The SAVE Concept:

Sustainability Assessment & Enhancement Through Novel Visualisation

Isaacs, John P (1); Stojanovic, Vladeta (3); McCreadie, Chris (2); Falconer, Ruth E (3); Gilmour, Daniel J (2); Blackwood, David J (2)
Organization(s): 1: School of Engineering, Computing and Applied Mathematics, University of Abertay Dundee, United Kingdom; 2: School of Contemporary Sciences, University of Abertay Dundee, United Kingdom; 3: SIMBIOS Centre, University of Abertay Dundee, United Kingdom

Abstract:

The SAVE framework promotes an integrated and iterative approach to inclusive decision making for Sustainable Development, involving three inter-related components; Assessment, Visualisation and Enhancement.

The assessment and enhancement components are highly interrelated and must commence together at the visioning stages of projects. This enhancement component requires the development of a full understanding of the ways in which decisions are made on a project in order that the information needs of stakeholder are understood. The enhancement component then ensures that due consideration is given by decision makers to potential impacts on the direction of the assessment indicators at key decisions points throughout the project development stages.

At the heart of the framework is a simulation and visualisation tool that has been developed to enable all stakeholders, regardless of background or experience, to understand, interact with and influence decisions made on the sustainability of urban and rural design. This tool takes the unique approach of combining 3D interactive and immersive technologies with computer modelling to present stakeholders with an interactive virtual development.

This paper describes a number of case studies where the SAVE Framework has already been applied and outlines its further development and future application.

1 Introduction

While it is now acknowledged that sustainability must be incorporated into decision making at all scales, this is a complex process that requires the consideration of the social, economic and environmental consequences of the decisions being made. As effective decision making is dependent on genuine stakeholder contribution during the decision making process, it is vital that all the stakeholders are involved, but the current prevailing practice in urban design is for decision makers to seek agreement for proposals once the key decisions have already been made (Geldof, 2005). All stakeholders will pursue their individual or group interests whether these are on local, national or global scales. This combined with the range of issues, interests and levels of decision making ability of the stakeholders, makes the decision process extremely complex (Scheffran, 2006).

In particular, engagement with the general public throughout the decision making process presents challenges in communicating not only the complex and interdependent facets of sustainability in decisions, but also in providing an understanding to stakeholders of the short and long term implications of alternative courses of action. It is the aim of the research presented in this paper to investigate how a different approach to sustainable decision making can be taken trough holistic assessment, stakeholder engagement and continued enhancement.

2 Save Framework

The SAVE framework promotes an integrated and iterative approach to inclusive decision making for Sustainable Development, involving three inter-related components; Assessment, Visualisation and Enhancement as shown in Figure 1. The assessment and enhancement components are highly interrelated and must commence together at the visioning stages of projects. This enhancement component requires the development of a full understanding of the ways in which decisions are made on a project in order that the information needs of stakeholder are understood. Key decision points in the process, the stakeholders involved in these decisions and their information needs must be identified at this stage. This also informs the selection of an appropriate set of indicators to assess and monitor the sustainability of the development or management option. The enhancement component then ensures that due consideration is given by decision makers to potential impacts on the direction of the assessment indicators at key decisions points throughout the project development stages. This requires the identification of current and future points in the project development process where key decisions will be made to ensure that information on the potential impact of decisions on the overall sustainability of the project is provided at the right time and in the right form (Blackwood et al, 2012).

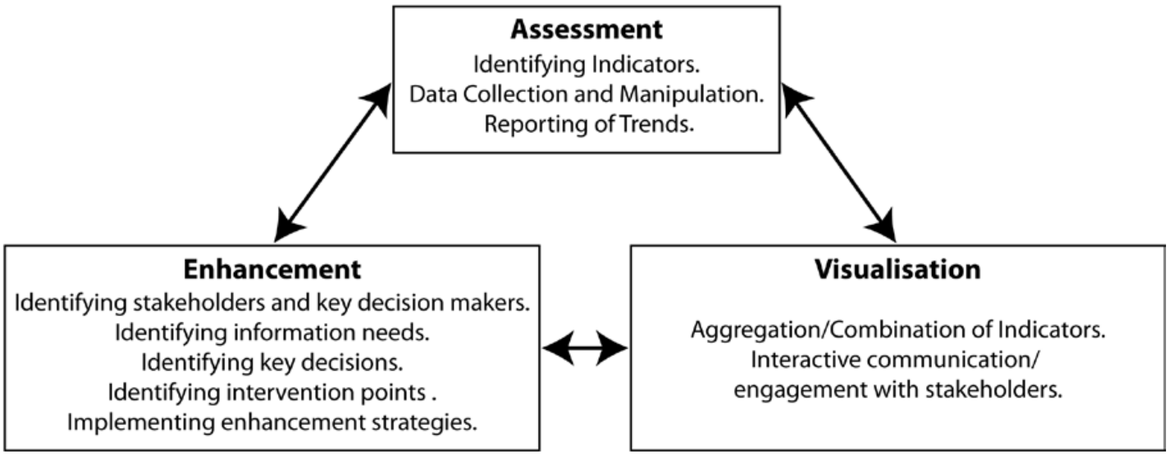

Figure 1: The SAVE Framework (Blackwood et al, 2012).

At the heart of the framework is a prototype simulation and visualisation tool (the SAVE Engine) that was developed to enable the results and the findings of the assessment and enhancement activities to be presented to a wide range of stakeholders. The next section describes a number of applications of the SAVE framework concentrating on the use of visualisation in communicating the sustainability of the decision being made.

3 Visualisation of sustainability

Previous research has suggested that 3D visualisation will be the key to new decision support tools which will enable a wider participation of stakeholder by enabling more effective communication between experts and non experts (Kapelan, Savic, & Walters, 2005). in particular it has been shown (Bown et al 2010), that the use of games technology in related 3D interactive applications is able to immerse the user far better than traditional observation and decision making methods. There are a number of examples where visualisation applications have been developed to aid stakeholder involvement in the decision making process (Ball, Capanni, & Watt, 2007; Bishop & Stock, 2010; Gill et al, 2010; Hamilton et al, 2005; Hamiltonet et al, 2001; Miller et al, 2008; Salter et al, 2009). However, all of these examples concentrate on the physical appearance of the decision being made and were not designed to confer any further information to the stakeholders.

Each of the case studies presented here utilise a common 3D rendering platform, the SAVE Engine, which drives the visualisation and incorporates the underlying dataset and modelling. Based on contemporary computer games and rendering techniques, the SAVE Engine is a custom virtual environment which has been specifically designed to closely couple a realistic representation of the real world with underlying scientific models whilst still providing the user with a real time interactive experience.

The visualisation component facilitates effective stakeholder engagement using these immersive communication technologies to help convey the complex facets of sustainability to non-expert stakeholders. However, through the underlying models, a detailed impact assessment of any proposed action or development is provided along with information about the possible tradeoffs between the three aspects of sustainability. This allows stakeholders and decision makers to determine the social, economical and environmental impacts of decisions they make before the actual decision is made.

3.1 Sustainable Urban Environments

The sustainable city visualisation tool (S-City VT) is a decision support tool designed to allow wider stakeholder engagement in urban planning decisions. S-City VT was developed specifically to determine the viability of using virtual environment based decision support systems with a range of stakeholder groups. Using the Dundee City Central Waterfront redevelopment project as a case study S-City VT allows stakeholders to compare the impact of development decisions being made(Isaacs et al, 2011a). Figure 2 shows the Dundee Central Waterfront project recreated in the S-City VT application.

Figure 2: The S-City VT application showing the Dundee Central Waterfront development

S-City VT is separated into three sections: the sub models that describe the interdependency between the indicators; the opinion analysis which uses the analytical network process (ANP) to generate priorities for the indicator set based on stakeholder's opinions and the 3D visualization which combines the sustainability results derived from the sub and ANP models with a 3D representation of the urban development.

The sub models were developed based on an six indicators selected from a larger range of indicators identified during the sustainability assessment of the Dundee Waterfront. The selected indicators; energy efficiency, noise pollution, economic benefit, acceptance, housing provision and employment, provide a spread across the three pillars of sustainability (economy, society and environment). Furthermore they were identified as having readily available data to calibrate the models. The sub models provide a value for each indicator for each component of the development, i.e. each floor of a building or each street, describing how these indicators change through space and time (Isaacs et al, 2011b).

The opinion analysis phase addresses the fact that stakeholder views are often in conflict, with one stakeholder placing more importance on a specific aspect (Social, Environmental or Economic) or indicator than another. The opinions of the stakeholders are incorporated using multi-criteria evaluation methods, namely the ANP method to order and weight the indicators in terms of their importance to the current user.

To determine a sustainability measure for a specific component at a given time, in the development the normalised indicator values, obtained from the sub system models are multiplied by the weights/priorities provided by the ANP model. This gives a quantitative measure of sustainability for each building. SCity-VT does not provide the user with a definite measure of sustainability, but allows the user to compare the relative sustainability of alternate decisions.

The visualisation tool employs a number of visualization techniques to display the sustainability results to the stakeholders. The simplest method involves aggregating the six indicator values into a single sustainability index Figure 3. This single value is then mapped to a colour scale. Using the hot-cold scale demonstrated in Figure 3, a building or floor with high relative sustainability would appear blue while a building with lower relative sustainability would appear red. This provides the user with a simple way of comparing scenarios.

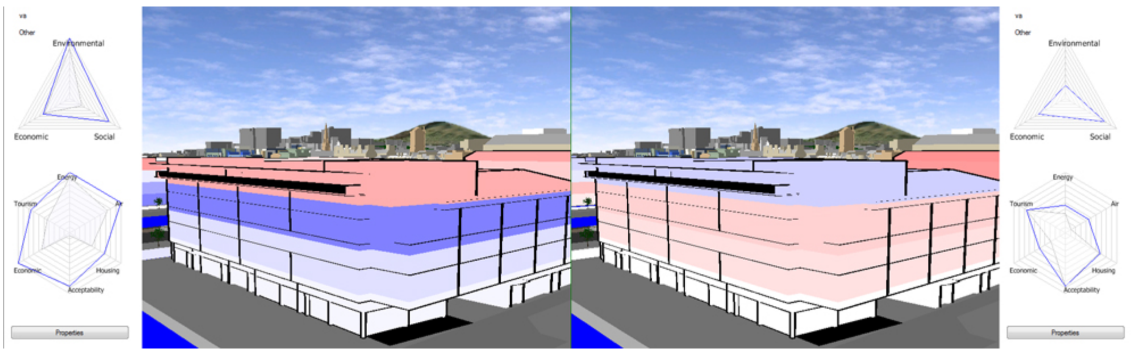

Figure 3: Two options being compared using the blend technique

The weave technique is designed to preserve the underlying sustainability information (Figure 4) enabling the user to identify which indicator is having the greatest impact on the sustainability of the scenario. The colour weaving technique uses a different colour scale for each indicator (Hagh-Shenas et al. 2007). The colours from each scale are then randomly weaved into a texture which is applied to each floor of the building . The texture encapsulating the sustainability data will give an overall representation of the sustainability of each indicator, with opaque colours representing low sustainability and more transparent colours representing higher sustainability.

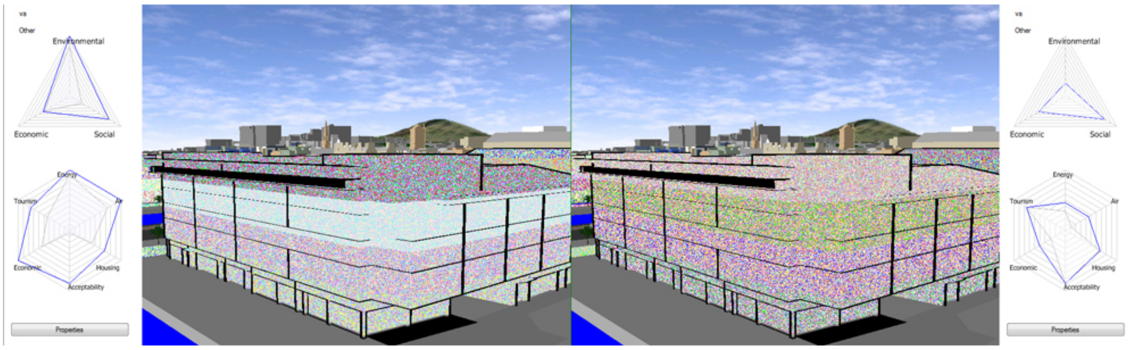

Figure 4: Two options being compared using the weave technique

As S-City VT is based on techniques used in the computer games industry, some more animated techniques were also utilised to confer information. For example a traffic visualisation was implemented which shows predicted traffic density simulated with moving cars on the streets of the urban environment. Directional sound effects are also modelled to represent the sound levels which would emanate from these traffic densities.

The creation of a 3-D virtual environment allows stakeholders to be immersed in the development. By projecting the sustainability results onto a virtual representation of the proposed development, S-City VT allows the user to immediately envisage the consequences of any decisions made, and the differences in specific scenarios, over time.

3.2 Sustainable River Pollution Management

PhiZ, developed as part of a UK Water Industry Research Ltd (UKWIR) project, has been designed to allow the assessment and communication of the relative sustainability of Phosphate management scenarios (UKWIR, 2008). The PhiZ system takes the approach of combining a number of computational models capturing the economic, social and environmental aspects of sustainability and presents this information in a virtual environment (Falconer et al, 2012; Isaacs et al., 2011c)

Previous studies have highlighted the need for a catchment scale assessment considering both point (water treatment facilities) and diffuse (inorganic fertilizers) pollution sources on phosphate levels in rivers. A number of possible scenarios relating to land management and water management strategies were devised and their environmental, social and economic impact assessed.

To determine the scenarios effectiveness at reducing the phosphate levels the current baseline situation and the impact of each scenario on the phosphate level was modelled using the INCA-P modelling system. INCA-P is a computational model that predicts water quantity and quality in rivers (Wade et al. 2001). The social, economic and environmental impacts of these scenarios were then determined using Present Value/Capita (£/capita) of interventions from the baseline positions, a CO_2

model which details the carbon cost or saving from the different management scenarios and a social acceptance indicator developed from the work of Balkema et al. (2002).

PhiZ creates a virtual representation of the river catchment and its surrounding area, incorporating the rivers tributaries and major landmarks. Figure 5 shows the river reaches and subcatchments which are colour coded in reference to water quality.

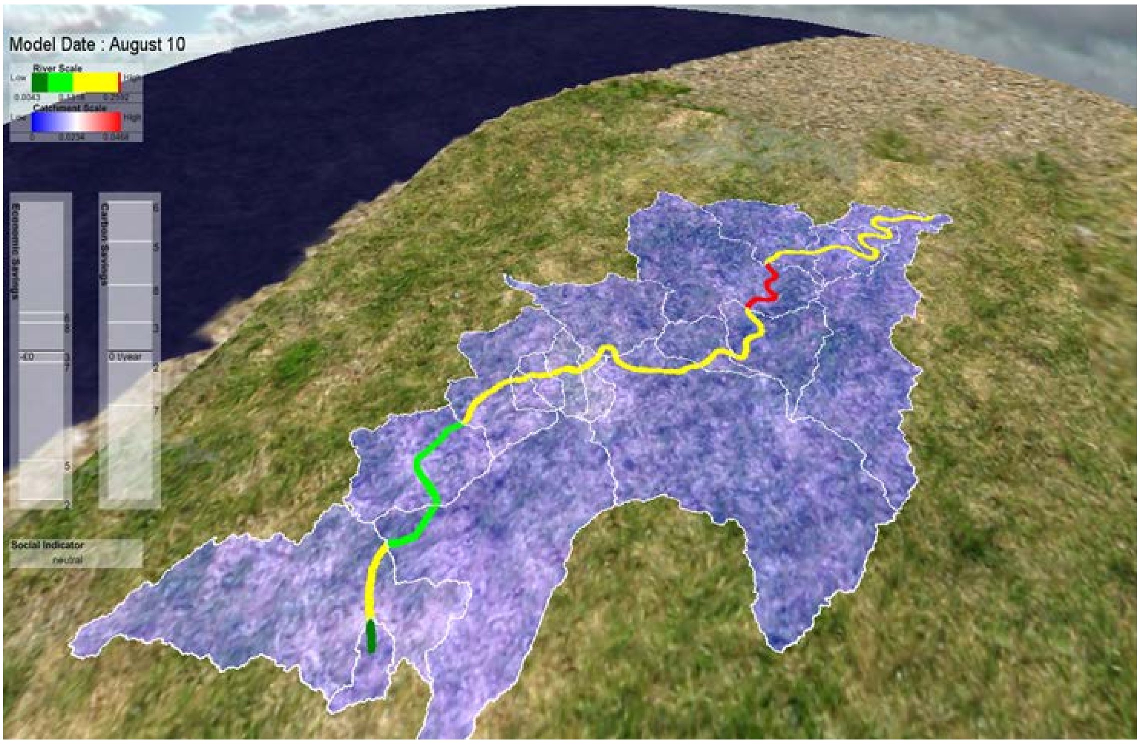

Figure 5: The main display screen of the PhiZ system.

A colour scale is used to represent the environmental quality standard (EQS) and thus show where the phosphate concentration exceeds permitted levels. In Figure 5 a simple 4 colour scale is used showing the 4 levels of the EQS: red showing poor quality (fail), amber showing moderate, light green showing good, and dark green showing excellent.

The economic and carbon cost/savings graphs show the economic and carbon savings associated with each scenario. The social indicator box provides an explanation of the social acceptability associated with a particular management option.

The model date indicator displays the current day in the INCA model run being shown on the 3D display. The stakeholders are able to move forward or backward in time using the time control, to determine if specific river reaches or treatments works have a greater impact during different seasons. But most importantly the stakeholder can easily swap between the management options and get a visual indication of the changing water quality and sustainability of the scenario.

3.3 Sustainable Land Use

RS-VT has been developed to allow a better understanding of rural sustainability and the dynamics of land cover change. These are complex issues and much research has been directed into understanding the drivers of these issues so that they can be managed and optimised providing an environmentally friendly solution that is both economically viable for farmers/stakeholders and socially acceptable (McCreadie et al, 2012).

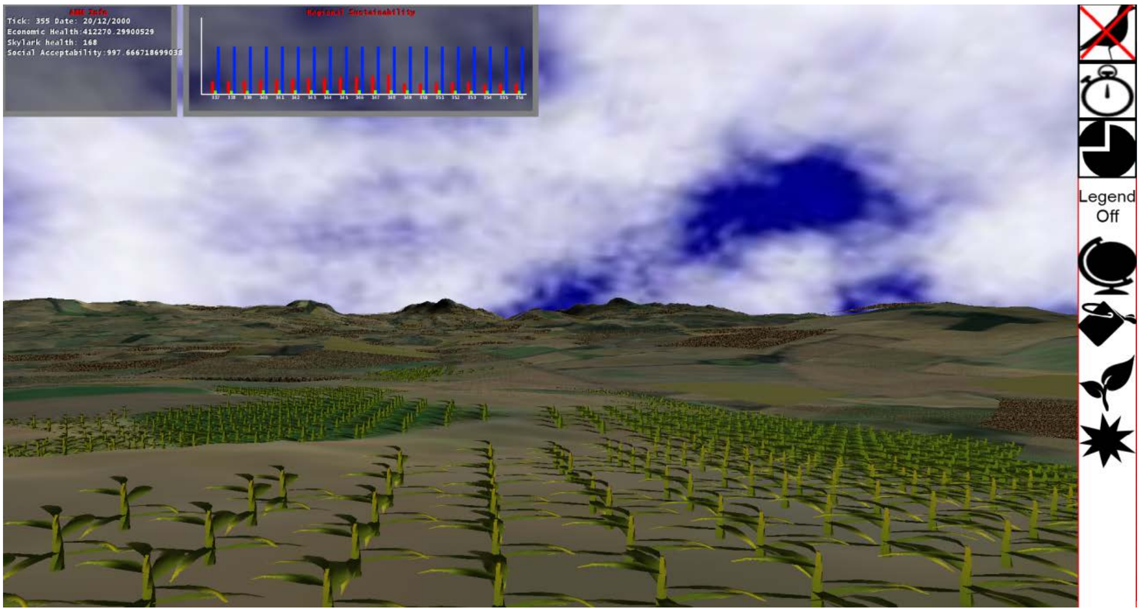

Figure 6: RS-VT showing land use changes on the Lunan River Catchment

The main modelling component that delivers data to the visualisation is an Agent Based Model that simulates the consequences of farmers decisions, manifested in the crop regime they adopt, on rural sustainability and in particular skylark population. The agent based model parameterises both animal (skylark) and human (land owners) behavioural traits which are used to create rules that each individual agent adheres to. These agents interact with each other, basing their decision making on the current state of the landscape and on the actions of other agents. The agent based model records the impact these decisions have on the overall sustainability (economic – land parcel crop price, social – acceptability of land use, environmental – attributes of land use & current skylark health) of the region.

Although there are an increasing number of examples that display in 3D the output of Agent Based Models (ABM) many lack features such as bi-directional control and dynamically changing environments. Growing crops can be rendered using artist's 3D models and hardware instancing to render thousands of models (crops, skylarks) that depict the dynamics of land use cover. The landscape depicts the crop, type, height and density in a number of different ways – colour, textures and 3D representations . The skylark population is also depicted to give an indication of the health of the ecosystem.

3.4 Sustainable Regional Planning

One of the main problems in developing visualisations for stakeholder engagement is variability of the available data. Often the data is held by different organisations, in different formats and in varying scales. The Landscape Explorer (LEX) was developed to overcome this problem, through the development of an integrated application that can parse, edit, convert and visualise a wide variety of geospatial data. The LEX tool allows stakeholders to visualize different aspects of the selected land area corresponding to the provided ordinance survey data. The tool allows users to view different

GIS map data overlays, town plans and other important data that is critical to the decision making process used by the stakeholders Figure 7.

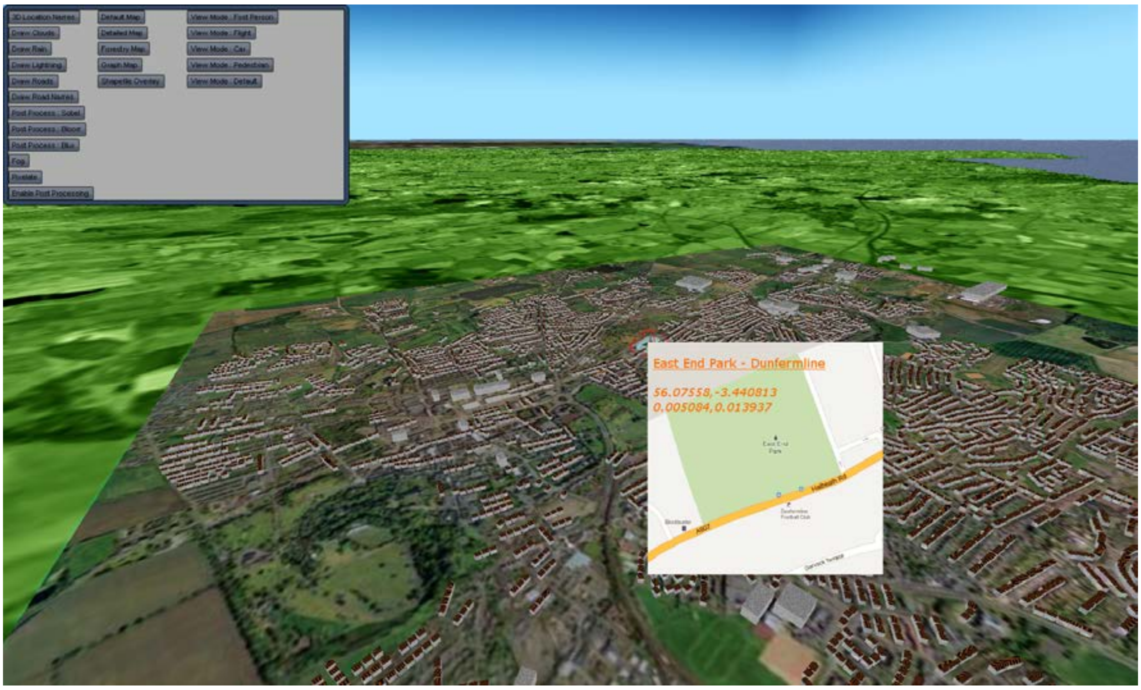

Figure 7: LEX Showing aggregation of different data sources: Aerial Photography, Google Maps and USGS Digital Terrain Models

LEX is being created using an active case study located in the north east of Scotland. This has allowed actual geospatial data, master planning and development data to be tested in the application as it is created. The application combines this data and allows the user to view the scene in real time 3D. The main viewing mode allows the user to view the scene from a birds-eye view, with the possibility to zoom out and scale the scene to the entire Scotland land region of the UK. Additionally, the different viewing modes include: a simple flight simulation viewing model, a pedestrian simulation viewing model, a car driving simulation model and a first person viewing model (often featured in many action video games). The main Scotland land areas, as well as the featured Fife land areas, are visualised based on 2D satellite image data, obtained from Google Earth and USGS. The more detailed Dunfermline land area is visualised based on the aggregated data that was provided by the Local Authority. Additional land area information for the area was also obtained from Google Earth. The LEX application is also able to simulate various environmental phenomena, such as cloud formations, rain, thunder and fog. Additionally, post processing filters with the use of real time shaders are used to provide different enhancements to the final rendered scene.

The LEX system produces an interactive 3D scene that can engage both expert and non-expert stakeholders without having to rely on the use of GIS specific software that is aimed at expert stakeholders only. The visualised data can be simplified and presented in such a way that any group of stakeholders will be able to identify the key visual elements in the presented 3D scene. These key visual elements can then be used to support the decision making process of all the concerned stakeholders (Figure 8).

Figure 8: LEX being used to display the Dunfermline and West Fife Development Plant

3.5 Sustainable coastal zone management.

Sustainable Coastal Management in practice focuses on integrated coastal zone management and is an interdisciplinary problem. In the UK there are many organisations that hold pertinent data about the costal zones. These organisations, such as environmental agencies, countryside trusts, universities and government organisations, usually will not have the data in formats which allow easy sharing and comparison across intuitions. Coupled with this the complexity of the interacting elements of coastal zone management makes it difficult for the consequences of certain actions/decisions to be fully understood.

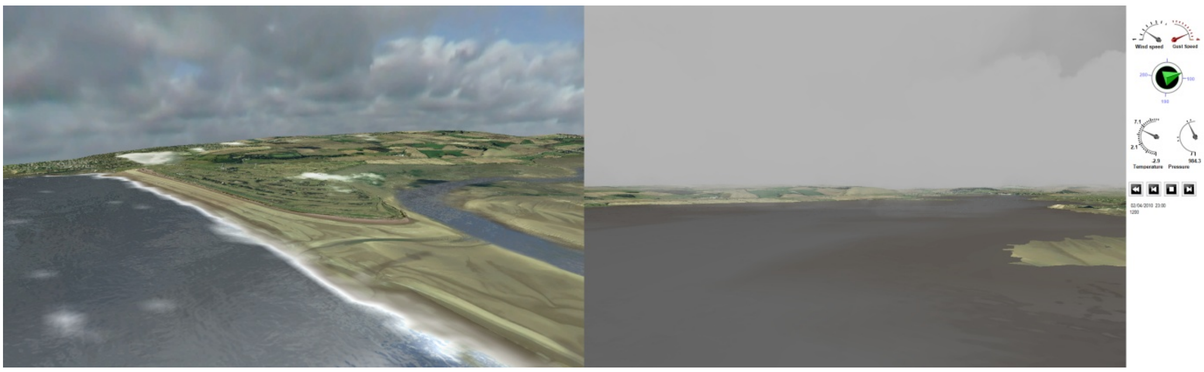

Figure 9: Visualisation of the Eden Estuary, Fife, Scotland

The data displayed in FLEX includes GIS, aerial photography, historic maps, synoptic charts, tide tables and various proprietary data formats. Figure 9 (Left) shows a recreation of the Eden Estuary and St Andrews in the FLEX system. Figure 9 (Right) shows a render of a real storm event on the estuary, the data for this event was sourced from flood maps of the area, tide tables and weather data from the meteorological office. Recreating events in this way aids the understanding how catastrophic flooding events have been in the past and also how bad they could be in the future due to poor costal management. FLEX will enable the effective engagement of stakeholders during the development of realistic scenarios i.e. hard and soft engineering for coastal defence.

4 Conclusions

The SAVE framework has been developed to provide an integrated platform to support the decision making process and to enable decision makers to identify sustainable solutions. A set of tools and techniques have been created and assembled to provide the necessary understanding of the decision making process to ensure that analytical models can be developed to provide the right information at the right time for key decision makers.

As has been discussed one of the major problems in sustainable decision making is the inclusion of all the stakeholders in the decisions being made. A decision can only be sustainable if the people who are to live, work and play in the areas the decision effects feel a part of the decision and do not feel disenfranchised by the decision makers. The example case studies detailed above demonstrate that visualisation can be used to combine a wide variety data and provide a common language for experts from different domains to communicate.

Through this type of visualisation the sustainability assessment activities of the save group can be communicated to all stakeholders regardless of background or experience. The visualisation also enhances the decision making process by allowing the stakeholders to understand the information being presented. Thus ensuring that the information collected in the assessment phases can be used throughout the decision making process.

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