Developing Sustainability Pathways for Social Simulation Tools and Services

Scoping and Business Models Report

Meik Poschen, Rob Procter, MeRC

With contributions by Mark Birkin, Alex Voss, Nicolas Malleson

1 Introduction and Aims

The aim of this work was to scope the community for needs, raise awareness and encourage adoption of new social simulation models and tools developed in the National e-Infrastructure for Social Simulation (NeISS) and gather findings, establish contacts, and build capacity for future activities.

2 Approach

The NeISS project is strongly embedded within a number of different projects and activities, section 3 sheds some light on its foundations, community and linkage with a focus on general outreach and impact. The business model investigation is aligned with five target user markets shown in Table 1: 1) Research, 2) Teaching, 3) Policy-makers and planners, 4) Public and 5) Business Organisations and is discussed in section 4.

This outreach and community scoping work started with the NeISS exemplars, especially Epidemiology, SimCity for Real and Ageing and Inequality. The aim of these has been to develop tools within NeISS for a specific application area, driven by the exemplar owners as the domain experts. For our outreach activities this meant liaising closely and to scoping the relevant community and establishing an understanding of what the general and specific needs for a social simulation infrastructure will be. Three exemplars (Virtual Exhibition Space, Credit crunch and CityDB) are public outreach demonstrators developed by CASA and will be covered briefly under general outreach activities (section 3).

Activities included following up established contacts (Demographics User Group[1]), establishing new ones (Transport for Greater Manchester[2], Oldham Council), and creating and making of training materials (website, videos, Population Simulation tool, Social Simulation Course) to raise awareness, gathering insights on the usefulness of social simulation infrastructure components, evaluating tools and training modules.

3 NeISS Project Outreach and Impact

A number of ESRC-funded projects and activities are connected to NeISS (e.g. MoSeS, GeoVUE and GENeSIS; CASA activities like SurveyMapper and MapTube; TALISMAN; details see below) and have helped to constitute and conceptualise the project, its evolution and the continuation (post-project) of ideas, methods, outputs and tools. This section gives a brief overview of the general outreach and impact created.

The main drivers for NeISS lay in previous work and existing networks and people of research groups at Leeds, London, Stirling, Daresbury and Manchester, and a number of projects and nodes within the National Centre for e-Social Science (NCeSS), funded by ESRC, namely:

- The Modelling and Simulation for e-Social Science (MoSeS, http://www.ncess.ac.uk/research/geographic/moses/) project and the Centre for Spatial Analysis and Policy (CSAP, http://www.geog.leeds.ac.uk/research/csap), University of Leeds. The foundation for a number of methods and models was laid here and further developed, re-used and refined in GENeSIS, NeISS and TALISMAN.
- The Geographic Virtual Urban Environments (GeoVUE, http://www.ncess.ac.uk/research/geographic/geovue/) project and the Centre for Advanced Spatial Analysis (CASA, http://www.bartlett.ucl.ac.uk/casa), University College London (UCL). Work on tools such as GMap Creator (and other software: http://www.bartlett.ucl.ac.uk/casa/latest/software), MapTube (http://www.maptube.org/) and SurveyMapper (http://www.surveymapper.com).
- GeoVUE and MoSeS then became GENeSIS: GENerative E-SocIal Science (http://www.genesis.ucl.ac.uk/) in a further phase of ESRC funding, with CASA and CSAP as leading centres of expertise in spatial modelling and simulation collaborating even stronger.
- The Data Management through e-Social Science (DAMES, http://www.dames.org.uk/) project and the School of Applied Social Science (http://www.dass.stir.ac.uk/), University of Stirling.

[1] http://www.demographicsusergroup.co.uk/

[2] http://www.tfgm.com/

Type of User	Size of user community	Why interested in NeISS outputs	Current functionality	Contacts
1. Research a. Geography b. Criminology c. Health sciences d. Social Policy e. Economics f. Transport g. Town Planning h. Engineers i. Research Institutes **2. Teaching** a. Higher Education b. Secondary Education c. Professional organisations **3. Policy-makers & planners** a. Schools b. Housing c. Roads/ transport d. Economic development e. Work and pensions f. Land-use planning g. Health and social services h. Police i. Central Government j. Non-Government Organisations **4. Public** a. Individuals b. Community organisations c. Special Interest Groups **5. Business Organisations** a. Retailers b. Financial services c. Property developers d. Consultants e. Utilities f. Insurance companies g. Data providers h. Intermediaries	$N=10^2$ $N=10^4$ $N=10^3$ $N=10^7$ $N=10^3$	Evaluate the impact of policies and strategies Target resources Explore relationships between activity and environment Search for evidence of spatial and temporal trends Identify opportunities Early warning systems for problems Performance assessment Justify decisions Scenario-based planning Optimise delivery Visualise distributions	REPAST MASON ESRI MapInfo MIMAS ESDS EDINA TranSims EpiSim SPSS/SAS/Stata SimCity SiModel LARIA Dr Foster MVA Saturn UrbanSim Wikipedia Ask Google OS CACI Experian Acxiom Verdict	Met Office, UK Water Industry Research Universities of Manchester, Leeds, Southampton, Stirling, Glasgow, London. Daresbury. Macauley. Liverpool. Sheffield. Villach. Arizona State, University of Illinois. Argonne. BGS. George Mason. NCG Maynooth. University of Paris. NATSEM (Canberra). DCC, LUDOS Jean Sykes (British Library). AGI. Institution of Civil Engineers, Institution of Mechanical Engineers, Institution of Engineering and Technology. DEFRA, DfT, DCLG, DECC, Cabinet Office, Infrastructure UK, Environment Agency, Highways Agency, Transport Scotland, CABE, Association of North East Councils, Hampshire County Council Mayor of London/LCC/ GLA Economics Leeds City Council Social Services/ Chief Regeneration Officer/ Chief Housing Officer Trafford; Telford; Barnsley; Bradford DWP. North-West Regional HA. Safer Leeds. Mersey Police. Yorkshire Forward; Acxiom User Group. Town and Country Planning Association, Local Government Association, Royal Town Planning Institute. Home Office. SurveyMapper. MapTube. Sainsburys; Asda-Walmart; Tesco; Planet Online. GMAP; CACI; Experian; OS; Acxiom. Scottish and Southern Energy, E.On, BP, National Grid, Network Rail, United Utilities, Yorkshire Water, Northumbrian Water, Veolia, BT. AEA Technology, Arup, Atkins, Black and Veatch, Halcrow, JBA, Mott MacDonald, MWH, Royal Haskoning, Parsons Brinckerhoff, Swanbarton. Willis. Bam Nuttal, Costain Demographic Decisions Google. PLP Architecture. Volterra Consulting.
		School of Geography, University of Leeds Letters of Support (NeISS/TALISMAN/GENeSIS). Infrastructure Transitions Research Consortium GENeSIS/ TALISMAN NeISS Partners		

Table 1: NeISS Outreach Areas (Mark Birkin).

- STFC, Daresbury Laboratory (http://www.daresburysic.co.uk/about-us/campus-partners/daresbury-laboratory.aspx); provider of the Sakai Research Support Portal (http://portal.ncess.ac.uk:8080/portal ; formerly NCeSS portal).
- Manchester eResearch Centre (MeRC, http://www.merc.ac.uk/?q=node/338), successor of the National Centre for e-Social Science (NCeSS) Hub, University of Manchester. Also: The NCeSS e-Infrastructure for the Social Sciences (NeSS) project, managed by the NCeSS Hub and funded by the ESRC.

All of the above became NeISS project partners and most of them have been involved in complementary activities since then; in this context the following list shows a selection of relevant communities and areas connected to pathways for existing and future outreach and impact:

- The **Infrastructure Transitions Research Consortium** (ITRC, http://www.itrc.org.uk/) "delivers research, models and decision support tools to enable analysis and planning of a robust national infrastructure system".
- **Research methods and teaching**: **TALISMAN** is a node of the National Centre for Research Methods (NCRM), funded by ESRC (http://www.geotalisman.org/) and again involving both CSAP and CASA. It is continuing the pathway for impact for research and teaching within the NCRM (http://www.ncrm.ac.uk/) network on methods for geospatial data analysis and simulation. Further development and deployment of NeISS services is planned through the Talisman training programme.
- **GEOG2080 teaching**: Simulation tools of planning decisions for use with u/g students have been developed at CSAP (class of 110 students; how to scale this to a social simulation infrastructure and across institutions is being explored).
- **PhD project on methods**: An ESRC studentship at CSAP ("Geodemographics: Creating a classification at the finest spatial scale") is using NeISS models as a platform for spatial analysis of outcomes.

- **PhD project on Health**: An ESRC TALISMAN studentship at CSAP is looking into "Modelling the impacts of demographic ageing on the delivery of health care services".
- **Criminology**: The JISC funded geocrimedata project (http://geocrimedata.blogspot.co.uk/) is bridging from academics to practitioners in this research domain by "taking existing geospatial data making it useful for crime analysis". NeISS models and tools could be further tailored to work with this community.
- **Housing** (housing benefits): CSAP is working with Leeds City Council on scenarios and simulations.
- **Crowd-Sourcing**: A new project collaboration between CASA and CSAP includes Twitter work and new modelling approaches based on NeISS.
- **CASA Conference**: CASA regularly (usually yearly) hosts a conference especially aimed at policy makers and the public in general (free to attend, around 200 attendees on a regular basis).

To illustrate how different projects, activities, communities and people are interlinked, here is a more detailed example from Andy Turner (University of Leeds) and Tom Doherty (National eScience Centre, Glasgow) on demographic model development and simulation work involving NeISS, GENeSIS and GridPP (as of March 2012):

> "The demographic model development work was largely GENeSIS work. In NeISS we have refactored the code so that the programs will run as part of a 'Genesis Simulator' that uses GridPP site data storage and compute elements. We have tested that the system works and have produced individual level demographic simulation results for Leeds … We are currently making some changes to enhance the model and outputs and are preparing data to generate simulation results for England from 1981 to 2011."

Activities directly connected to other NeISS work packages:

- **Transport Scenario**: NeISS developed a use case for transport[3], which has been used to illustrate the project's work in a number of user and outreach meetings (e.g. with TfGM).
- **SurveyMapper** (a free real-time geographic survey and polling tool developed at CASA: http://www.surveymapper.com/) and as an especially successful example the **CreditCrunch Survey** (http://www.surveymapper.com/mapView.aspx?id=2): The Credit Crunch Survey provided pathways to impact and public outreach examples of research services. Excellent outreach with 22,000 inputs was achieved in providing an early example of crowd sourcing in association with BBC Radio 4.
- **CityDB** (http://citydashboard.org/ is an endeavour by CASA providing an online City Dashboard/Database for viewing live data feeds.
- The **Virtual Exhibition Space** (CASA) is an online space for the display of NeISS outputs. See http://www.digitalurban.org/2012/02/data-space-agent-based-models-sketchup.html.

4 Community Scoping

4.1 Research

4.1.1 Interviews

Eight telephone interviews were conducted with international social simulation domain experts, with the aim of determining base requirements for the NeISS infrastructure, functionality and data, to scope the social simulation expert domain and to gain insight into potential benefits of using NeISS.

The Social Simulation sub-disciplines covered were social & economic, health, agriculture, environmental, innovation and transport/travel. The experts mostly work with small area or general spatial microsimulation, both static and dynamic. They work nationally and internationally, and are particularly interested in developing and comparing methods, models, outcomes and policies pertaining to social simulation, not only in the academic sector, but also in terms of consulting for policy makers.

The following main benefits of a Social Simulation Infrastructure like NeISS were highlighted:

[3] Birkin, M., Procter, R., Allan, R., Bechhofer, S., Buchan, I., Goble, C., Hudson-Smith, A., Lambert, P., De Roure, D., Sinnott, R. (2010). Elements of a computational infrastructure for social simulation. Philosophical Transactions of the Royal Society, Series A, 368(1925), 3797-3812. http://dx.doi.org/10.1098/rsta.2010.0145

- Provide web-based access to a general infrastructure and resource for microsimulation, providing generic tools and data input/output functionality.
- It is important to have a usable interface for experts and non-experts from academia and policy decision making/consulting to run microsimulations (using various datasets and algorithms).
- Foster comparison of different methods, models and outputs (also internationally long term).
- Provide links to resources, documentation (wikis) and publications.

A number of recommendations and potential caveats were also identified:

- Validation of models, methods and algorithms is essential, things have to work as expected and people have to trust the expected outputs.
- The speed with which results can be generated. To satisfy policy makers, being able to generate results in near real-time is important.
- Covering a number of methodologies and datasets would help adoption.
- Access rights policies, IPR, open access and cost models have to be considered.

4.1.2 Population Simulation Tool Exemplar

The NeISS Population Simulation tool (http://drupals.humanities.manchester.ac.uk/neiss3/content/neiss-population-simulation-guided-simulation) is a guided simulation allowing the user to run through a complete simulation workflow for a selected area of the UK and visualise the results. The simulations are guided in the sense that there are limited variables and therefore pathways to choose, but the actual computation is run live (if a previous result is not already saved); output files are available for download after each step is completed and the user can go forwards and backwards through the different steps and results, run new selections and go back to completed ones.

The tool was used as a demonstrator across various disciplines and domains. Currently, the simulation uses 2001 Census data, but it is intended to add the recent 2011 Census data when available.

4.1.3 Age & Inequality Exemplar

The Age & Inequality exemplar focuses on using social simulation for studying social inequality and developing methods to forward-project occupational and educational qualification structures in this context (social mobility and inequality: ageing population; changing family structures; educational expansion; immigrant influxes; wellbeing. A workshop on 'Simulation Analysis of Ageing and Inequality' was held at the University of Stirling to present the NeISS approach and to show how social simulation can be useful for this specific domain.

The event was followed up by five telephone interviews with workshop participants to elicit more detailed feedback on potential benefits and impact of social simulation for their research communities. The interviewees use classical quantitative statistical models and mostly longitudinal surveys/data for their research, but none used simulation techniques so far. Three potential audiences in this domain were identified, 1) the largest group would be interested in general outputs as results of social simulation; 2) a relatively small group of quantitative sociologists/economists interested in the general field; 3) groups interested in methodological issues:

Most workshop participants and interviewees agreed that making the effort to bridge the disciplinary gap between the social simulation community and other domains – especially those already using quantitative statistical methods – would be worthwhile. The following points were emphasised:

- The specific terminology around social simulation and the benefits of using such an approach have to be made clear cross-discipline: What is social simulation? How can social simulation help solving research questions and to what end? It should be presented as an additional means to tackle problems, give indications and present trends, another way of describing social phenomena.
- Validation and transparency of method and results is crucial, a kind of audit trail would be very useful (together with references and documentation) to enable reproducibility of results.

At the same time some caveats have been identified:

- The use of terminology like forecasting, prediction and social simulation is sometimes seen as too absolute or dubious within social science/sociological paradigms. If predictions are made, "there needs to be some sort of measure of both kind of the accuracy and also the kind of consequence".

4.1.4 UK Disability Estimates Exemplar

The NeISS UK Disability Estimates tool (http://drupals.humanities.manchester.ac.uk/neiss3/content/uk-disability-estimates-methodbox) is based on MethodBox (https://www.methodbox.org/) and provides a Health Survey for England (HSE) 2000 subset which can be used along with a prepared HSE 2001 data subset and cut down Census data info to calculate disability prevalence for 2001 to 2031 in UK districts. The script uses the R statistical programme and is based on the Small Area Estimation work by Dr Alan Marshall (available from http://www.ccsr.ac.uk/esds/data/).

4.2 Teaching

4.1.5 Social Simulation Course

A five day Social Simulation Course module at the North West and White Rose Doctoral Training Centres (DTC) was run in April/May 2012 (https://sites.google.com/site/socialsimulationcourse/home).

The course was primarily aimed at Social Science postgraduates and research staff, and focused on encouraging participants to think through the possibilities for applying social simulation in the context of their own research. The course introduced the methods and techniques of social simulation, including microsimulation and agent-based modelling, and discussed a number of detailed case studies ranging across the social sciences. See the social simulation module report for details.

4.3 Policy Decision Makers & Planners

4.1.6 Transport for Greater Manchester (TfGM)

NeISS arranged a meeting with TfGM in order to identify and explore possible ways in which the NeISS project might be relevant to TfGM. A follow-up meeting was held in late autumn of 2011 to further discuss mutual interests and benefits of collaboration. Based on this, NeISS contributed a letter of support to TfGM's successful bid to the DfT's Local Sustainable Transport Fund (LSTF).

TfGM uses a number of conventional, more static models for transport looking at interventions and developing business cases, but would like to improve decisions making based on more dynamic modelling and simulation. One example would be how to get information/data on people's travel, how choices are configured and might be influenced by planning and measures. The difficulty lies in building a picture on the micro-level and then putting it into the larger picture to help with decisions.

TfGM's bid to the DfT's Local Sustainable Transport Fund (LSTF) focused "around the three core themes of active travel, smarter travel information and promotion, and network efficiency" (http://www.tfgm.com/ltp3/LSTF.cfm. One focus lies in collecting (more) real life data, looking at the 'softer issues' and implications. For collaboration with NeISS: "[...] the area of most interest to TfGM at the moment would be exploring how your techniques could help analyse behavioural responses to sustainable travel initiatives [...] one item for discussion would be how we could jointly develop a research proposition for the bid, which could sit alongside the programme over the next 3 years or so."

A number of areas have been identified for TfGM to benefit from NeISS:

- Agent-based modelling would be a useful approach for addressing behavioural patterns; at TfGM Agent-based/Activity modelling is not really applied at the moment, because of its complexity and limited in-house resources.
- TfGM would benefit from insights on how to educate decision makers (the social simulation pilot module for training would be especially useful in this context) on how to configure models and interpret findings. One example would be the congestion charge.
- Potential arrangements for collaboration have been discussed: a) embedding a post-graduate with TfGM, e.g. to use specific simulation methods in a project; good results have been achieved in the past with a PhD student working on a housing market segregation model in the East Leeds Area, and looking at crime.

Further meetings with TfGM to discuss collaboration on the successful LSTF bid are currently being scheduled.

4.1.6.1 Oldham Council (Geographic Information Manager, Corporate Policy and Research)

At Oldham Council the interviewee has been working on the local information system for seven years and is concerned with tasks and functionality similar to a 'data observatory', mapping statistics down to

the small area level and providing the figures to people to use. The interviewee's research team consists of eight members, in the same unit there is also a public health team with four more people; additionally there is a separate community safety unit dealing with crime.

What NeISS offers would especially be beneficial to link up certain data sets and services for modelling for, e.g. transport, population change (ethnicity, migration models) and other data. Having projections one to two years in advance would be very useful to be able to react to developments quickly (i.e. for migration) but, at the same time, they need to look at populations with models in a range of 20-25 years. In summary:

- Having a transport scenario simulating around impacts of the extension of the MetroLink in Greater Manchester would be a very worthwhile in order to "challenge the models or challenge some of the economic assumptions that are being used across the whole economic spending pattern".
- The interviewee could see potential of the NeISS Population Simulation tool. Oldham Council, as other Local Authorities "invest quite a lot every year in surveying the same set of variables (social surveys), so being able to project those ahead reliably" would be very useful. Oldham Council are very interested in topics such as community cohesion ("big issue"), "how people feel about their local areas and crime", social and digital exclusion, health, mental health and self-reported health as well.
- The NeISS Population Simulation tool is seen as useful as is as a means to compare projections of different areas on various topics like, e.g. smoking. The interviewee tested the tool shortly after the meeting and gave valuable feedback for improvements, especially on clarifying its processes, given values and outputs.
- It was agreed that it would be useful to set up another meeting with the whole team at Oldham Council to have a more focussed discussion on how to develop/adapt models/simulations beneficial for Oldham Council. This could then be used as a proof of concept example to help understand how to create models and deliver a service that will be useful for other Councils and Local Authorities.

4.2 4.5 Business Organisations

4.2.1 Demographics User Group (DUG)

The DUG (see http://www.demographicsusergroup.co.uk/ was set up in1998 to give its member organisations a forum to discuss experiences and good practice on making use of demographic information "to analyse customers, identify markets and avoid risks [...] to target their resources to achieve maximum effect." We interviewed the founder to get an overview of DUG, to identify business problems that its members are wrestling with, and to come to ideas on how social simulation and NeISS might be of use in this context. This was followed up by a presentation focusing on Retail Planning, Demographics and CMA (customer marketing areas), their scope for modelling and potential value for predicting customer behaviour at the quarterly DUG members meeting in late 2011, which led to a discussion on the possibilities of developing modelling in new areas.

All member companies have teams involved in market analysis, customer analysis and customer insight, which involves holding huge internal customer file information databases. They are also interested in external, government datasets like the Census, on data.gov and movement surveys, and in geo-located data (mapping) in general. Commercial suppliers of data and know-how are also extensively used. Three main areas can be identified which are common for most:

- Their forecasting is quite mature for applications such as: "Where to locate stores? What should be put in those stores? What are the catchment areas? Who are the competitors? How do we access local markets?"
- Customer database analysis is used to try and identify characteristics of individual customers, based on their past behaviour in order to predict current and future needs. This ranges from financial services to various 'club cards' of large retailers to figure out what the customer might be interested in. The notion has changed to the 'single-customer view' in the sense that the history of past purchases or financial services is now linked under the individual customer's profile.
- Organising market research surveys is often out-sourced to big market research companies. The main discussion at DUG meetings in this context involves looking at branches, locations, catchments and then cross-referencing the data with the customer files. There is also an increased interest in data from the internet, although this is "rather flakier" quality-wise.

Forecasting and prediction are used in a specific way in this commercial domain as trends are looked at and decisions are made for a quite short-lived cycle; in practice, this means analysing only the next day, the next week or month or at maximum three to six months into the future (predicting sales, turnaround, customer types). The knowledge of housing developments (and therefore new customers) also is a factor. In the case of companies with fewer but bigger stores, additional forecasting in a longer-term sense can be applied to determine if, e.g. a specific region will have demand for such a store over the next 10 years.

A recurring theme in retail, which is becoming more and more important, is being aware of population movement 24/7 (i.e. mobility of the population, residential vs. workplace population, people moving around cities, transport). Over the course of a day, the behaviour by different groups can be identified, for example, starting with residents getting active very early, followed by commuters coming in and using ATMs and going to coffee shops, then disappearing into their workplaces and coming out again at lunchtime to buy things and so on. The interesting point is modelling the ebb and flow of the activities and being able to measure the impact. Mobile phones have become more and more important in this context to acquire data, find hotspots, as is tracking and mapping the bike rides within the London Cycle Hire Schemes. Map mash-ups and in that context areas of classifications are of continued interest. Here, new methods and approaches, 'plausible models or indicators' are welcome.

Overall it is fair to say that all companies collect rich and important data sets on their own, while also looking into uses of external data. They are very mature in certain areas of analysis, but find themselves in a process of continuous exploration in regard to linking up data sets, making use of new methods and understanding how they can best make sense of the vast amounts of data available and benefit from them.

- Modelling over short time periods is generally needed, longer-term forecasting could be beneficial in cases (specifically for one large retailer).
- New methods and approaches, 'plausible models or indicators' for population movement 24/7 in the widest sense (i.e. mobility, residential vs. workplace population, people moving around cities) would be of interest.
- Transport is an important area of interest, like traffic speed, road works, and the general access to areas. NeISS has produced work on transport simulation, which might be adaptable.
- Another issue lies in finding the right datasets out of the huge amount of data, for example, on the data.gov website, but also in regard to the potential that lies within companies' own 'big data' warehouses. This problem has two facets, a) to be able to find a subset of datasets of interest and b) to find better means of access and representation of the data to 'drill down' and make sense of it. It would be interesting to see how/if simulation might be able to draw on some of the data.gov data sets and make them more operational.
- In terms of business models, companies do and would buy in services for particular projects or activities they have or which they think might help them. For NeISS, this would mean they would have to see how their needs can be addressed successfully before taking the next step.
- Despite most of the large companies having their own computer centres, one of the distinguishing features about NeISS is that it offers the capability of doing large-scale and complex modelling and forecasting which in our current thinking most clients would not be able to provide themselves.
- The presentation at the DUG meeting provided an overview of urban systems and the scope for modelling. This led to a discussion of the possibilities of developing modelling in new areas, with mention of: temporary phenomena, such as changes in petrol prices, and their consequences for store catchments; recession changing consumers' behaviour; simple 'forecasts' are no longer enough, flagging the importance of econometrics & time series; impacts, ranging from local changes in store opening hours, to opening a 3rd runway at Heathrow; the relationship with behavioural economics; and consumers' mindsets "people don't know why".

5 Sustainability and Business Models

The Software Sustainability Institute has developed a list of possible approaches for sustaining research software. This can serve as a basis for the development of sustainability approaches for NeISS. Sustaining the software underlying a service is a pre-condition for sustaining a service, so each of the models for sustaining a service goes along with a number of options for sustaining the underlying

software. As services are often composed of a number of different software components, different sustainability options may apply to each of them.

The basic elements of service sustainability are operational support (system administration) and user support (Procter, Poschen and Voss, 2012). If both are in place, it is possible to distinguish a first set of sustainability options by considering who provides each of these elements when a service is maintained in full operational form (see Table 1). In addition, a full sustainability strategy would also have in place a plan for continuing development of tools and resources.

When choosing a sustainability option it is important to think about possible future developments and to ask whether the choice made today precludes other choices being made in the future. That is, choosing an approach should not simply consider a single choice but a potential sequence of options that can lead to a desired outcome.

Any given sustainability option is only feasible if a revenue stream can be identified that will generate sufficient funding to cover its costs. The JISC-sponsored Models of Sustainability Workshop (JISC, 2007) produced a set of business models for sustainability. The two categories featured are full commercialisation and open source. Their respective strengths and weaknesses are summarised in Table 2. Of course, a mixed business model, where software is made freely available as open source, but support services are provided at an additional charge to the user has become widely used in the last ten years, as evidenced by the popularity of Linux-based systems. This is the approach that we would follow for NeISS.

A number of service options have been identified, around which business models for NeISS could be developed. They are listed below in order of increasing resource demands. We have matched them to the sectors that our investigations suggest the different service options and business models would be most applicable:

- Support and maintenance: the least expensive option, but dependent on research funding, which many be intermittent, and insufficient to support improvements to existing services and development of new ones. Making the software available under a standard open source licence allows anyone to re-use it for non-commercial purposes. Community contributions become the main route to further development.
- Hosted services, where simulations are run on NeISS infrastructure: suitable for academic, public and private sectors, where requirements can be met with little or no customisation of services.
- Training services (hosted on NeISS or client infrastructure): applicable to all sectors.
- Consulting services (hosted on NeISS or client infrastructure): suitable for public and private sector clients and capable of significant revenue generation.
- Customisation services (hosted on NeISS or client infrastructure): most suitable for private sector clients, such as members of the DUG, requiring bespoke services.

The report from workshop breakout sessions also pointed to the inherent contradictions in relying on academic researchers to take the lead in ‘translation’ i.e., the embedding of prototype services in the wider user community:

> “Academia provides an optimal model for the proving of concepts, and can, under specific circumstances, demonstrate that highly integrated approaches are achievable. However, the incentive structure … demands both ongoing reinvention and a measure of isolationism and one-upmanship; the model is developer focused and does little to reward productisation of concepts that have already been proven.”

Transition to a sustainable service marks a change in purpose from one that is primarily research oriented to one that must focus on the provision of a service. For this to be successful, responsibility needs to be handed over to those who have expertise and experience in service provision (Barjak et al., 2013).

Infrastructure resourcing issues for hosted services are explored in detail in the Technical Roadmap report.

A clear majority of respondents to our Doctoral Training Centre survey thought that a reasonable fee would be in the range of £100-200 per student. Hence, running two such modules per annum with a student complement of 25 each would generate income of up to £10000 per annum, a sum that we estimate would be sufficient to maintain the existing software and infrastructure, but insufficient to develop it further. The results of canvassing of public and commercial sector clients suggest that fees for these would be of the order of £1000 per participant. This would offer the possibility of supporting

some modest levels of further development. However, it would also entail some additional investment of effort in materials to improve their quality and in service enhancements to ensure adequate levels of performance regardless of laod, including probable migration to a cloud infrastructure.

The more business models applicable, the better the opportunity for building a market. On this basis, we believe that NeISS is in a good position to generate sufficient revenue to become sustainable. We expect in the next 12 months to explore the details of these business models with the clients identified in this study.

Following on from the pilot social simulation module targeted at DTCs, we conducted a short survey among other DTCs of the market for such a module. The results are reported in the social simulation module report.

Approach	Analysis/Evaluation
Commercialisation: Migration of prototype technologies and approaches onto licensing or incorporation paths.	Strengths: o End user focused. o Enforces rigour, accountability and benchmarking. o Potentially rewarding for licensors and incorporators. Weaknesses: o Data IP is hard to bring to market, although passive revenue streams (e.g. advertising or B2B commerce) may be exploitable with sufficient accrual of data. o Software IP can be fragile and transient. Fast start up investment is required to reach capitalisation. o Feasible for near market opportunities. e-Science platforms are not near market. Niche components are. o Volatile. Market positioning effects can be detrimental to the preliminary user community in the short term. o Incorporation fragments academic research teams.
Open Source Open Development: Productisation of prototype technologies via crowdsourcing.	Strengths: o End user focused, transparent and flexible. o Low cost, low overhead (requires a website, light touch coordination and prescient governance). o Can generate robust software solutions; good technologies attract good developers. Weaknesses: o Challenging to apply to data, particularly scientific data. o Governance and focus can be points of vulnerability (risk to livelihood on not reaching market, for those implementing governance, is usually more direct under commercialisation). o Quality assurance and patching becomes difficult over time; developer base can grow exponentially with user uptake. o Resulting collage of interchangeable solutions, of uncertain robustness, can be highly confusing for the end user.

Table 2: Business Models for Sustainability (JISC, 2007).

6 Summary and Outlook

Raising awareness, scoping different communities and domains and gathering useful requirements was often a long process, but resulted in a rich picture of how NeISS can be beneficial to users. The NeISS Population Simulation Tool, as well as the collaboration with the exemplars, have been instrumental in generating interest and collaboration within the work of this deliverable and for the project.

A number of contacts could be established and new collaborations started – which opens up routes for further work (further development of the population simulation tool with Oldham Council; collaboration after successful NeISS supported TfGM bid to the LSTF; using and tailoring the social simulation course for more audiences, contexts and locations). Other activities, e.g. with businesses did not result in immediate collaboration opportunities but generated interest from participants, which can be explored further.

Overall, the community intelligence gathered provided insights into users' needs, potential benefits will be helpful in following up with new activities in the context of social simulation and for the sustainability of NeISS. Future community and stakeholder workshops would be a useful means to follow up and further foster established relationships, continue to bring different communities together,

spread the word of the usefulness of social simulation and to gather more requirements to improve and develop social simulation tools and evaluate existing infrastructures.

7 Bibliography

Barjak, F., Eccles, K., Meyer, E. T., Robinson, S. and Schroeder, R. (2013). The Emerging Governance of E‐Infrastructure. Journal of Computer‐Mediated Communication.

JISC (2007). Models of Sustainability Workshop. Available at http://www.jisc.ac.uk/whatwedo/programmes/einfrastructure/modelsofsustainability#

Procter, R., Poschen, M. and Voss, A. (2012). NeISS Sustainability Report.