Seamless SDI Design by Using UML Modelling

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Abstract

The integration of marine and land based spatial information will support sustainable management and development of the coastal zone. Therefore, the development of a seamless platform covering the land and marine environments would facilitate more efficient and effective decision-making capabilities for any jurisdiction with land-marine interface. This paper discusses the potential for developing a seamless platform covering the land, marine and coastal environments as part of the National Spatial Data Infrastructure (SDI) enabling a more integrated and holistic approach to management of the land-marine interface. It addresses the feasibility of seamless platform towards spatially enabled society and government. Further, it provides an insight to the design and development of the Seamless SDI model by introducing Seamless SDI conceptual model. The Seamless SDI class and its inherited characteristics and properties will be discussed. In addition to the conceptual phase, the development of a Seamless SDI model also consists of two more stages: design phase and implementation phase. The Use Case Diagram and Class Diagram of the Enterprise Viewpoint will be developed. Finally, it highlights the importance of the creation of appropriate Seamless SDI governance structures that are both understood and accepted. This would help to develop an extended framework to support a spatially enabled jurisdiction covering the land-marine interface. Ideally this extended framework would result in harmonised and universal access, sharing and integration of coastal, marine and terrestrial spatial datasets across regions and disciplines.

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1. INTRODUCTION

The integration of land and marine base information is an increasing problem in many countries. Indeed, many development plans have failed due to the lack of necessary integration of information. This especially applies to archipelagos where seawater is the “bridge” connecting islands (Vaez et al. 2009) While most of the countries are aware the problem of disconnected land and marine information, few have committed to resolving the problem (Murray 2007). This is partly due to complexity as it requires two or more organizations and users to identify and address the key issues.

Historically land, marine and coastal Spatial Data Infrastructure (SDI) has operated in isolation to one another. The coastal zone includes both contexts and administrative voids and overlap between local, regional, state, and national management bodies are common (Strain et al, 2006, Benett et al, 2010). There is a need to develop a Seamless SDI that can include data from the land, coastal and marine environments which will improve access and sharing of data between these environments. This leads to a more integrated and holistic approach to management (Vaez et al, 2007). With this in mind, the importance of understanding the link between land and marine environments (they cannot be treated in isolation) and the need for cooperation between nations as maritime actions transcend national boundaries is a major issue.

In order to have such an environment, there is also a need to identify technical, institutional and policy issues hindering the implementation of the Seamless SDI model. Successfully addressing the issues associated with building a Seamless SDI results in more efficient implementation of initiatives such as coastal flood visualisation, disaster management and response, and/or Integrated Coastal Zone Management (ICZM) (Vaez et al, 2008; Vaez et al, 2009).

With this in mind this paper aims to address these issues identified in Vaez et al. (2007; 2008; 2009) by presenting the design and development of a Seamless SDI model. First, it justifies the need to design the seamless SDI platform by describing the role of the seamless platform towards spatial enabled society and government. Second, it proposes the conceptual model of a Seamless SDI by using Hierarchical Spatial Reasoning and the Seamless SDI class and its inherited characteristics and properties as discussed. Third, the Use Case Diagram and Class Diagram of Seamless SDI are designed. These diagrams describe the Seamless SDI systematically and its context, users, providers,
services and so on, necessary to establish them. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics. Finally, Seamless SDI guidelines as a necessary step by step approach to create a Seamless SDI for any jurisdiction with a marine environment is covered. It provides necessary information for practitioners in order to deal with the complexity of creating a Seamless SDI. The guidelines can be utilised as a part of the tool or as an individual document that helps identify potential barriers and possible enablers.

The development of a Seamless SDI model and implementation guidelines has been built on the investigation of real life experiences, discussion with practitioners and current theory and practice in SDI development throughout the world.

2. SEAMLESS PLATFORM TOWARDS SPATIAL ENABLEMENT

The integration of marine and land based spatial information will support spatially enabled society. Spatial enablement can deliver information integration and minimizes the need for redesigning legal, institutional and administrative frameworks. Spatial enablement is an evolving concept (Holland, 2009), however, it is generally considered the establishment of an enabling infrastructure to facilitate use of place or location to organize information about activities of people and businesses, and about government actions, decisions and polices (Williamson et al, 2006). In the context of coastal zone management, spatial enablement offers the opportunity to integrate land and marine information for a diverse set of stakeholders. Seamless SDI creates a spatially enabled land-marine interface and bridges the gap between the marine and terrestrial environments to more effectively meet sustainable development goals.

At the international level a number of global and regional initiatives aim to improve the management of the marine and land interface. These include the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA), Integrated Coastal Zone Management (ICZM) and the 3rd United Nations Convention on the Law of the Sea (UNCLOS). Whilst these initiatives do not explicitly mention spatial enablement, they are important steps towards a shared understanding of the need to improve coastal zone management. These initiatives are mimicking the well-developed land use management frameworks from urban areas. However, in the coastal zone, the diversity of interests, some terrestrial and some marine, compounds the issues (Vaez et al, 2009).

International land and marine administration communities are naturally more inclined to highlight the importance of the spatial information and its use in coastal zone management. In Malaysia in 2004 The Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) conducted a conference on
'Administering the Marine Environment – The Spatial Dimension.’ The meeting was endorsed by the United Nations (UN) and highlighted the importance of coastal information infrastructures. Accordingly a resolution was passed at the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) in Bangkok in 2006. The resolution defined the spatial dimension of the marine cadastre and recommended that a marine cadastre be added to existing national information infrastructures to ensure a continuum across the coastal zone (UNRCC-AP, 2006). Additionally, the International Hydrographic Organization (IHO) is developing strategies for integrating land and marine SDIs. Its seminar on “The Role of Hydrographic Services with regard to Geospatial Data and Planning Infrastructure” formally recognized an option for Hydrographic Offices to become national SDI partners (Maratos, 2006).

In Australia the need was recognized by most recently by the Australian Parliament’s Standing Committee on Climate Change, Water, Environment and the Arts. Recommendation 11 of their 2009 Report on ‘Managing our coastal zone in a change climate’ calls for the establishment of a ‘National Coastal Zone Database to improve access to and consistency of information relevant to coastal adaptation.’ The significance of an integrated coastal information infrastructure for managing the coastal zone is now patently clear at the highest levels of government. The report ‘National Coastal Zone Database’ will be an important tool in the management of climate change. However, the report only focuses on the provision of elevation and vulnerability data. Also in Australia, research into the coastal zone is a National Research Priority as work in the area is seen as supporting environmental sustainability and also responds to climate change and variability.

3. SEAMLESS SDI CONCEPTUAL MODEL

The SDI concept has until recently only been used to describe land related spatial data and information. While these concepts might be applicable and desirable to improve marine and coastal administration, the nature, definition and components need to be examined and tested for their ability to describe marine and coastal spatial data and information. An SDI is a platform that facilitates the interaction between people and data by providing required access channels, policies and standards (Rajabifard and Williamson, 2001; Nebert, 2004; Masser, 2006) as illustrated in Figure 1.
In designing the Seamless SDI model many of the characteristics and components of SDI in general will be used but the attributes of these components are different from the existing model. Overall, a Seamless SDI should have four characteristics which are 1) Seamless 2) Multi-purpose 3) Multi-users 4) Interoperable. Seamless SDI needs seamless spatial data from land, marine and coastal environments which is a continuous spatial dataset that traverses the coastal zone. It should be possible to combine seamlessly spatial data from different sources and share it between many users and applications. The seamless platform would facilitate greater access to more interoperable spatial data and information across the land-marine interface enabling a more integrated and holistic approach to management of the coastal zone (Vaez et al 2007; 2009).

However, in order to design and implement the Seamless SDI, a conceptual model of the Seamless SDI is required. The first step for implementing any model including the Seamless SDI is developing a conceptual modelling. Conceptualisation phase comes before implementation and design phase. A conceptual model can be defined as a model which is made of concepts and their relationships.

In order to develop a conceptual model, multiple classes of SDI (land, costal and marine), which have some properties in common, composes an aggregate class. The Seamless SDI model can be postulated as one aggregate class SDI with attributes and operations/methods designated to this class.

Aggregation is a kind of association that specifies a whole/part relationship between the aggregate (whole) and component part. A part classifier can belong
to more than one aggregate classifier and it can exist independently of the aggregate (Fowler 2004). Therefore, the land, marine and coastal SDI can exit independently of the Seamless SDI. Figure 2 illustrates the aggregation relationship where Seamless SDI class plays the role of a container and land, coastal and marine SDIs classes at the bottom play the role of contained entities.

Figure 2: Seamless SDI model - aggregation relationship with Seamless SDI as an aggregate class and land, coastal and marine SDIs as component classes

Land, coastal, marine SDI will be combined to form a Seamless SDI. The Seamless SDI does not own component parts nor have a parent-child relationship (when parent deleted all its child’s are being deleted as a result) between the two. Land, marine and coastal SDIs refers to the parts of this composite class while it keeps its own functionality. Each component has specific properties and characteristics which are not shared by the Seamless SDI.

4. SEAMLESS SDI DESIGN

In addition to the conceptual phase, the development of a Seamless SDI model also consists of two more stages: design phase and implementation phase. The design stage has utilised Unified Modelling Language (UML) in order to model the architecture, components and activities within the system. It can be used to describe Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish them.
The Reference Model of Open Distributed Processing (RM-ODP) (ISO/IEC 10746 1995) has been used. The choice of using RM-ODP concepts to model SDIs was motivated by RM-ODP being an international standard already, and that it is a good base to facilitate understanding of SDIs. RM-ODP allows describing complex distributed systems giving a framework of different levels of abstraction (Delgado 2004). It defines a framework comprising five viewpoints: Enterprise, Information, Computation, Engineering and Technology. However, it is only the first viewpoint that has been taken into consideration which describes the purpose, scope and policies for SDI.

UML consists of a number of diagrams for different aspects of modelling. The most useful, standard UML diagrams are Use Case Diagram, Class Diagram, Sequence Diagram, State Chart Diagram, Activity Diagram, Component Diagram, and Deployment Diagram (Eriksson and Penker, 2000) which are useful in different model development phases. For instance, a Use Case Diagram provides a way of describing the external view of the system and its interactions with the outside world. The Class Diagram describes the types of objects in the system and various kinds of static relationships that exist between them. In this research, the Use Case Diagram and Class Diagram which have been developed for Seamless SDI design are presenting in the next sections.

4.1. Seamless SDI Use Case Diagram

In many design processes, the Use Case Diagram is the first that designers will work with when starting a project. More formally, a use case is made up of a set of scenarios. Each scenario is a sequence of steps that encompasses an interaction between a user and a system. The use case brings scenarios together that accomplish a specific goal of the user.

A use case diagram of Enterprise Viewpoint for Seamless SDI shows the stakeholders and their role within Seamless SDI. Stakeholder is 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). As can be seen in the Use Case Diagram (Figure 3), each stakeholder within a Seamless SDI can be part of different use cases. For example, the same stakeholder could determine the scope of an Seamless SDI, use services from Seamless SDI (such as searching for, obtaining, and using data), and build the infrastructure used by the Seamless SDI (whether it be the networks, computers, software or whatever else). Each one of these interactions then comprises a separate use case.
Interactions with the scope and policies of a SDI can be separated into the various stakeholders that either define the scope or implement the scope. The same applies for the policy, thereby resulting in those that define and/or implement policy. The reason for this division of labour is that the groups responsible for developing and for maintaining the two parts of the use case have different interests and points of view from one other, even though on a high level their general interest should be mutual. The stakeholder actor in Figure 3 can be
sub-divided into six individual actors which are provider, producer, policy maker, user, value added reseller and broker, all having a role to play in the use cases. Use Case Diagram also helps the identification of required objects and relationships between them in a Class Diagram. The Class Diagram describes the types of objects in the system and the static relationships between the objects. The next section discusses the objects and relationships of Seamless SDI.

4.2. Seamless SDI Class Diagram

A Class Diagram is a type of static structure diagram that describes the structure of a system by showing the system’s classes, their attributes, and the relationships between the classes. A Class Diagram partitions the system into areas of responsibility (classes), and shows “associations” (dependencies) between them. The purpose of a Class Diagram is to depict the classes within a model. In an object oriented application, classes have attributes (member variables), operations (member functions) and relationships with other classes (Martin 2008).

The possible interaction between classes of objects are defined by links (Larman, 1997). The fundamental element of the Class Diagram is an icon that represents a class. In order to see how the different parts of the use cases fit together, an initial view Class Diagram for Seamless SDI have been developed, as shown in Figure 4. This diagram depicts different system’s classes along with the relationships between these classes with SDI model. For an instance, it illustrates IHO, ISO, ICA, OGC are all systems’ classes which develops SDI standards classes. However this is not fully developed diagram. In the case of fully developed diagrams, there are problem of dealing with a large number of classes with a large number of associations. In a fully developed class diagram, SDI components as illustrated in Figure 1. will be presented as Seamless SDI classes. It depicts the land, marine and coastal data, metadata, services and necessary standards as well as the association between these classes.

The core components of Seamless SDI can be viewed as policies, services, standards, metadata and data. These components can contain people as well as systems. Different categories can be formed based on the nature of their interactions within the Seamless SDI framework. For example, consider policies, standards and services, by their nature, they are very dynamic due to the rapidity with which technology develops and the needs change for mediation of rights, restrictions and responsibilities between people and data.

This suggests an integrated SDI cannot be composed of spatial data, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks. This in turn reflects the
dynamics of the whole SDI concept. Anyone wishing to access datasets must go through the technological components. These components need to set up appropriately to ensure interoperability.

Figure 4: Class Diagram of Seamless SDI

Given the complexity of Seamless SDI with inter-related and interconnected technical and institutional elements and the multiplicity of stakeholders involved, it is clear that governance is an important aspect of the institutional framework necessary to support decision making about all aspects of this Seamless SDI. It is necessary to go beyond establishing the model for SDI coordination and give top priority to the creation of appropriate SDI governance structures that are both understood and accepted.
5. SEAMLESS SDI GOVERNANCE MODEL

Over recent years, governance has gained an important role in SDI literature with calls to develop appropriate governance arrangements to address contemporary SDI implementation challenges (Kok & van Loenen, 2005; Masser, 2005; Masser et al, 2007; Box and Rajabifard, 2009). Similarly in practice, the need for improved governance has been recognised (FGDC, 2005; Kelly, 2007; Finney, 2007).

Given the typically large number and diversity of SDI stakeholders linked through multiple overlapping and interacting networks and the need to facilitate the rapidly evolving and increasingly collaborative approaches to SDI implementation, governance represents a significant challenge (Box & Rajabifard 2009). In addition, the adoption of Service Oriented Architecture (SOA) approaches to building the SDI which necessitates collaboration between the owners, developers, operators, and users of the service across departmental and organisational boundaries brings a whole new set of governance challenges.

Many countries are recognising more inclusive models of SDI governance to meet the requirements of a multi-level multi-stakeholder SDI. Therefore, it seems necessary to go beyond establishing the machinery for SDI coordination and prioritise the creation of appropriate SDI governance structures. Obviously, it will often not be possible to bring all stakeholders together for decision-making purposes, and structures must be devised for keeping all informed and providing an opportunity to have their opinions heard. The simplest solution is to create hierarchical structures at national, state and local levels.

Masser et al. (2007) note that hierarchical governance structures are required to enable the participation of national and local governments and the private sector addressing decision-making in the context of multi-level SDI implementation. Hierarchical structures are typically perceived as operating “top-down” with authority flowing from higher to lower levels and they refer the main to government initiated activities. However, SDIs are typically built at local levels from the “bottom-up” (Box & Rajabifard 2009). They contrast with “bottom-up” approaches, which occur predominantly at the local level and which guide the development of application-specific and enterprise-wide activity. At this level, the hard fabric of the infrastructure is being built by a networked community through the incremental development of services, by the deployment of applications, and through the adoption and development of standards.

In the case of Australia, experience gained in developing a Marine SDI has led to a proposal for a bottom-up governance framework. The framework is premised on the development of a SDI using an SOA approach, and is based around open source community governance models. The main components in the bottom-up
governance framework are: a community-based standards management system that would link to national and international standards efforts; a system for managing the operation of the infrastructure; and methodologies, instruments and processes that would create a motivated, open, collaborative development environment (Finney, 2007).

As described by Box & Rajabifard (2009), the need for clearly defined leadership, a sustained formal mandate including a policy framework, and the neutrality and community-oriented action of organisations playing key governance roles are all critical requirements for SDI governance.

Therefore, it is recommended that a high-level policy framework to provide sustained formal mandate and mechanism for collaboration between individual agencies in land and marine environments should be established. Aligned with that, there is a need for a lead agency to be identified and provided with a clear mandate to lead, a role that must be exercised with neutrality as well as an independent chair for the lead agency.

6. SEAMLESS SDI GUIDELINES

Having discussed the conceptual and design phases, the next step would be the implementation phase of the Seamless SDI model. In section 2 a conceptual model of the Seamless SDI has been developed. The design stage has utilised UML in order to develop Use Case Diagram and Class Diagram for Enterprise Viewpoint of for Seamless SDI. These diagrams have been used to describe Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish it.

The implementation phase takes the requirements and design phase products and implements them using appropriate tools. The model proposed in the design phase is developed during the implementation phase. In this regard, guidelines facilitate the development process.

The development of guidelines is highly dependent on the needs and objectives of the respective jurisdictions and the context of the respective SDIs. Each SDI has its own considerations and guidelines. In the case of Seamless SDI, the guidelines are specifically focused on facilitating the integration of land and marine spatial datasets. The guidelines can be utilised by practitioners to learn the issues and problems expected and possible solutions.
Identifying key stakeholders

Developing National or Regional initiatives/legislation

Capacity building

Identifying fundamental datasets

Capturing digital data

Creating metadata and make metadata searchable

Finding data custodianship

Developing the technical architecture

Making data available

Monitoring and reporting

Figure 5: Seamless SDI guidelines components
Therefore, the Seamless SDI guidelines is a document that details the preliminary Seamless SDI framework for any jurisdiction with a marine environment which might support and participate in the Seamless SDI incorporating necessary step-by-step approaches to create a Seamless SDI. It provides necessary information for practitioners in order to deal with the complexity of creating a Seamless SDI. It also discusses potential barriers and proposes available technical solutions and non-technical enablers (Vaez, 2010). It is not definitive in its nature, preferring instead to provide guidance on how best to achieve this through practical advice, simple step-by-step processes.

The development of a Seamless SDI implementation guidelines have been built on the investigation of real life experiences, discussion with practitioners and current theory and practice in regards to SDI developments throughout the world. Figure 5 above illustrates the incorporated components into the Seamless SDI guidelines.

The document presented here seeks to support Seamless SDI guidelines. However, SDI coordinators may develop and expand the components and items of beyond these guidelines.

7. CONCLUSION

SDI model that seamlessly covers both land and marine environments can be used by jurisdictions to create an enabling platform for the use and delivery of spatial information and services. This development aims to aid in meeting the initial needs of stakeholders in the coastal zone. It is particularly in line with the sustainable development (economic, environmental and social) goals of the region through the development of a seamless enabling platform to provide more efficient and effective decision-making capabilities across both the marine environment and land-marine interface.

In order to design and implement a Seamless SDI, we need a conceptual model of a Seamless SDI. Based on Hierarchical Spatial Reasoning method, the Seamless SDI model can be proposed as one abstract class SDI at the higher level (parent level) with attributes and operations/methods designated to this class. The Use Case Diagram and Class Diagram have been developed for the Seamless SDI design. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics.

Given the complexity of the Seamless SDI with inter-related and interconnected technical and institutional elements and the multiplicity of stakeholders involved, it is clear that governance is an important aspect of the institutional framework necessary to support decision making about all aspects of this Seamless SDI. It
has been proposed that appropriate governance models could assist SDI development.

Furthermore, in implementing the Seamless SDI model for any jurisdiction, guidelines consisting of ten components, have been outlined. These items were:

- Identifying key stakeholders within land and marine environment;
- Developing national or regional legislation/policy;
- Capacity building;
- Identifying fundamental datasets in land and marine environments;
- Capturing digital data;
- Creating metadata and making them searchable;
- Developing the technical architecture;
- Making data available; and
- Monitoring and reporting.

The Seamless SDI guidelines highlight the key considerations for effective land and marine spatial data integration.

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