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NISMOD-DB: A National Asset

A system-of-systems database that will be deployed nationally as an infrastructure analytics, modelling and visualisation resource available to all. That's the ambition for NISMOD-DB ... and one that is already well on the way to being realised, say Stuart Barr and Craig Robson

Good quality spatial and temporal data and information lies at the heart of developing long term robust and economically sustainable infrastructure investment plans. Indeed, many operators in the energy, water and transport sectors have recognised the importance of developing data and information management approaches in planning and implementing asset investment decisions.

While information on the location and state of assets is critically important, the ability to plan long term infrastructure provision requires such data to be augmented with information on the myriad vulnerabilities, demand/capacity constraints and lifespan renewal issues of an infrastructure system. Additionally, information and understanding of the dependencies and/or interdependencies that exist between infrastructure sectors is also required.

Recognising the need for a system-of-systems approach to critical infrastructure analysis, modelling and planning, the Infrastructure Transitions Research Consortium[1] has developed the first UK National Infrastructure Systems Model (NISMOD). A key component of the model is a UK national scale spatial and temporal infrastructure systems database (NISMOD-DB) ... one that underpins all the analysis, modelling and visualisation work.

Overview

NISMOD-DB addresses the representation and management of multiple infrastructure systems and sectors via a hierarchical representation model. Within the model, assets form infrastructure networks that, collectively, form sectors/systems and which, themselves, aggregate to form the overall holistic infrastructure system (Fig.1).

Within NISMOD-DB not only are the key characteristics of these hierarchical components represented (assets, networks, sectors/systems and system-of-systems), but also collections of infrastructure components at one level that aggregate to form an integrated component at the next level. At each level of granularity, different

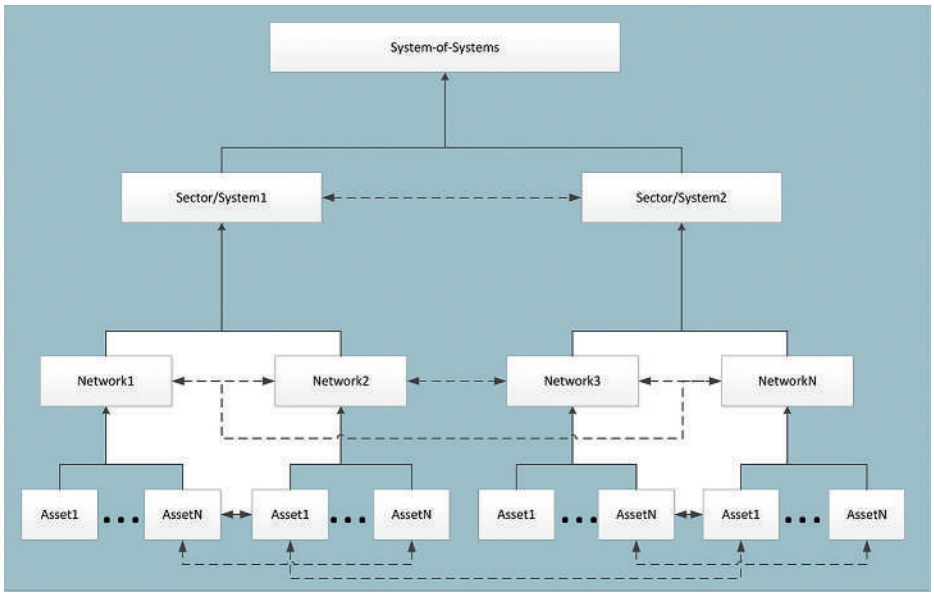

Fig.: Hierarchical representation of infrastructure data within NISMOD-DB.

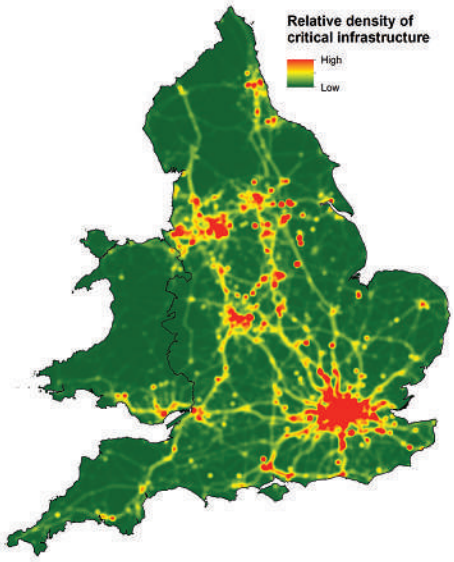

Fig.2: Spatial location of critical infrastructure network assets in England and Wales according to population demand and the dependence on electric, gas, water supply, waste water, telecoms (mobile connection), rail and road infrastructure services.

types of information are stored depending on their key characteristics, geography, generic attributes, relationships, data management types and key tasks.

The NISMOD-DB database management system has been implemented in an entirely Open Source framework and comprises of four key modular components:

1. The physical database comprising a PostgreSQL RDBMS along with its PostGIS spatial extension. This combination provides the full functionality of a relational database management system plus the ability to represent spatial data layers in the form of geometry tables.
2. A suite of NISMOD-DB-Scripts for day-to-day data management. These include generic scripts in standard SQL for data loading, cleaning, relation initialisation, relationship mapping and basic querying. Scripts for advanced management and analysis have been developed using the PostgreSQL procedural programming language pgSQL.
3. A specialist software suite (NISMOD-DB-Networks) for the construction, storage, management and analysis of spatial infrastructure network models including interdependent infrastructure network models. This software is written in Python and employs the Python network module NetworkX ... one widely used in network complexity analysis.
4. A suite of software tools (NISMOD-DB-Vis) that allow users to interact with the NISMOD-DB database and visualise data-sets and result-sets. These tools have been written using Highcharts JS, OpenLayers, jQuery, Flot and D3js and are coupled directly to the database store using GeoJSON.

Applications

At present, NISMOD-DB comprises in excess of 450 national-scale spatial data layers. These represent data/information on current and future projected population demographics and economic activity/performance, as well as, spatial network representations of the assets within energy, water, solid waste, telecoms and transport infrastructure sectors. NISMOD-DB also comprises of a suite of national-scale spatial data layers that characterise current and projected climate-driven hazards such as rainfall, flooding and heat.

As part of the ITRC project, NISMOD-DB not only stores primary data, but is also the central platform for much of the analysis and simulation modelling.

For example, the new interdependent spatial infrastructure network database schema and associated scripts of NISMOD-DB-Networks is used in NISMOD-RV (Risk and Vulnerability modelling) for analysing and modelling the spatio-temporal vulnerability and risk of infrastructure networks within the UK. One example is shown in Fig.2 and where, in collaboration with Infrastructure UK (part of H.M. Treasury), ITRC spatially modelled population dependence across a range of critical network assets.

NISMOD-DB is also employed in coarser-scale but still spatially explicit long-term modelling of UK infrastructure services (NISMOD-LP); both for individual sectors and also as a system-of-systems interdependent model. In this work, NISMOD-DB acts as a result-set 'broker' between the sector system models. Model result-sets are written to the database, at which time dependent models can make a request to the database for the result-set fields they require for their own parameterisation.

As many infrastructure sector models involve complex relationships and interactions, with intra-system and network interactions expressed in the modelling outputs, this results in a large and complex sub-database structure. To address this, NISMOD-DB has a bespoke metadata high-level set of tables and relationships, along with associated database scripts. This manages all NISMOD-LP data and results; undertakes provenance management of the result-sets generated by NISMOD-LP, and generates the required reporting tables, relationships and metrics required for subsequent reporting via the NISMOD-DB-Vis dashboard tools

Ongoing development

In January 2016 the ITRC consortium was successful in securing a further five-year funding to develop MISTRAL (Multiscale InfraSTRucture systems Analytics). This project, by 2020, will extend the national-scale work of ITRC to downscale our understanding of future infrastructure demand to individual household level for the entire UK; upscale the analysis to consider continental and global impacts of infrastructure demand and provision; and also extend the work to other national contexts.

NISMOD-DB will be significantly extended under MISTRAL to handle the additional spatial complexity of downscaling and upscaling and, by the end of 2020, be deployed as a national infrastructure analytics, modelling and visualisation hub ... a resource that will be open to academic researchers, industrial practitioners and policy makers alike.

[1] *http://www.itrc.org.uk*

Dr. Stuart Barr (Stuart.barr@newcastle.ac.uk) is a Senior Lecturer in Geographic Information Science while Craig Robson is a Research Assistant, both with the School of Civil Engineering and Geosciences at Newcastle University (www.ncl.ac.uk)