The Online What if? Planning Support System

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Abstract The chapter introduces the Online What if? (OWI) GIS-based planning support system, which is being made available through the Australian Urban Research Infrastructure Network (AURIN). AURIN has been established to provide an advanced information infrastructure to support discipline-specific and multi-disciplinary research and promote sustainable urban development in Australia. OWI is an open source online version of the widely used desktop What if? planning support system developed by Klosterman (1999). OWI enables a range of end users to create and explore what if? land use change scenarios. This chapter discusses OWI in the context of a demonstrator case study in Hervey Bay,

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Queensland, and introduces future applications of this collaborative planning tool to support the sustainable planning of cities in Australia.

1 Introduction

Dramatic advances in the integration of eResearch infrastructure (also known as cyberinfrastructure) and geographic information systems (GIS) promise to fundamentally improve public sector planning and policy making in an increasingly complex and urbanised world. They will do this by providing understandable and easy to use on-line tools that will allow specialist users (planners, public officials, institutional stakeholders, and researchers), as well as private citizens to quickly and easily evaluate the potential effect of alternative public policies on the sustainable future growth of cities and regions. In particular, the migration of specialist tools into the Web environment reduces the obstacles faced by potential users and thus reduces the threshold of access in terms of cost (hardware, software and data licenses), and enables collaborative analysis.

The paper describes the development and applications of the online What if? planning support system (OWI) that is being developed as a component of the Australian Urban Research Infrastructure Network (AURIN—www.aurin.org.au) project. The core component of AURIN is a rich online eResearch Infrastructure platform that is being developed to provide urban researchers, planners and policy makers' access to diverse sources of data, data integration capabilities, and advanced capabilities for analysing and visualizing those data through a user-driven Web-based environment offering a one stop shop lab-in-a-browser. The project will facilitate research activity in order to enhance our understanding of key issues relating to the sustainable development of Australia's national settlement system and improve the evidence base for informed public policy making and business operations. This is particularly important as the nation debates the implications of population growth, how the population will be distributed across space, the urban environments in which people will live, and how the nation can promote the sustainable development of its cities and towns (AURIN EIF Final Project Plan)AURIN 2011.

OWI is an innovative, open source GIS-based planning support system (PSS) that can be used to prepare conditional what if? scenarios for an area's future land use, population and employment patterns. It is being developed by porting the widely used desktop What if? system (Klosterman 1999, 2008) into the AURIN environment. The OWI tool builds on a state-of-the-art eResearch Infrastructure realised through a service-oriented architecture (SOA) that offers seamless access to diverse data sets, with advanced user-interface capabilities and transparent access to high-performance computational resources. OWI is one of a broad range of advanced computational and visualization capabilities for supporting urban research and planning that are being integrated within the AURIN environment.

This chapter begins by describing how OWI aims to overcome the limitations of current GIS for planning. It then introduces the technical architecture of the system and its integration within the wider AURIN e-infrastructure. It then briefly describes the application of OWI in the context of a previous research application in Hervey Bay, Queensland. The paper concludes by discussing OWI and its potential for supporting sustainable urban planning in Australia.

2 Background

2.1 From GIS to Planning Support Systems

The ability of GIS to combine easy-to-understand maps, standard database operations, and sophisticated spatial analysis tools has proven to be extremely useful for a wide range of scientific, public-, and private-sector applications. However, the general applicability of current GIS has not met the needs of particular users such as public sector planners and urban researchers. Rather, GIS has traditionally been used almost exclusively to analyze current and/or past conditions and has not addressed planners' unique concerns with helping public and private decision-makers deal with an uncertain future. The limitations of current GIS to meet the particular needs of planners has led to the development of a large number of planning support systems (PSS) which combine the spatial analysis and display capabilities of GIS with specialized forecasting and visualization tools that serve the needs of planners (see, for example, Brail and Klosterman 2001; Geertman and Stillwell 2003, 2009; Brail 2008.

PSS have been developed and applied literally around the world. Most PSS are academic prototypes or "one off" professional applications but a small number of systems such as Community Viz (http://placeways.com/communityviz), Sleuth (Clarke 2008), UrbanSim (Waddell 2002, 2011), What if? (Klosterman 1999, 2008), and, in Australia, the LSUM-SEQ (Large Scale Model for the Brisbane-South East Queensland Region) (Stimson et al. 2012) have gained a level of acceptance and uptake. However, a number of fundamental problems have limited the use of PSS in academic research and professional practice (Vonk et al. 2005). A particularly important obstacle to widespread PSS use is the difficulty of implementing and accessing current PSS which have generally only been available as proprietary desktop applications. OWI directly addresses this limitation by providing any time any place online access to a state of the art PSS that users can freely use to access a rich variety of data and create a range of what if? scenarios to meet their own particular needs.

2.2 Online What if? Description

As its name suggests, OWI does not attempt to predict future conditions exactly. Instead, it is a policy-oriented planning support tool that can be used to determine *what* could happen *if* clearly defined policy choices are made and assumptions concerning the future prove to be correct. Policy choices that can be considered in the model include the staged expansion of public infrastructure and the implementation of alternative land use plans or zoning ordinances. Assumptions for the future that can be considered in the model include future population and employment trends, assumed household characteristics, and anticipated development densities.

OWI is a bottom-up growth allocation model which starts with vector overlay-generated homogeneous land units, applies alternative policy choices to these units, allocates projected land use demands to them, and then derives small area land use, population and employment projections by aggregating the values for these land units. The model projects future land use patterns by balancing the supply of, and demand for, land suitable for different uses at different locations. Alternative visions for an area's future can be explored by defining alternative suitability, growth, and allocation scenarios.

OWI does not include measures of spatial interaction, represent the interlinked markets for land, labor and infrastructure or model the behavior of actors such as households, businesses, and developers. Instead, it provides an easy-to-use and understand GIS-based policy-oriented model that can accommodate the spatially-referenced data and policy choices for a particular study area, providing a readily available foundation for community dialog and decision making.

OWI augments current efforts such as public participation GIS (PPGIS) and volunteered geographic information (VGI) which attempt to use the power of GIS to empower private citizens and marginalized groups (see, for example, http://www.ppgis.net/). It does this by, for the first time, allowing urban professionals, public officials and members of the public to use the Web to explore what if? scenarios which describe alternative futures under different assumptions about the future and alternative public policy choices.

2.3 eResearch Infrastructure: The Way of the Future

Development of an online PSS has much to benefit from advances in eResearch infrastructure. Seamless and secure access to digital data, tools and computational resources has been at the fulcrum of major efforts in the UK through the UK e-Science Core Program, in the US through the cyberinfrastructure initiative and in a range of European-wide efforts such as the Enabling Grids for e-Science (EGEE). The Australian Government has also made considerable investments in this area as part of its Aus$1bn Education Investment Fund Super Science

Initiative. Major programs include the Aus$47 m National eResearch Collaboration Tools and Resources (NeCTAR—www.nectar.org.au) project, the Aus$50 m Research Data Storage Initiative (RDSI—https://rdsi.uq.edu.au) project, and the Aus$20 m AURIN—http://aurin.org.au/) project (amongst many others).

The AURIN eResearch infrastructure has been established to support the urban research community across Australia by providing better access to data, interrogation and visualization tools. AURIN is end-user driven and includes ten 'aspirational' strategic implementation streams or 'lenses', which relate to issues of national urban policy priority. The lenses are: (1) population and demographic futures and benchmarked social indicators; (2) economic activity and urban labour markets; (3) urban health, wellbeing and quality of life; (4) urban housing; (5) urban transport; (6) urban water and energy supply and consumption; (7) city logistics; (8) urban vulnerability and risks; (9) urban governance, policy and management; and (10) innovative urban design.

AURIN is providing online access to 2001, 2006, and 2011 census data provided by the Australian Bureau of Statistics (ABS) and a number of census-derived data products including: location quotients, demographic and social-economic percentages, and shift-share statistics. AURIN is also providing access to the national cadastral boundaries and geocoding facilities made available via the Public Sector Mapping Agency (PSMA), along with crowd-sourced Twitter data. These are seamlessly delivered through a one-stop shop web-based portal offering access to distributed (federated) data sets with accompanying analytical tools such as OWI, a Walkability tool, and a library of spatial statistical routines. Once users have completed their analysis they are able to visualize their results as choropleth maps, graphs and charts. Security plays a key role in this and the AURIN platform has been fully integrated into the Australian Access Federation (www.aaf.edu.au), which provides decentralized (federated) access control, whereby end users are able to access distributed resources available through AURIN through authentication at their home institution.

3 Technical Architecture

As shown in Fig. 1, OWI has been developed as a core component of the AURIN infrastructure. The AURIN eResearch infrastructure is accessible through the single entry point—the AURIN portal. This portal provides access to a wide variety of heterogeneous authoritative data from a variety of data sources, and provides the ability to combine, analyze and visualize these data within the portal, or download them if users have permission to do so.

The AURIN internal technical architecture is based on a loosely-coupled design that includes a collection of independent web services communicating through documented Application Programming Interfaces (API). Internal AURIN services are mostly communicating through REST-based APIs, but the architecture supports also Open Geospatial Consortium (OGC)-compliant and SOAP services.

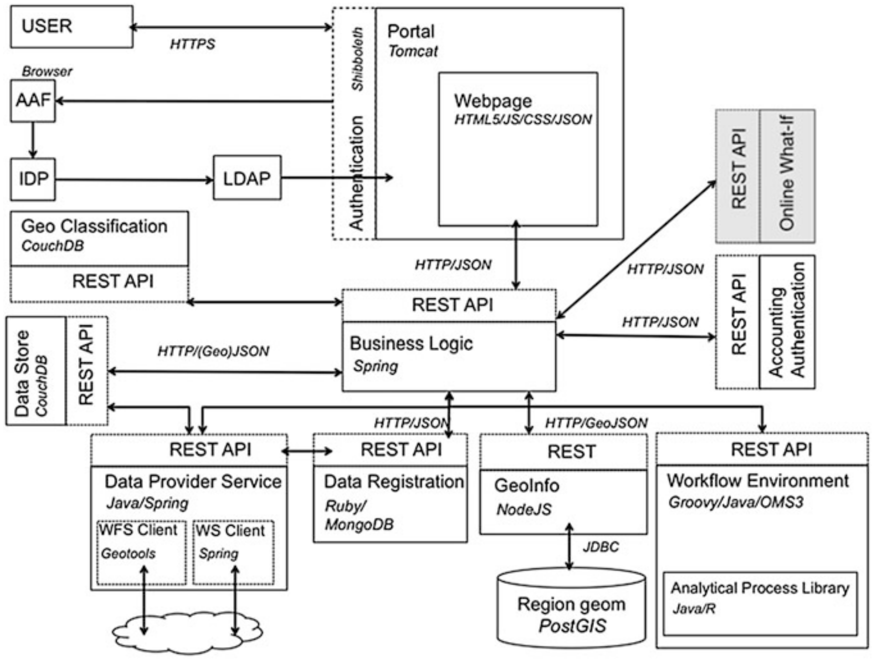


Fig. 1 The high-level schema of the AURIN technical architecture, with the OWI functionality integration highlighted in *grey* (adapted from Sinnott et al. 2012)

This architecture enables AURIN to flexibly respond to the evolving requirements of the project and integrate data and systems from diverse sources. The ability to adapt to technological changes during the lifetime of the project and the long-term maintainability of the platform were among the key requirements for implementing the AURIN framework.

AURIN's infrastructure supports the discovery and acquisition of data from federated data sources and allows user-based data upload and download (subject to security based on data custodian-defined rules). The data are internally stored in the AURIN Data Store, which offers persistent storage. Interim data results, such as those generated during the testing of multiple OWI scenarios can also be stored in the Data Store. The data stored in AURIN can also be protected and have associated restrictions on their use. The user interface enables interactive visualization of data, enhanced by advanced cartographic brushing capabilities Pettit et al. (2012). A workflow environment facilitates complex data analysis and processing such as the GIS analysis required to implement the OWI model. More complex analytical tools, including advanced user interface interaction modalities and data processing functions, such as OWI, are exposed as self-contained applications.

The AURIN infrastructure needs to ensure system scalability, enforce component isolation, provide communication through publicly documented interfaces, and support a heterogeneous software stack that adapts to the technological requirements of the individual components.

AURIN leverages the support of high-performance computing infrastructure, such as the Cloud-enabled computing environment of the sister NeCTAR project. This enables computationally intensive applications, such as the analysis of OWI scenarios for large regions, to run efficiently, providing better response times than is possible with a desktop tool. It also reduces the barriers to access for researchers, policy makers and ultimately members of the public who do not have computational infrastructure support.

4 The Online What if? Technical Architecture and Software Component

Re-engineering the existing desktop What if? tool as a core module of the AURIN eResearch infrastructure required recoding the existing desktop implementation into a web-based, service-oriented environment. The implementation has reused the standard GIS visualization components implemented in the main AURIN infrastructure to provide a user-friendly experience. The OWI model has been coded entirely with open source software and will in due course be available under an open source license.

Figure 2 illustrates how the various OWI sub-modules interact with each other. In this architecture, when the user requests a What If? analysis within the AURIN portal. The AURIN environment delegates this request to the What If? Controller, which performs a REST request with the What If? information that is acknowledged by the What If? Analysis Services, where the algorithm processing takes place. The Analysis Services can be located physically on any server. After the appropriate information is obtained, this service processes the appropriate What If? Suitability, Demand, or Allocation Service. When the analysis is completed,

Fig. 2 AURIN online What If? module architecture

this module notifies the What If? Controller (Geertman and Stillwell 2009), which then informs the AURIN environment that the analysis results are ready to be shown in the view layer (Klosterman 1999).

4.1 Implementation Strategy

The OWI PSS uses core Java Enterprise Edition (version 5.0) APIs to access the required geospatial and non-geospatial information. The persistence technology used for the OWI model is integrated with the AURIN portal (noSQL CouchDB and postGIS database). All of the model entities are stored in the database as business objects, which comply with the database guidelines for ACID (atomic, consistent, isolated and durable) transactions. By using the AURIN data store standard connectors, the persistence layer provides direct access to any database, through a standard JDBC library, or the REST APIs to access noSQLs storage services. This flexibility allows most of the AURIN capabilities to be quickly and easily migrated to any major database implementation in the future.

4.2 GeoTools—The 2D Spatial Data Handling API

The geospatial API used for the OWI model is the Java-based GeoTools Open Source (LGPL) library (http://www.geotools.org/) which provides extensive modules to support spatial data access, manipulation and remote interrogation in compliance of the Open Geospatial Consortium (OGC) specifications (in particular the Simple Feature Specification compliant data models). This allows OWI to transfer information between database objects and create spatial features stored and analysed in Java. The implementation also leverages the Java Topology Suite library (JTS), abstracting the geometry functions in a numerically robust, scaleable and performance manner.

At the core of the analysis lies a multi-criteria weight based comparison between diverse attributes that share the same spatial geometry. This analysis is straightforward thanks to the FeatureType interface provided by GeoTools. The suitability analyzer component factors in all the relative importance set up by the user simultaneously for each spatial unit/feature, and then produces a suitability score that is stored with the proper spatial reference in a GeoTools DataStore. This very flexible interface allows querying for relevant features in the complex allocation stage of the analysis. Using another flexible module, the GeoTools Filter and Expression interface, the analyser uses the common query language (CQL) to perform the relevant sorting and filtering according to allocation controls at each projection year, thus being able to produce several what if? outcomes efficiently without having to reload the complex setup and geospatial information.

4.3 Persisting Spatial Data and Scenario Configurations

Two types of data are accessed by the OWI application in order to analyse the land use scenarios: spatial data themselves, and the configuration of the scenario, as set-up by the expert planners or during community consultation.

Raw spatial data that are used by OWI include information about land-use, population, employment, terrain characteristics, and others. These conflicting data layers are processed (usually offline, in a desktop GIS software) in an overlay process resulting in homogenous land units, also called Uniform Analysis Zones (UAZ) file. Each UAZ contains all the relevant information necessary to perform a what if? analysis, ensuring that all features will be properly analysed and the outcomes will be consistent. In summary, this is a spatial dataset that is homogeneous with respect to all of the factors considered in the model (Klosterman 2007).

The configuration information is required for the interpretation of the UAZ file's attributes and the classification of their values, and defining scenario and analysis options. This setup information is encoded in a Java Script Object Notation (JSON) object and persisted in the Business Logic layer of the AURIN environment as illustrated in Fig. 1. For example, a land suitability class is defined as a JSON object. These user-defined objects will be parsed, persisted and translated into a land use suitability entity that will be attributed a projection and geometry to constitute a GeoJSON object. This GeoJSON can then be understood by GeoTools for performing geoprocessing, such as spatially overlay driven land suitability analysis. This approach in formulating (Geo)JSON objects is also undertaken in setting up the OWI Demand and Allocation routines—see Fig. 2.

4.4 User Interface

Figures 3, 4, 5, 6 show the AURIN portal and OWI interfaces for analysing the suitability of different locations for accommodating different land uses and viewing the resulting suitability scenario maps for Hervey Bay. Figure 3 shows the AURIN portal interface and mapping window, which highlights the Hervey Bay study area and can be used to show different input data layers. Figure 4 demonstrates the procedure for selecting a previously defined suitability scenario or creating a new one. Figure 5 shows the interface for specifying the weights for different suitability factors (e.g., slopes and prime agricultural soils), the rating for each factor type (e.g., different slope values), and the land uses that can be converted to other uses to accommodate future land use demands. Figure 6 shows the suitability maps for one suitability scenario and the system's ability to display multiple suitability scenarios.

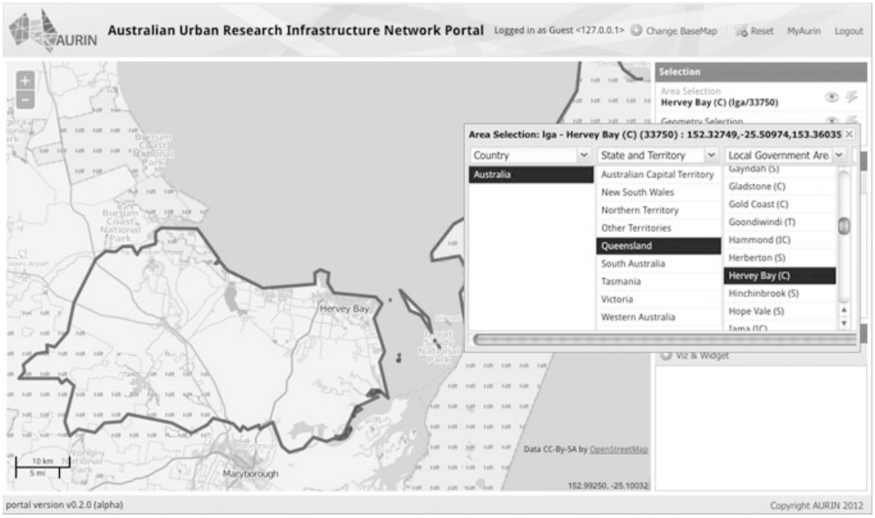


Fig. 3 AURIN portal interface showing selection of the Hervey Bay case study area

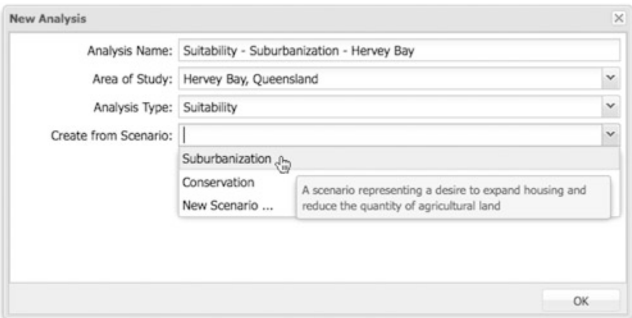
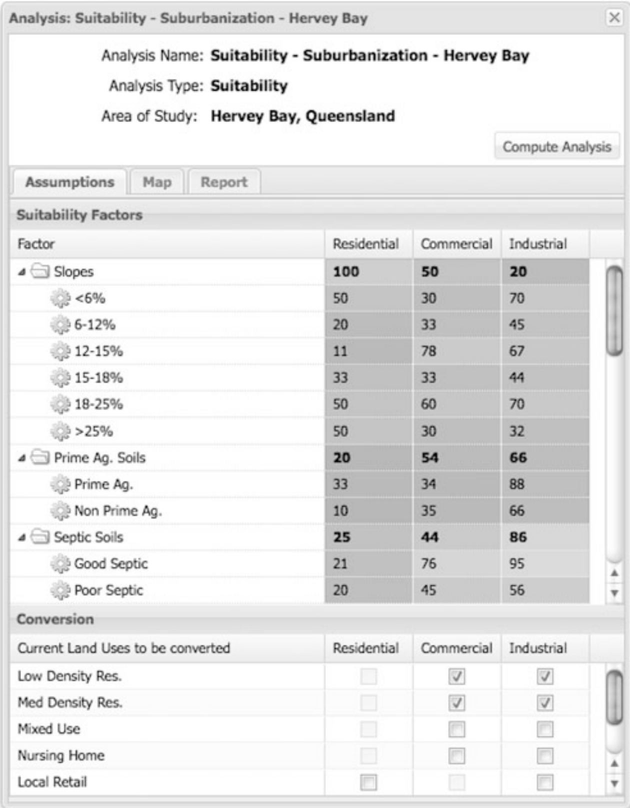


Fig. 4 Suitability scenario selection form

5 Case Study Demonstrator

The data set for Hervey Bay, Queensland, a previous application of the What if? model (Pettit 2005), is being used to develop the initial OWI application and provide an exemplar for the model implementation. The model is also being implemented in Perth, which is experiencing rapid urban growth due to the Australian mining boom, and in Townsville, which is one of first twenty-four cities in the world to be involved in the IBM Smarter Cities Challenge.

Hervey Bay, including Fraser Island (a World Heritage area), is a popular destination for tourists along the east coast of Australia because of its natural amenities and traditional rural characteristics. Furthermore, Hervey Bay is characterised by strong population growth and high levels of unemployment. As a


Analysis: Suitability - Suburbanization - Hervey Bay

Analysis Name: **Suitability - Suburbanization - Hervey Bay**
Analysis Type: **Suitability**
Area of Study: **Hervey Bay, Queensland**

Compute Analysis

Assumptions | Map | Report

Suitability Factors

Factor	Residential	Commercial	Industrial
Slopes	**100**	**50**	**20**
<6%	50	30	70
6-12%	20	33	45
12-15%	11	78	67
15-18%	33	33	44
18-25%	50	60	70
>25%	50	30	32
Prime Ag. Soils	**20**	**54**	**66**
Prime Ag.	33	34	88
Non Prime Ag.	10	35	66
Septic Soils	**25**	**44**	**86**
Good Septic	21	76	95
Poor Septic	20	45	56

Conversion

Current Land Uses to be converted	Residential	Commercial	Industrial
Low Density Res.		☑	☑
Med Density Res.		☑	☑
Mixed Use		☐	☐
Nursing Home		☐	☐
Local Retail	☐		☐

Fig. 5 Suitability assumptions specification form

result, the local government faces a need to promote future growth while preserving the area's environmental quality and tourism industry planning. A number of land use scenarios were initially developed to explore the issue of competing land uses (Pettit and Pullar 2004). The 'sustainable development' driven scenarios initially generated in the What if? PSS (Pettit 2005) have been re-implemented in OWI.

The OWI application allows the planners, policy-makers and citizens of Hervey Bay to examine scenarios and projections that urban planning experts have generated and made freely accessible via the AURIN portal. More importantly, it permits stakeholders and citizens in Hervey Bay to access the AURIN portal and use OWI to develop their own scenarios and determine the implications that their assumptions and forecasts may have for their community. The tool also increases their understanding of the land use development process and the complex public policy issues that land use experts confront.

The AURIN OWI application has initially been set-up with the Hervey Bay data so that the re-coding of the desktop What if? model can be validated with a

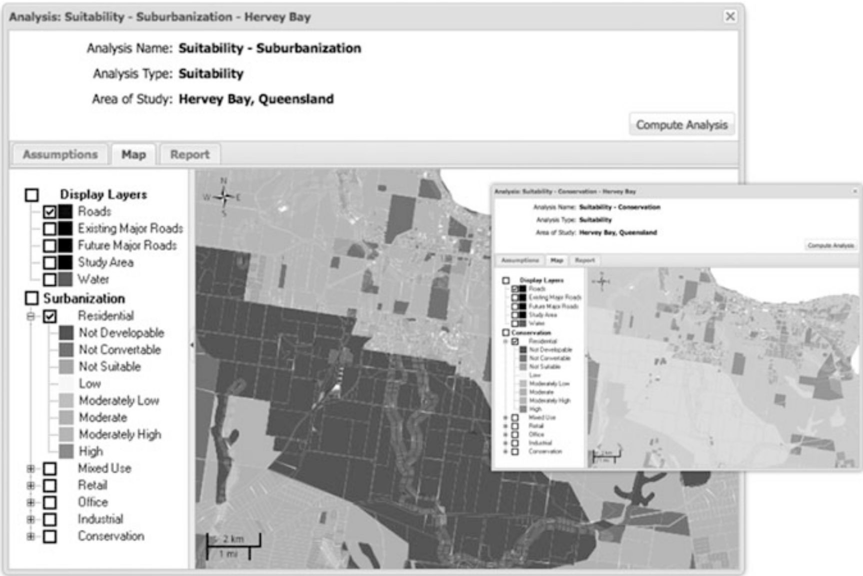


Fig. 6 Suitability map for suitability scenario with functionality to view and compare multiple scenarios

known case study example. This allows the OWI set-up, suitability, demand and allocation modules to be tested against previously published sustainable urban development scenarios (Pettit 2005). Future applications of OWI will examine the likely implications of greenfield urban development around the City of Perth in Western Australia and the future growth in and around the city of Townville in North East Queensland, which is considering novel ways to promote sustainable urban development. OWI can help improve planning in Australia by providing a framework for bringing together social, economic, environmental and physical datasets, and support more evidenced-based decision-making. Analyzing these data in a GIS-based planning support system will also allow what if? scenarios for alternative sustainable futures to be explored by policy-makers, planners, stakeholders and citizens throughout Australia.

6 Conclusions

The AURIN OWI application offers several benefits for planners, public officials and private citizens. For the first time, it provides direct online access to a state of the art PSS that allows for both professionals and non-professionals to create and view alternative scenarios for their communities. Making the software systems available online from a single source will both encourage uptake, and leverage the integration and extensions of the system together with state of the art development tools and processes available through AURIN. This includes for example feature and bug tracking, software updates and patches, and configuration management and deployment support (Sinnott 2013). The software will be released under an open source license which will allow it to be adopted elsewhere.

However, there are also challenges in adopting an online open source approach. OWI is being developed as an open source tool, which means that its underlying logic and algorithms can be freely extended over time by anyone. However, OWI is part of a complex AURIN technical architecture that utilizes a number of dependencies on different system components and libraries. This means that implementing OWI outside the AURIN eResearch infrastructure will require substantial software engineering experience, which is not traditionally the strength of planners and GIS experts.

Nevertheless, OWI illustrates the potential that advanced eResearch infrastructure can provide for helping planners, decision-makers and private citizens explore alternative futures for cities and regions around the world. Further research and development will see the OWI applied in exploring sustainable urban futures in Australia and these results and the lessons will be reported in due course.

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