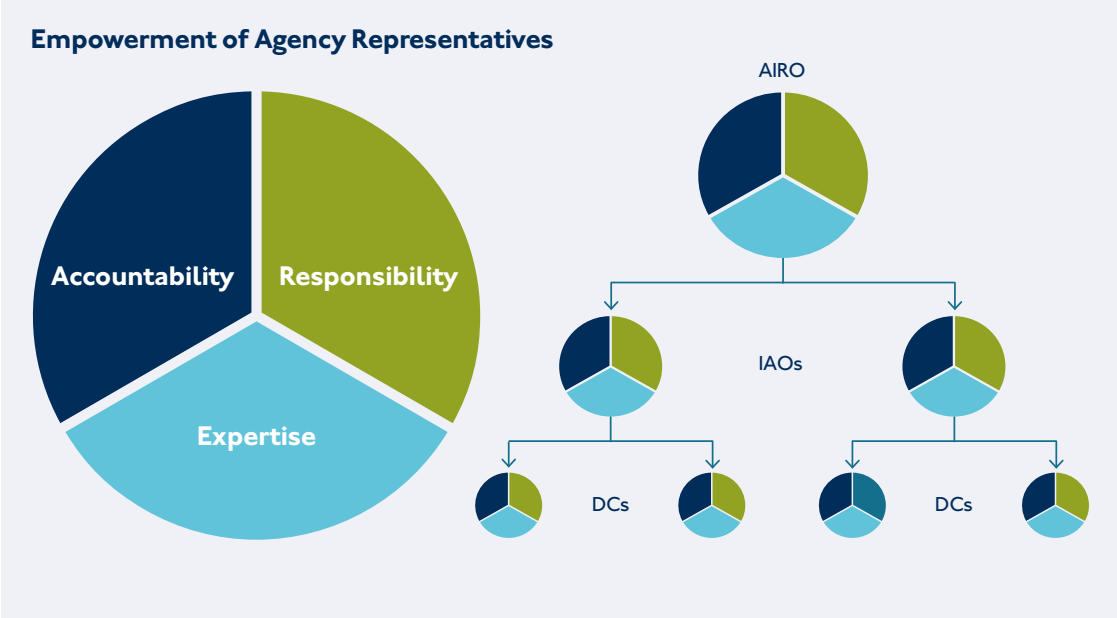


Figure 18: Due to the fast pace of technological change, the agile decision-making required to sustain an effective IGIF-MSDI implementation is ideally supported by a balance of accountability, responsibility and expertise amongst agency representatives and their peers on any given IGIF-MSDI reporting body.

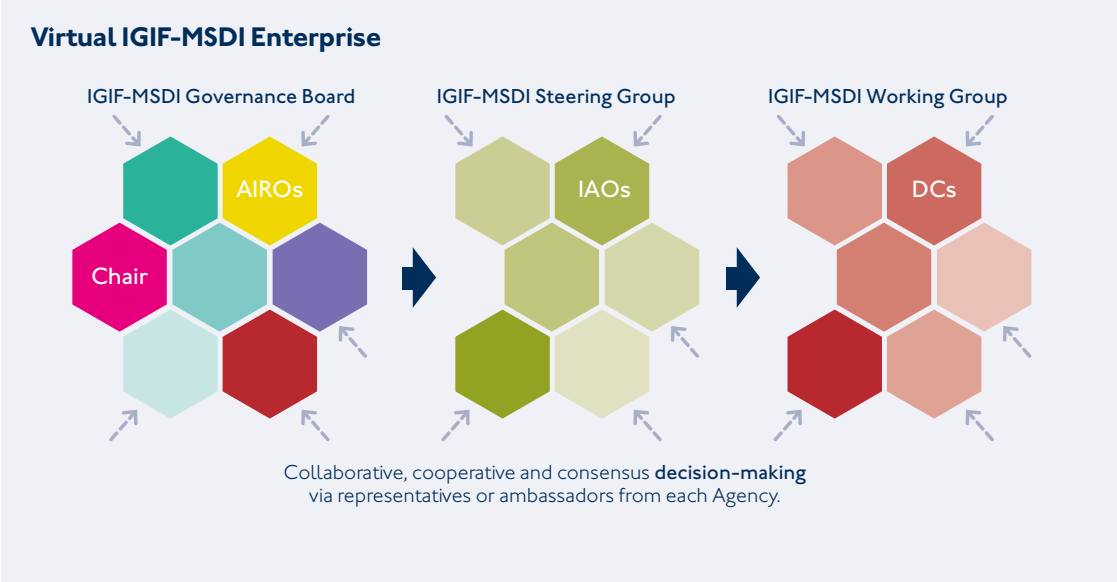


Figure 19: A conceptual diagram of how (in an ideal situation) representatives from different Agencies come together into IGIF-MSDI decision-making bodies under standardised Governance roles .

Figure 20: A conceptual diagram of how (in an ideal situation) the IGIF-MSDI decision-making bodies combine to create a virtual enterprise for delivering new geospatial capabilities in an integrated manner, where home Agencies inject or provide resources and expertise to achieve joint outcomes .

Selected characteristics of effective IGIF-MSDI Governance

One crucial characteristic is a healthy scepticism and a drive to improve ineffective practices, especially where they've become entrenched as tradition, convention or the "way it's always been done here". Such perceptions can be mitigated within organisations, particularly those that genuinely desire to evolve, with the view that "if you always do what you've always done, you'll always get what you've always gotten". Long-term existing practices evolved in the past to meet some genuine requirement at that time in that environment and may have once satisfied a need very effectively, but the problem is stagnation while the technological and socio-economic environment have continued to move forward.

Another important trait is avoiding unwarranted change for its own sake, as the mirror opposite of static tradition or convention, but this time as the modern trend of "continuous disruptive change without strategy". This type of "burn it all down" or wrecking-ball approach to Governance omits that many long-term practices can still be effective and that change needs to be incremental, integrated and monitored; not only with institutional structures but also human behaviour, means, motivation and opportunity (often the true critical factors). Adapting, modifying, and repurposing established policies or existing processes can help preserve "change capital" for those changes that are genuinely novel or necessarily disruptive. It can also mitigate frictions with those invested in existing practices, such as their users, instigators, designers, and owners; instead bringing them onboard and engaging them with the repurposing and updating.

The third characteristic in a triangle of ideal traits with the other two, is to have a keen applied interest in human behaviour around the use (and misuse) of data or information. Traditional or conventional "Hard Governance" centres around the assumption that people only make the wrong decisions because they have the wrong information or not enough of it. Hence, the traditional view of Governance coalesces into hard compliance measures and management surveillance, which includes formal audits, regular in-depth reporting, restrictive checklists, with a focus on top-down, non-negotiable command and control. This approach was suited to traditional mass manufacturing of standardised products but is insufficient by itself for modern data services that are digital-first by design and characterised by near real-time changes.

Soft Governance works with the grain of human behaviour to achieve better results by enablement and empowerment, rather than by command and control alone – principles take precedent over prescription, thus allowing an organisation to leverage the deep insights and frontline experiences of their entire workforce. Shortcut thinking, lack of active engagement and wrong assumptions are some of the key targets for a Soft Governance approach, which still always requires the ultimate backstop of Hard Governance – but meaningfully targeted and monitored using a risk-based approach. Combining the two approaches can yield outsized and transformative results.

Finally, some supporting characteristics to boost the Big Three above include being able to transcend organisational hierarchies, stovepipes and functional siloes. It is crucial not to bury IGIF-MSDI or Data Governance within the data, digital or technology domains but to reach out, persuade, influence, and engage far wider afield – especially with customer-facing or revenue-generating areas. The mission is to demonstrate that Governance is not merely a cost centre to meet a required need at a minimum level, which is the traditional, outdated viewpoint, but is a key investment in an external marketable strength that can grow business opportunities. Governmental, private and industry users of digital information services are increasingly keen to partner only with trusted providers whose Governance they can have evidenced confidence in for the assured data they consume.

Governance is related, but ultimately distinct from Management

For IGIF-MSDI considerations, Governance and Management systems are symbiotic, but whilst being mutually interdependent, the two systems fulfil very different functions[6]. An effective Governance Framework will allow these two systems to work together to the benefit of the organisation's overall stakeholder community. The amount of time and effort devoted by an IGIF-MSDI Governance function to compliance and accountability can be significantly reduced if organisational objectives, ethics, and culture are sound.

As evidenced by published papers from numerous professional and academic institutions, the concepts behind the design of Governance and Management systems are areas of endless attention. The following distinctions between these two areas in Figure 19 and Figure 20 is the most concise and practical here. It is a common observation that Governance meetings can easily devolve into Management considerations, without a firm focus which can usually be provided by an effective and experienced Chairperson.

The key takeaway message is for an IGIF-MSDI Governance Board to avoid being distracted from strategic matters of Governance, leaving the operational management of projects and programmes to the Steering Group. Likewise, the tactical delivery of technological solutions should remain the preserve of the Working Group in response to cascaded requirements from the Steering Group.

6 Governance & Management Systems, White Paper WP1084, Mosaic Australia (Sept 2012).

Governance informs the forecast, planning and organisation (M1 to M2) stages of Management with Governance objectives, ethics (values), culture, Governance Framework, and accountability expectations (G1 to G5). Management then commands, directs, leads, coordinates and controls (M3 to M5) to ensure compliance, which is then reported back to the last Governance function (G6). The process then iterates according to the wider corporate cycle – usually either annually or quarterly.

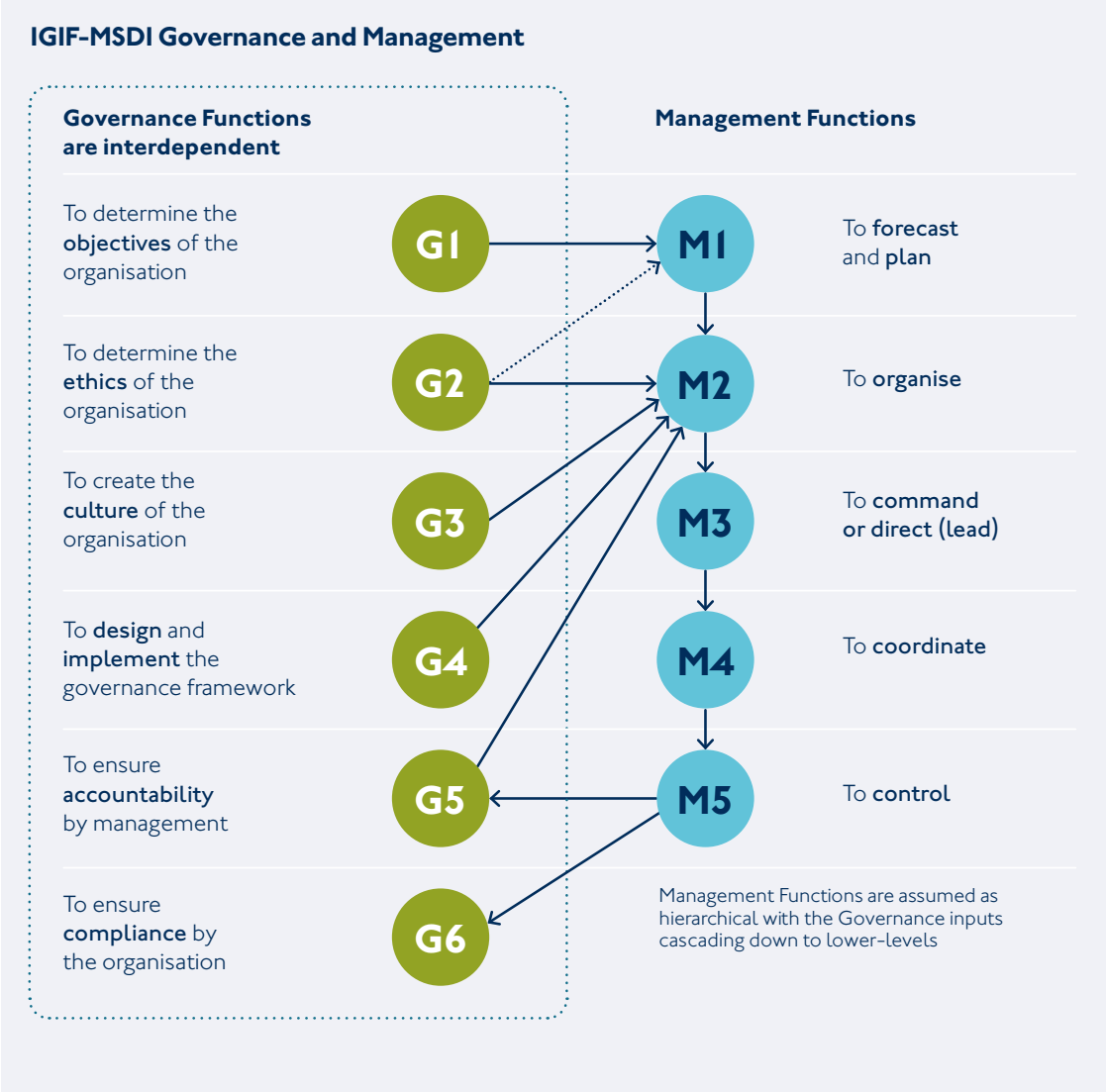


Figure 21: The functions of management by Henri Fayol in "Administration Industrielle et Generale" (1916) serves a similar historical role for the field of Management[7], as Adam Smith's "Wealth of Nations" (1776) does for Classical Economics. The connections between Governance and Management[8] are not linear when compared to the production of traditional products (such as paper charts). Governance as a Service (GaaS) is ideally suited for supporting Data and/or Information as a Service.

7 The Functions of Management, White Paper WP1094, Mosaic Australia (Mar 2019).
8 The Six Functions of Governance, White Paper WP1039, Mosaic Australia (Nov 2014).

UK Hydrographic Office