Institution: University of Abertay Dundee

Unit of Assessment: 15 General Engineering

Title of case study: Interactive Visualisation of Sustainability Indicators for Urban Planning

1. Summary of the impact

This case study concerns S-City VT, a Simulated-City Visualisation Toolkit. S-City VT is an urban planning tool based on computer games technology and computational modeling for efficient 3D real-time and interactive visualisation of complex data sets. S-City VT is founded on computational models that assess environmental, societal and financial measures of buildings and their functions. We have researched methodologies to enable stakeholders to explore city spaces, change construction properties and locations of buildings, and observe the consequences of those changes through intuitive 3D representations. SAVE has contributed to the £1B development of the Dundee Waterfront, one of the largest regeneration projects in the UK. Stakeholders impacted were local government organisations, the public, water companies and their regulators. The application of the research has changed not only public policy and services, but also how information is displayed to stakeholders, and in so doing has enabled sustainability assessment, supporting stakeholders in making informed decisions.

2. Underpinning research

This case study is built on fifteen years of inter-disciplinary research, and strong interactions with stakeholders, combining expertise in computer games technology and evaluation of the effectiveness of visualisations for users together with expertise in environmental engineering and mathematical modeling. This interconnected research base is drawn together in our SAVE group (Sustainability Assessment Visualisation & Enhancement) and has delivered S-City VT, an integrated interactive visualisation toolkit for sustainable assessment in the context of urban planning and stakeholder decision-making.

The initial driver for the work was to inform stakeholders on how to assess sustainability plans for the regeneration of the Dundee Waterfront. The Dundee Waterfront is an investment of £1B over a 30-year period: the most active development outside of London (2013) and the 16th largest regeneration project in the UK (2013). This development includes the Victoria and Albert Museum at Dundee, which will be an international centre of design for Scotland and will host major exhibitions helping people understand their cultural heritage. The Waterfront development played a major part in the shortlisting of Dundee as City of Culture (2017). Importantly, we have adopted a modular software development methodology so that S-City VT can be readily adapted to other projects where decision-making is required. The evidence of the successful translation of this framework to multiple problem spaces is found in a growing portfolio of impacts, as noted below.

S-City VT is founded on a suite of sustainability indicators, derived in partnership with key stakeholders, for urban infrastructure (Gilmour et al. 2011). A subset of these indicators are used to construct empirical sub-models describing energy efficiency of buildings, traffic noise pollution, economic benefit of different building functions, social acceptance of building use and housing provision / employment opportunities over time. These sub-models are then integrated through the analytic network process methodology that serves as the simulation engine (Isaacs et al. 2011).

Clearly in any urban planning decision trade-offs must be made among these factors and decisions must be reached amongst competing stakeholders. We have integrated these models into S-City VT to provide intuitive representations of these trade-offs to support decision-making (Isaacs et al. 2011). First, S-City VT integrates 2D planning and building models – typical of architects plans – into a 3D world (Figure 1) that both allows interactive navigation around the environment and computes the empirical models (simulation engine) over time (Figure 1, 3D visualisation).

A key challenge is then relating those sustainability indicators to the buildings within the planned region. In Isaacs et al. (2013) we have developed weaving techniques to overlay onto those buildings in real-time those sustainability indicators. Building properties can also be modified, relocated and moved in real-time. This degree of interactivity and flexibility is only possible through exploitation of GP-GPU graphics card technologies. Further S-City VT has developed a method for the pairwise (split-window) comparative assessment of sets of complex data underlying different planning scenarios, which has clear benefits for decision-making.

Finally, we have evaluated the effectiveness of our visualisation for communicating sustainability indicators to stakeholders. In Isaacs et al. (2013) we undertook an experiment where we presented, in a randomized order, multiple pairwise scenarios and varied the degree of difference in overall sustainability of building designs. Participants were able to correctly identify the most sustainable design in all cases.

Valuable insights impacting on this project have been derived from a series of EPSRC Consortia projects on sustainability assessment and enhancement (projects 1 to 3, section 3) and include:

- Appropriate methods of engagement of key stakeholders, including the public, in decision making processes (projects 1, 2, and 3);
- The potential for application of decision support tools such as cost-benefit analysis and multi-criteria decision analysis, (project 1 and 2);
- Techniques that can help understand how decisions are made (project 2);

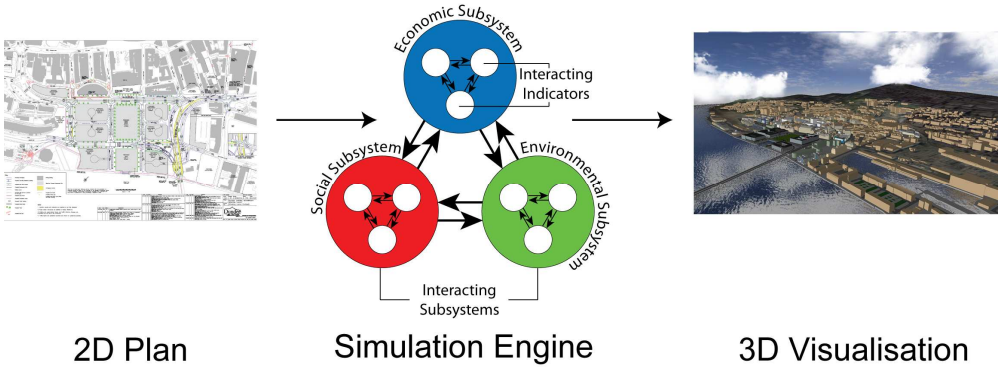

Figure 1: translation from 2D plan with simulation engine to interactive 3D environment

Projects using SAVE (projects 4-11, section 3) have allowed further development and user testing. These projects have provided insights on:

- How to embed the effective consideration of sustainability in real-life decision processes based on (i) understanding how decisions are made and by whom and hence (ii) the selection of appropriate sustainability indicators for key stakeholders to support their decisions;
- Development and testing of novel methods of modeling and visualising sustainability indicators to a wide range of stakeholders;
- Determining which visualisation methods are appropriate for communicating time-varying multivariate data.

Figure 2: comparison of construction material (top), and weaving to show sustainability (bottom)

The research team comprises Dr Isaacs and Dr Falconer (interactive visualisation) together with Mr Gilmour and Dr Blackwood (environmental sustainability).

3. References to the research

- Gilmour D., Blackwood, D., Banks, I. and Wilson, F. (2011). Sustainable development indicators for major infrastructure projects Proceedings of the Institution of Civil Engineers. Municipal Engineering, 164, 15 – 24.
- Isaacs, J., Falconer, R., Gilmour, D. and Blackwood, D. (2011). Enhancing urban sustainability using 3D visualisation, in Proceedings of the Institution of Civil Engineers. Urban Design and Planning, 164, 163 – 173.
- Issacs, J., Blackwood, D., Gilmour, D. and Falconer, R. (2013). Real-time visual simulation of urban sustainability. (REF output 1 for Isaacs)

RESEARCH AWARDS (EPSRC)

1. EPSRC Sustainable Cities Initiative. Sustainable Disposal of Domestic Sanitary Waste (1996 - 1999). Dr David Blackwood and Mr Daniel Gilmour, Researchers.
2. EPSRC The Water Infrastructure and Treatment Engineering Programme: (1998 – 2001) A multi-criteria analysis/Risk management tool to assess the relative sustainability of water systems. EPSRC grant Ref. GR/M15545. Dr David Blackwood, Co-Investigator, Mr D Gilmour, Research Officer. (£120,000)
3. EPSRC SUE Programme: Water Cycle Management for New Developments WAND. Led by Imperial College (2004 – 2007). Dr David Blackwood, Co-Investigator, Mr D Gilmour, Research Officer. (£36,000)

RESEARCH AWARDS (OTHERS IN SECTION 2)

4. Sustainability Assessment and enhancement of Dundee Central Water Waterfront. (2006 – date), funded by Dundee City Council. £96,000.
5. A series of projects related to Sustainable Management of Phosphates in the water cycle, funded by United Kingdom Water Research Ltd (UKWIR), led by Atkins Global. (a) Source Apportionment for Phosphorus From Domestic Sources (2007 – 2008) (b) Phosphorus Lifecycle Management, (2008 – 2010) - in association with the University of Oxford. (c) Alternatives to phosphate for plumbosolvency control, (2010- 2011). £40,000.
6. Fife Coast and Countryside Trust. Visualisation of Eden Estuary and Natura 2020. (2011/12) £27,000.
7. Fife Council. Visualisation of Strategic land use at Dunfermline Western Edge. £10,000
8. TAYplan Strategic Implications for Land Use: What key societal, economic and climatic changes may occur over the next 20-40 years (2012/13) £9,000.
9. TAYplan -3D visualisation for TAYplan strategic land use planning £10,000
10. Scotland's Environment Web Visioning. £17k to provide recommendations to the SEWeb (LIFE) Project on the future development opportunities of their web site and overall web presence allowing effective, useable and accessible access to Scotland's environmental information.
11. Scottish Water Sector Overview Map for CREW (Center of Expertise for Water) £60K To produce an overview of Scotland's water sector in the form of a map which demonstrates the scope and scale of the sector and shows, in manner that can be easily understood by a wide range of stakeholders, how the different parts of the sector link together.

4. Details of the impact

The S-City VT case study research and knowledge exchange has had a significant impact on local government organizations and the public in terms of:

- Raising the awareness and understanding of key stakeholders;
- Increasing the ability of the stakeholders to make informed decisions;
- Impacting policy debate on the environment;
- Changing public policy and services;
- Changing to the way key information is presented to stakeholders.

Raising the awareness and understanding of key stakeholders;
Increasing the ability of the stakeholders to make informed decisions

S-City VT was used by Scottish Enterprise to inform the public through presentations to community groups and as exhibits at science festivals and art events (Dundee Science Festival, Fife Science Festival). It was also used by Scottish Enterprise to communicate plans for the redevelopment of an area of Dundee to potential developers. The interactive visualisation of Eden Estuary and Natura 2020 for Fife Coast and Countryside Trust has enabled the effective engagement of stakeholders during the development of coastal management practices and to develop realistic scenarios, which can be communicated to all stakeholders.

The team was invited to present S-City VT to the Scottish Government, Scottish Environment Protection Agency, Fife Council and the regional planning authority TAYplan. Local Authorities have confirmed the value of the tool in stimulating stakeholder engagement to inform planning decisions. Fife Council have commissioned the University to apply the framework to strategic land

use planning for the Dunfermline western edge development to support planning meetings and stakeholder engagement sessions. Through Project 6 the value of the interactive visualisation has been recognized and it has changed the way data collected by different agencies is communicated to stakeholders including the public. For example, a S-City VT-based exhibit will be displayed at the Eden Estuary Visitor centre. Project 8, was also commissioned by TAYplan "to help public sector bodies formulate policy in relation to land use change" and the results have informed policy formulation for the Strategic Development Plan for the TAYplan area.

Impacting policy debate on the environment

Project 8, in collaboration with the Universities of Dundee and St Andrews, was commissioned by TAYplan Strategic Development Planning Authority "to help public sector organisations formulate policy and strategy in relation to landscape change". Project 6, 7 & 9 have helped change policy on how to communicate development plans to the public as well as influencing a data-mapping framework for development plans. The Abertay team was invited to workshops to help develop the data mapping concept and to contribute to the development of Fife Council's Planning Department's communications strategies. More broadly projects 6, 7 & 9 have engendered discussions as to how creative technologies can be embedded in the planning process to encourage better engagement. In the SEWeb (Life) Project (10) we provided a visioning report to this project which is already being used by SEWeb to influence how Scottish Environmental organisations gather, share and present information to and from stakeholders. The report helped the partner organisations establish a clear, focused purpose for the site and included recommendations on aspects such as utilisation of social media, crowdsourcing and remote access (recommendations are now being implemented). Project 11 (now underway) will be used by the Scottish Government as a tool that can be used to manage, control and influence Scotland's water resources.

Changes to public policy

Our research provided new insights into the effective consideration of sustainability in real-life decision making processes. A set of sustainability indicators was developed and are now published by the Council to monitor the overall sustainability of the Dundee Waterfront Development. In parallel a series of interventions were implemented in the Council's project design and construction processes where the directions of the sustainability indicators could be influenced.

Changes to the way key information is presented to stakeholders

TAYplan's vision is to widen stakeholder engagement and participation in planning to foster a sustainable TAYplan region. A key element of this vision is enhanced communication of information in terms of both clarity and engagement. TAYplan commissioned us to develop better information visualisation methods and toolsets as a direct result of seeing S-City VT in the public domain, including working with TAYplan to select 2D views of our 3D visualisations for leaflet production. We have developed customised delivery of multivariate data relating to alternative Spatial and Green Network Strategies. Furthermore given that TAYplan wish to widen stakeholder engagement we are currently migrating the sophisticated 3D visualisation system underlying S-City VT to the web, making the interactive plans available to users with Internet access. The recent availability of web-based game libraries has now made possible this level of interactivity.

5. Sources to corroborate the impact

1. Director of Planning Fife Council will provide evidence of how our work has contributed to change their approach to consultation on planning issues in Fife and on the way in which planning information is communicated to Stakeholders
2. Chief Executive, Fife Coast & Countryside Trust, will provide evidence on the use of visualisation to change approach to communication with stakeholders.
3. The Strategic Development Planning Authority for Dundee, Perth, Angus and North Fife) SDPA Manager will evidence that our novel visualisation methods had influenced how the green network and spatial planning strategy is communicated to stakeholders (TAYplan).
4. Principal Policy Officer - SEWeb (LIFE), SEPA. Will evidence how the project led to changes in the way SEWeb and partner environmental organisations source and provide access to environmental information.