A review of the ICA model of stakeholders in a spatial data infrastructure (SDI)

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Abstract: The Commission on SDI & Standards (and its predecessors) of the International Cartographic Association (ICA) has developed formal models of a spatial data infrastructure (SDI), using the viewpoints of the Reference Model for Open Distributed Processing (RM-ODP) and the Unified Modeling Language (UML). The Commission described an SDI from the Enterprise Viewpoint (purpose, scope and policies for an SDI), Information Viewpoint (semantics of information and information processing in an SDI) and Computational Viewpoint (functional decomposition of the SDI into a set of services that interact through interfaces). The Enterprise Viewpoint model included six types of stakeholders in an SDI: Policy Maker, Producer, Provider, Broker, Value-added Reseller and End User. Subsequently, the Commission identified 39 sub-types of these stakeholders, though a better description of them might be as specializations, special cases, attributes, activities or roles.

We have identified and reviewed all the literature that has referenced the Commission's papers on the SDI models. Most use the Commission's papers for the definitions of an SDI and of the parts, processes and stakeholders in an SDI. In this paper, we discuss all those that have applied the ICA SDI stakeholder model, proposed improvements to the model and/or highlighted parts of the model that are not well understood. We also discuss some issues we identified when reviewing the models. Subsequently, we plan on proposing some revisions and expansions on this ICA model of the stakeholders in a spatial data infrastructure.

Keywords: spatial data infrastructure, SDI, stakeholder, ICA model

1. Overview of the ICA SDI models

A *spatial data infrastructure* (SDI) is an evolving concept about facilitating and coordinating the exchange and sharing of geospatial data and services between stakeholders from different levels in the geospatial data community (Hjelmager *et al* 2008). An SDI is more than just the technology of a distributed geographical information system (GIS): it is generally considered to be the collection of technologies, policies, institutional arrangements and stakeholders that facilitates the availability of, and access to, geospatial data and services. An SDI can range from having a rigid, well-defined framework, to one that is fluid and unconstrained [Nebert 2004; Cooper *et al* 2011].

The Commission on SDI & Standards (and its predecessors) of the International Cartographic Association (ICA) has developed formal models of an SDI, using three of the five viewpoints of the *Reference Model for Open Distributed Processing* (*RM-ODP*) [ISO 1998], and the *Unified Modeling Language* (*UML*) [ISO 2005] for the detailed modelling. The Commission described an SDI from the *Enterprise Viewpoint* (purpose, scope and policies for an SDI) and *Information Viewpoint* (semantics of information and information processing in an SDI) of RM ODP [Hjelmager *et al* 2008], and from the *Computational Viewpoint* (functional decomposition of the SDI into a set of services that interact through interfaces) [Cooper *et al* 2012]. The Enterprise Viewpoint model included SDI *stakeholders*, defined as:

> *An individual or group with an interest in the success of an SDI in delivering its intended results and maintaining the viability of its products. Stakeholders either affect the SDI or are affected by it* [Hjelmager *et al* 2008][1].

The ICA Commission did not investigate the *Engineering* and *Technology Viewpoints* of an SDI, because they are implementation-specific, and the Commission has aimed at providing technology-independent models for an SDI

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[1] Adapted from the glossary of the Interoperability Clearinghouse, which is no longer available online.

[Cooper *et al* 2012]. Others have looked at the Engineering and Technology Viewpoints, such as for the corporate SDI for a power company [Oliveira *et al* 2017; Torres *et al* 2017a; Torres *et al* 2017b]. Unsurprisingly, they also modelled this corporate SDI from the other three viewpoints [Oliveira *et al* 2016a; Oliveira *et al* 2016b].

The Commission identified six types of stakeholders [Hjelmager *et al* 2008]. Any one person, group, committee or organisation can play multiple stakeholder roles, which could be done simultaneously. A stakeholder in an SDI could also be an *actor* {Oliveira & Lisboa-Filho 2015]. A stakeholder could be active or passive in each of its roles, etc. The types of stakeholders are:

Policy maker: A stakeholder who sets the policy pursued by an SDI and all its stakeholders.

Producer: A stakeholder who produces SDI data or services.

Provider: A stakeholder who provides data or services to users through an SDI.

Broker: A stakeholder who brings users and providers together and assists in the negotiation of contracts between them. They are specialised publishers and can maintain metadata records on behalf of an owner of a product. Their functions include harvesting metadata from producers and providers, creating catalogues and providing services based on these catalogues.

Value-added reseller (VAR): A stakeholder who adds some new feature to an existing product or group of products, and then makes it available as a new product.

End user: A stakeholder who uses the SDI for its intended purpose (Hjelmager *et al* 2008).

In retrospect, the definition of the *Producer* should have included the production of metadata as well, and the differences between a *Broker* and a *VAR* should have been made more obvious.

Subsequently, the Commission assessed if these SDI models catered for user-generated content, or volunteered geographical information (VGI), and found the models are sufficiently robust to do so [Cooper *et al* 2011]. However, the Commission realised that the stakeholders needed to be described in more detail as *specializations, subtypes* or *special cases* of the general roles of the six types of SDI stakeholders. The Commission identified 39 subtypes, with several having further sub-subtypes, see figure below. For example, a *Producer* could have a subtype *Status*, which in turn could have the subtypes *Official Mapping Agency*, *Commercial Mapping Agency*, *Community Interest* or *Crowd Source* [Cooper *et al* 2011].

Collectively, the Commission's Enterprise, Information and Computational Viewpoints and the detailed stakeholders form what is known colloquially in the literature as the *ICA model* or *ICA's formal model* of an SDI [Box 2013; Oliveira *et al* 2016a; Torres *et al* 2017a]. This paper presents a review of all the literature that has referenced the ICA Commission's papers on the SDI models. Note that the ICA models are *descriptive* and are not meant to be *prescriptive*, and they are implementation-independent and hence somewhat abstract.

The 45 types and subtypes of stakeholders in an SDI, taken from Cooper et al [2011]
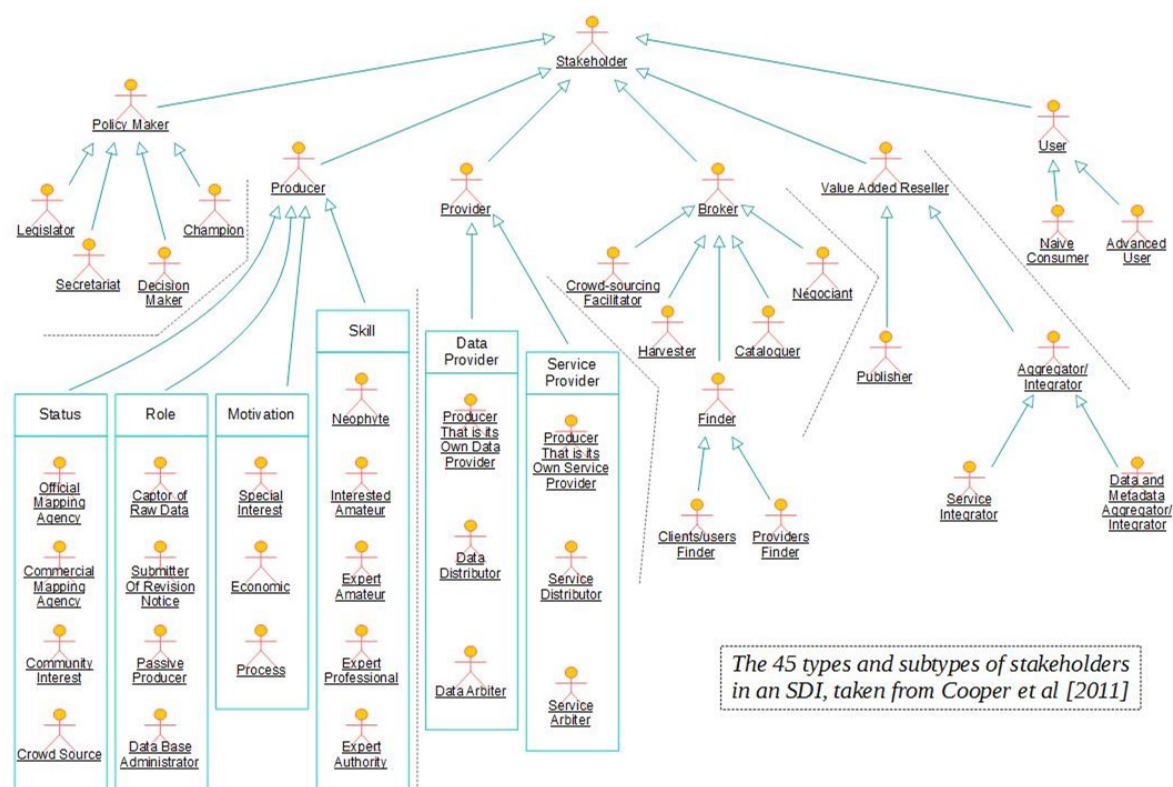
Most of the literature uses the Commission's papers for the definitions of an SDI and of the parts, processes and stakeholders in an SDI. Here, we discuss only all those that have applied the ICA SDI stakeholder models, proposed improvements to the models and/or highlighted parts of the models that are not well understood. We also discuss further issues the members of the Commission have identified when reviewing the models. Subsequently, we plan on proposing some revisions and expansions on this ICA model of the stakeholders in an SDI.

2. Suggestions from the literature

2.1 The SDI model of Bejar *et al* [2012]

Bejar *et al* [2012] extended the ICA model to cater for relationships amongst different SDIs and amongst the stakeholders participating in them. They used the term *actor* for the stakeholders and identified 12 *actor role types*. The authors probably had not seen the expanded ICA stakeholder model [Cooper *et al* 2011] by the time they submitted their paper. Oliveira & Lisboa-Filho [2015] also compared these actors of Bejar *et al* [2012] to the stakeholders in the ICA SDI model. These 12 actor role types [Bejar *et al* 2012] are presented here.

User: this is the same as the *User* in the ICA model.

Contributor: who contributes and/or withdraws assets (datasets or services) to or from the SDI and is hence a *Provider* in the ICA model. Note that the *Contributor* controls their assets explicitly.

Custodian: this is the same as the *Producer* in the ICA model.

Governing body: this is the same as the *Policy Maker* in the ICA model.

Operational body: this is the same as the *Secretariat*, a subtype of the *Policy Maker* in the ICA model.

Contact: who represents a community in their interactions with other SDIs, with some similarities with the *Broker* in the ICA model [Bejar *et al* 2012]. However, this actor's activities probably also overlap with those of other stakeholders, such as the *Decision Maker* and the *Champion*. Hence, it might be useful to add the *Contact* separately to the ICA model, perhaps as a subtype.

Educator: who is responsible for teaching and training to "cultivate the skills, technical competence, knowledge and best practices needed to maintain and use an SDI" [Bejar *et al* 2012]. An *Educator* should probably be added to the ICA model and similarly, perhaps a *Researcher* as well.

Promoter: this is the same as the *Champion* in the ICA model.

Funder: who provides direct and/or indirect funding for the SDI itself and for all the relevant stakeholders to function. A *Funder* should probably be added to the ICA model, though "the role of releasing resources for the SDI to

work" [Oliveira & Lisboa-Filho 2015] also exists in the *Secretariat*.

Member: this represents all communities involved with an SDI, including federations of communities. Effectively, this is the same as the *Stakeholder* in general in the ICA model, but Bejar *et al* [2012] found it useful to include the Member for their modelling.

Communication channel: this is not a person or a group but is the collection of technologies enabling communication between the stakeholders and the SDI, and presumably with one another. It is needed for their SDI models [Bejar *et al* 2012]. The ICA Commission defined a stakeholder explicitly as "an individual or group", and hence did not consider including technologies as stakeholders. The *communication channel* is probably similar to the *connectivity* class in the Enterprise Viewpoint of the ICA model.

SDI catalog: again, a collection of technologies, this time for obtaining metadata.

Bejar *et al* [2012] also included *artifact roles*, *enterprise objects*, *policies* and the *interactions and processes* in their SDI models, but these are not directly relevant to modelling stakeholders specifically in an SDI. There is a class for *Policies* in the Enterprise Viewpoint model. While the *enterprise object* does include *person*, *team* and *organization*, as stakeholders these are catered for by the *actor role types* discussed above. However, this does raise the question of how linkages between different stakeholders could be included in the ICA stakeholder model, though note that the ICA model allows one stakeholder to have many roles simultaneously.

2.2 The SDI governance model of Box [2013]

The ICA SDI stakeholder model does not cater for *oversight* explicitly, which is probably a role distinct from the others of the *Policy Maker*. The oversight role is to keep the *Legislator*, *Decision Maker* and *Secretariat* honest, accountable and responsive – while the *Champion* should really be too biased to have an oversight role as well! Such a stakeholder could be responsible for ensuring ethical behaviour, shared principles and adherence to codes of conduct, and for peer review, and monitoring and evaluation of the SDI and stakeholders. The stakeholder could be labelled as an *Ombud*, which is a clipped form of the word *ombudsman* to make it gender-neutral (used in South Africa, at least).

Adding the *Ombud* would ensure the *Policy Maker* covers all aspects of governance described by Box [2013]. He defined *SDI governance* as "an overarching and enabling decision-making and accountability framework comprising authority structures, roles, policies, processes, and mechanisms that enable collective decision-making, and collaborative action to achieve common goals" [Box 2013].

2.3 Improvements suggested by Oliveira *et al* [2015 *ff*]

Oliveira & Lisboa-Filho [2015] unified the stakeholders in the ICA SDI model [Hjelmager *et al* 2008; Cooper *et al* 2011] with the actors proposed by Bejar *et al* [2012]. They noted the following about the ICA SDI stakeholder model:

- There is no subtype of the *Producer* for services and no mention of a *Producer* removing, updating or maintaining data in the SDI.
- There is no explicit provision for updating or removing policies in the SDI, nor for liaising with other organisations.
- Some of the roles of the *Operational Body* [Bejar *et al* 2012] are missing, or were not mentioned explicitly, such as systems administration, technical support, quality assurance and managing the catalogue gateway (see Nebert [2004]).
- A *Contact* and an *Educator [*Bejar *et al* 2012] have not been included.

They then identified seven main actor roles for SDI participants or *Members* [Oliveira & Lisboa-Filho 2015]:

User: the same as the *User* in the ICA model.
Producer: the same as the *Producer*, but with the *Submitter of Revision Notice* and the *Data Base Administrator* moved to the *Operational Body*.
Provider: the same as the *Provider*.
Broker: the same as the *Broker*.
Value-Added Reseller: the same as the *VAR*.
Operational Body: essentially a combination of the *Secretariat*, *Data Base Administrator* and *Cataloguer*.
Governing Body: the same as the *Decision Maker* (Oliveira & Lisboa-Filho 2015].

2.4 Improvements suggested by Silva *et al* [2022]

Silva *et al* [2022] consider the ICA stakeholder model to lack a means for representing schematically the responsibilities of stakeholders, so they adapted the model to a Responsibility Assignment Matrix (RAM). They deleted the *VAR*, *Policy Maker* and *Broker* stakeholders, assigning their functions to other stakeholders, and added a *Manager* stakeholder. They also added further functions [Silva *et al* 2022]. These changes are possibly due to misunderstanding the ICA stakeholder model, as discussed below in Section 3 on some issues with the stakeholders.

2.5 Improvements suggested by Tamene *et al* [2021]

While Tamene *et al* [2021] did not comment on the Commission's stakeholder model, they did modify the Commission's model of the eight SDI processes [Cooper et al 2013]. Specifically, they referred to the *Creation* process as *Establishment* and split *Processing* into *Data Curation & Manipulation*, and *Data Ingestion & Indexing*.

2.6 Improvements suggested by Sinvula *et al* [2017]

A research team that included some members of the ICA Commission applied the ICA stakeholder typology to the SDIs of Ghana, Namibia and South Africa [Sinvula *et al* 2012; Owusu-Banahene *et al* 2013; Sinvula *et al* 2013; Sinvula *et al* 2017]. While they found it useful for comparing stakeholders, they made several suggestions for improving the typology [Sinvula *et al* 2017].

- The key issue is how the original six types of stakeholders are expanded upon, because the subtypes are not necessarily subordinate to, or special kinds of, the more general type of stakeholder. The subtype of a stakeholder could be a descriptive attribute, such as the status, motivation, legal mandate or skill of the stakeholder. Hence, the typology could be improved by including both attributes and subtypes and renaming and restructuring the original subtypes appropriately.
- The current ICA stakeholder model does not characterise the maturity of the stakeholder or organisation.
- *Producer* should be expanded to include public-sector producers that are not an *Official Mapping Agency*, or to distinguish between local, provincial and national government Producers. A single Producer may also be represented by multiple individuals.
- Further roles for a *Producer* could be a coordinator, integrator and producer of derived datasets. However, an integrator is catered for as the *Aggregator/Integrator* form of *VAR* and a producer of derived datasets is probably a *Publisher* form of a *VAR*. The confusion probably arises because any person or organisation can have multiple stakeholder roles, so a mapping agency can be both a *Producer* (being a part of the organisation at the start of the value chain for that organisation) and a *VAR* (at the end of that value chain).
- A *coordinator* was described as playing "a coordinating role by arranging that street centrelines from local, provincial and national government are integrated into a single national base dataset" [Sinvula *et al* 2017], which is the *Secretariat* form of the *Policy Maker*. For the South African SDI [South Africa 2003], the *Secretariat* has delegated such a function to *Base Data Set Coordinators*, so they are agents for the *Secretariat* [South Africa 2015]. *Agency*, *contracting* or *representation* roles or functions are not necessarily separate stakeholders in the model.
- Having only two types of End User is limited, as was noted in Cooper *et al* [2011]. Further refinement could be based on how data are used (eg: view, manipulate or transform), the purpose for using the data (eg: mapping, visualization or analysis) and/or on whether the *End User* is an organisation or an individual.
- A *Decision Maker* is not necessarily a *Policy Maker* [Sinvula *et al* 2017], but this is probably a misunderstanding of a *Policy Maker*, so that definition needs improvement.

The anonymous referees who reviewed Sinvula *et al* [2017] also made suggestions on improving the stakeholder model, such as including SDI-financiers

(donors), SDI-researchers, SDI-educators and relevant non-government organisations (NGOs). They also asked about dealing with shifts in the roles and characteristics of SDI stakeholders over time.

2.7 Adapting model for smart cities Rabelo *et al* [2017]

Rabelo *et al* [2017] adapted the ICA model for smart city development and describe the use case of a traffic congestion prevention system. The system has to provide real-time data, so they included a new physical actor, called *Sensor*, in the model with the actors already proposed by Cooper *et al* [2011]. *Sensor* is responsible for providing real-time data and has two specializations: *Citizen Sensor* and *Physical Sensor*. Rabelo *et al* [2017] state that the formal SDI ICA model proposed by Hjelmager *et al* [2008] and its extension developed by Cooper *et al* [2011] are sufficiently robust for the development of a smart city architecture. However, due to the specificity and complexity of the domain in the case of the use they analysed, it was necessary to extend the model with two new specializations.

In practice, the *Sensors* are *Producers*, though Rabelo *et al* [2017] consider it necessary to distinguish real-time data collection from those with less stringent time or latency constraints, such as batch, *ad hoc* or collection scheduled periodically, for instance annual updates. A subtype for collection frequency could be added to *Producer*, with sub-subtypes as required. It should not be necessary to differentiate between human and machine stakeholders.

2.8 Possible attributes, adapted from Cooper [2016]

There are attributes that could be common across all six types of stakeholders in an SDI, such as their motivation for contributing to, or using, any particular SDI. Other attributes could relate to the stakeholder or to the contribution, such as data, products, services, software, metadata, policies, leadership, resources or technologies. Cooper [2016] identified the following attributes as being useful for classifying user-generated content, but they could also be attributes of stakeholders in an SDI:

- The *authority* or *ability* of the stakeholder to make the contribution and if they are *liable* for the contribution and any consequences thereof.
- The *ownership* or *authorship* of the contribution and issues concerning *intellectual property*.
- The nature of *funding* for the contribution, which could be benevolent, or to promote a vested interest or agenda.
- The *ethics* related to the contribution, including invasion of privacy, arbitrary restrictions, constraining other resources or mischief.
- The *personality* of the contribution, which could be impersonal, subjective, pseudo-objective or objective.
- The *nature*, *size*, *intelligibility*, *quality*, *value*, *relevance*, *utility* or *reliability* of the contribution.
- The documentation of the contribution, that is, the *metadata* [Cooper 2016].

2.9 Suggestions from the ICA Commission in Dresden

The ICA Commission on SDI & Standards met in Dresden, Germany, in August 2013, just before the 26th International Cartographic Conference. The Commission realized that 'subtype' was not necessarily a relevant label for refining the types of stakeholders. However, labels such as 'specialization', 'activity', 'perspective', 'dimension', 'viewpoint' or 'role' also do not by themselves and individually describe all the refinements adequately. Hence, it might be useful to use modelling terms such as *sub-class*, or *parent* and *child* class.

It should be possible to use the ICA models of an SDI without being experts on the model itself, or on UML or RM ODP. Similarly, it should not be necessary to have to explain the SDI concepts and issues, so all the concepts should be defined and illustrated properly. It also raises the question of if the models are too difficult or too abstract to use in practice – though they have been used successfully by Oliveira *et al* [2016a], Oliveira *et al* [2016b], Oliveira *et al* [2017], Torres *et al* [2017a], Torres *et al* [2017b] and Silva *et al* [2022], for example.

The Commission also observed that the *Secretariat* for an SDI is not necessarily organised optimally nor housed in the appropriate organisation, as it depends on politics, funding, etc. Then, what is the significance of a particular sub-type or specialization not existing within any particular SDI?

2.10 Improvements suggested by Coetzee *et al* [2017]

Subsequently, the ICA Commission examined academic SDIs for research and education [Coetzee *et al* 2017]. The Commission applied the high-level model with six stakeholders [Hjelmager *et al* 2008] to seven universities and research organisations around the world and suggested further additions to the ICA SDI stakeholder model, without defining these roles [Coetzee *et al* 2017].

- *Funder*, *Organisation* and *External Legislator* should be added as roles of the *Policy Maker*.
- *Researcher User*, *Educator User*, *Student User* and *External User* should be added as roles of the *End User*. This emphasizes that users can be differentiated based on their relationships to the SDI.
- A *Researcher* should be added as a role of a *VAR*.
- *Researcher*, *External Producer*, *Educator* and *Student* should be added as roles of the *Producer*. Then, *Class Participant* and *Research Student* should be added as roles of the *Student*; and *Class Lecturer* and *Research Supervisor* should be added as roles of the *Educator*.
- Adding to the *Producer* an attribute specifying whether or not they produce *data*, and another for *services*.
- Also adding to the *Provider* an attribute specifying whether they provide *data*, and another for *services*, and a third attribute specifying if the *Provider* is from a different SDI.

In practice for UML modelling, these *Researcher* roles will need to be separated from one another by adding a

prefix or suffix to the name of the role. The Commission also suggested adding attributes to two of the stakeholders:

3. Issues with the stakeholders

3.1 Confusion between types of stakeholders

All the subtypes or specializations of the SDI stakeholder were given definitions in Cooper *et al* [2011], though later it became clear that some of the types and subtypes were confused with one another. In particular, the *Producer* was sometimes confused with the *Provider*, particularly because many Producers are also Providers, and the *Broker* with the *Value-added reseller (VAR)*, because Brokers are sometimes also VARs. Perhaps the least understood subtype is the *Négociant*, the classic or nominate form of the Broker (bringing together Providers and End Users), because it might not be clear why it is needed. Further, these definitions probably mixed-up roles and actors and included, or presumed, the business models of actors. For example, the business model of an agent (selling a service) is not that of a stakeholder in the public sector whose role the agent takes on by agreement.

Care must be taken that the stakeholder model does not become too complex, such as by introducing stakeholders, subtypes or roles that are too specific for general application. Each needs to have a functionality in an SDI that is unique and well defined. Further, the stakeholders in an SDI should not be conflated with the natural and legal persons who act as the stakeholders, nor with their business models.

3.2 Negative SDI stakeholders

SDIs do not always succeed: Makanga & Smit [2008] found that there were two African countries with active SDIs in 2003 and three in 2008, but the two from 2003 were not operating by 2008. An SDI can also stumble along as a zombie by consuming resources without really delivering anything of value, just unread reports, duplicated spending, scope creep, unused metadata, poor and limited data, etc [Harvey *et al* 2015].

The ICA model assumed that all the stakeholders had positive relationships with the SDI. As stated by others, "The actors are individuals with an interest in the success of the SDI, and they may use it or contribute to it" [Oliveira *et al* 2017]. This is also implied by the definition of *End User*: "A stakeholder who uses the SDI for *its intended purpose* [Hjelmager *et al* 2008].

Unfortunately, it became clear that not all stakeholders have benevolent relationships with SDIs, whether the stakeholders be malevolent, or just too idle or incompetent to help the SDI succeed. In addition to "normal" errors and bias, a stakeholder can prevent an SDI from succeeding, if not deliberately helping it fail, such as by restricting the use of data (eg: for alleged security reasons); ignoring the requirements of end users; having a faulty business model, particularly without adequate and sustained funding; not cooperating; or steering the SDI inappropriately towards promoting any particular political, religious or social agenda [Cooper 2016; Coleman *et al* 2009].

Negative stakeholders could be catered for by having a type of multiplier that could be positive, zero or negative that gets applied to the competence or contribution of a stakeholder. This would also allow the most positive stakeholders to be highlighted.

4. Further improvements from the Commission

Subsequently, the members of the ICA Commission on SDI & Standards have identified further issues, some of which draw on the study by EuroSDR and OGC [EuroSDR 2020]. These matters are wide ranging and are not restricted to understanding stakeholders in an SDI, for example big data (though geospatial data were one of the first forms of big data, before the term even existed); dealing with legal and social issues, including ethics, privacy, liability and what are authoritative data (though these are tasks for stakeholders); or technologies such as the Internet of Things, cloud computing, data cubes, semantic web, linked open data, ontologies, 3D/4D data, and XaaS (X as a service). We have also considered the future of the concept of an SDI and if it will be replaced, such as by a spatial information infrastructure (SII), spatial knowledge infrastructure (SKI) or even a spatial wisdom infrastructure (SWI). Whatever the future geospatial ecosystem might be, there will be a need for something to bring together the geospatial data, services, stakeholders, technologies, policies and institutional arrangements, as envisaged by Hjelmager *et al* [2008]. Thus, the ICA Commission's model of stakeholders in the SDI "replacement" should remain sufficiently robust to cater for all the issues. The model is also independent of the applications of the SDI.

Artificial intelligence can introduce automated or virtual stakeholders, though it should not be necessary to treat these differently from people or organisations in the SDI stakeholder model.

5. Conclusions

We have reviewed here all the literature that has applied the ICA SDI stakeholder model, proposed improvements to the model and/or highlighted parts of the model that are not well understood. We have also discussed some issues we identified when reviewing the models. A preliminary version of this paper was presented at the 29th International Cartographic Conference (ICC 2019) in Tokyo, Japan, on 18 July 2019 [Cooper *et al* 2019].

6. Acknowledgements

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