Institution: Cardiff University

Unit of Assessment: 16A

Title of case study: Spatial Design Network Analysis (sDNA) – a network analysis tool for evidence-based urban planning.

1. Summary of the impact:

City plans and local urban design schemes, especially in rapidly developing countries like China, typically rest on limited evidence-based analysis. Governments are increasingly demanding better justification of such plans. This research has developed a tool that blends spatial analysis with economics into a unique methodology to appraise baseline plans and evaluate the impact of alternative urban configurations. It rests on the premise that complex information about the way people interact is mediated through a city's street network. Retrieving that information as indices and relating those indices to urban performance measures allows urban plans to be evaluated for specific outcomes.

2. Underpinning research:

The impact reported here derives from several streams of research in the School:

(a) Novel attempts to combine urban land-use models with modern economic theory. A series of now highly cited papers by Webster **[1]** (Professor 1984-2013) and Wu (Professor 1996-2010) spanning 1998-2001 explored new ways of building institutional economics into urban system performance models (funded by a Cardiff University post-doc fellowship), later developed by Wang (University of Southern California Doctoral researcher based at Cardiff University).

(b) New methods of network statistics by Shiode **[2]** (Lecturer) including new algorithms for identifying statistically significant clusters on a network (of crime incidents for example). This work significantly extends the ability to make reliable conclusions on the basis of observed spatial clusters.

(c) Developments of the economic theory of accessibility by Webster **[3]**, Orford (Senior Lecturer) **[5]** and Chiaradia (Lecturer) [**6**]. This work provides economic explanations for graph-theoretic measures of relational accessibility (ranking how close every space is to every other space). The theory explains how and why, for example, two different indices of connectivity measured from a city's grid - *betweenness* and *closeness* – can distinguish between streets that have negative and positive house price premiums and above and below average mental health outcomes, other factors being held constant.

(d) Developments of spatial metrics in epidemiology. Webster, Orford, Lee (Senior Lecturer), Shiode and Sarkar (Post Doc) **[4]** have worked with Cardiff Medical School to develop a methodology for adding built environment data (urban design, green space proximity, street connectivity, land use density, etc) to well- founded epidemiology models of heart, mental health and alcohol-related morbidities.

(e) Developments in the theory of hedonic house price modelling. Orford **[5]**, Webster, Chiaradia **[6]** and Wang (Lecturer) have long used statistical models to study the impact of urban configuration (including access to services, distance to city centre and so on) on land value and house prices. Our work is among the first to use street-network accessibility indicators to detect the impact of detracting and enhancing externalities (measured at multiple scales) on property prices (for example we have found that in Cardiff, house price is affected most powerfully by sources of positive and negative externalities located within an impact radius of 7000 metres from a house).

This body of research has come together to create a new software tool: sDNA (spatial Design Network Analysis). sDNA technically and theoretically extends UCL's highly successful Space Syntax tool by:
(a) offering an economic explanation of network performance statistics; (b) resolution of the Modifiable Link Unit Problem; (c) use of industry standard data structures and representation - OS ITN link-node; (d) a new set of spatial analysis functions related to spatial severance; (e) a new set

of control measures relating to network design problem; (f) offering open-source algorithms so sDNA can be used as a scientific tool as well as a professional design tool; (g) interfacing with AutoCAD as well as ArcGIS – the platforms of choice for professional architects and planners-spatial analyst; (h) increasing capacity and speed (sDNA is coded for super-computation).

3. References to the research (indicative maximum of six references)

1. **Wu F** and **Webster CJ** (1998) Simulation of land development through the integration of cellular automata and multi-criteria evaluation, **Environment and Planning B: Planning and Design** 25(1), pp103-126. Official URL: http://dx.doi.org/10.1068/b250103
   Research grant: Senior M (Senior Lecturer, 1993-2012) and **Webster**, ESRC grant R000222878 2005, £41,300.

2. Shiode S and **Shiode N** (2009) Detection of multi-scale clusters in network space. **International Journal of geographical Information Science** 23(1) pp75-92. Official URL: http://dx.doi.org/10.1080/13658810801949843
   Research grant: Deutsche Forschungsgemeinschaft grant awarded to **Shiode N** at SUNY Buffalo, continued when he moved to Cardiff 2008-13, £1.5M.

3. **Webster CJ**, (2010) Pricing accessibility: Urban morphology, design and missing markets. **Progress in Planning** 73(2), pp77-111. Official URL: http://dx.doi.org/10.1016/j.progress.2010.01.001

4. **Sarkar C**, **Gallacher J** and **Webster CJ** (2013) Built environment configuration and body mass index trends in older adults: The Caerphilly Prospective Study (CaPS). **Health and Place** 19, pp33-44. Official URL: http://dx.doi.org/10.1016/j.healthplace.2012.10.001
   Research grant: Fone D, **Webster** et al, National Institute for Health Research grant no 09/3007/02, 2011-2013; Webster, Cardiff University doctoral grant, £60,000, 2009-12; **Webster & Chiaradia**, Cardiff University Institute for Sustainable Places software development grant, £30,000, 2011-13.

5. **Orford S** (2002) Valuing locational externalities: a GIS and multilevel modelling approach. **Environment and Planning B: Planning and Design.** 29(1) pp105-127. Official URL: http://dx.doi.org/10.1068/b2780
   Research grant: Webster, ESRC grant R000222878 2005, £41,300, Orford EPSRC-RGS-IBG grant 2007, £2,200

6. **Chiaradia AJ**, Hillier B, Schwander C and Barnes Y (2013) Compositional and urban form effects on residential property value patterns in Greater London. **Urban Design and Planning: Proceedings of the Institute of Civil Engineers**, 166(3) pp176-199. Official URL: http://dx.doi.org/10.1680/udap.10.00030
   Research grant : **Chiaradia A** & Schwander C, iValul project £ 382,803; CIK: £ 840,991; Total: £ 1,223,794 within £5M Urban Buzz project, HEIF 3, HEFCE, DIUS, 2006-08.

sDNA has been launched as a public domain tool for wide dissemination. At the same time, we are exploring several marketable specific applications.

4. Details of the impact (indicative maximum 750 words)

The research is being used globally as a tool for providing scientific research and evidence in urban planning.

a. sDNA is being used in China. Chinese urban planners operate mostly with intuitive design skills, which are increasingly insufficient for planning development in a mixed-market land economy. The attraction of sDNA to China's army of urban planners is its ability to predict urban system performance (pedestrian and car movements and relative volumes, land use demand at different points in the urban grid, land value, and tantalisingly from our epidemiological studies, urban health

outcomes), all from network geometry. This offers the prospect of "proofing" strategic plans at all scales early on in the process of urban planning. Guoyan Zhou, director of Renew A+P Consulting, Shanghai, said "*SDNA is a great evaluation method for the analysis and decision-making on different plans in China.*" **[**Error! Reference source not found.**]**.

sDNA is being used, for example, by Renew A+P Consultants, Shanghai and Hefei University of Technology (HUT), Anhui Province, China to evaluate the spatial design of a major growth corridor in the city of Huainan, part of a plan to accommodate another 1.2 million people in the city; and by Tongji University design institute planning consultants to evaluate accessibility and economic performance of underground parts of cities.

b. The network approach to urban plan evaluation has been widely disseminated across China by the Cardiff team via keynote and invited speeches to large and high profile audiences. Together with the Space Syntax team at UCL and the MIT network analysis team, it has triggered new conversations, expectations and research among the professional and academic urban planning communities. On the basis of this research, Webster has been appointed, for example, to the influential Wuhan Urban Research Network, a cross-disciplinary expert forum giving strategic guidance to the economic, social and spatial growth of this city of 10 million.

c. sDNA has been used by consultants BRS (France) and dEp (UK) **[1]** to prepare spatial planning policy and an investment plan in one of Paris' five new towns (150,000 inhabitants). sDNA helped appraise community severance resulting from alternative spatial strategies. Impacts include: a plan

that more efficiently guides spatial development over the plan period; creation of a 1400km detailed pedestrian network model as a basis for the severance study (a world first in the sophistication of an analytical base for pedestrian/walking-oriented urban planning); a location plan for a new, light, and rapid transit option for this community as part of the Grand Paris multi-billion Euro regional transport project.

d. sDNA has been used by Arup **[2]**, in its preparation of a spatial strategy plan for Wiltshire County Council, with (Westminster Government) Homes and Community Agency funding. The action research involved creating a new methodology for a high resolution pedestrian network model. Currently detailed pedestrian networks in UK towns and cities are not readily available. The pedestrian model was used for evidence-based appraisal and evaluation of alternative town development strategies. Impacts include: Guiding spatial development with greater efficiency over the plan period of a market town centre in the UK; suggesting new strategies that might have otherwise been overlooked (town extension impact); providing a greater evidence base with a stronger technical narrative to lower the transaction costs of plan preparation and adoption; making planning strategies for different towns more consistent by virtue of a common analytical approach.

e. sDNA is being used in partnership with Cardiff University Medical School and with the UK Biobank project based at Oxford University to introduce objectively measured built environment indicators into analytical epidemiological models and public health debates. The UK Biobank is a major national health resource, with the aim of improving the prevention, diagnosis and treatment of a wide range of serious and life-threatening illnesses through data on 500,000 people. Funded by UK Biobank, sDNA is producing over 100 built environment metrics (epidemiology-modelling quality) for each of the Biobank"s 500,000 cohort members. This creates the world"s largest and most sophisticated cohort study for gene-built-environment studies of disease in the community. As a result of this work, the sDNA team is working with the Coalition Government"s Chief Planner (at the Department for Communities and Local Government) and with the Royal Town Planning Institute **[3]** to explore new protocols for evidence-based urban planning. An agreement has also been reached with the Dean of Medicine at the University of Hong Kong to apply sDNA to three big public health science cohorts in China. This collaboration has now started. In April 2013 the UK Biobank funding was supplemented by one of ESRC"s Transformative Research grants to conduct 'Urban WHealth modelling' at UK level.

f. sDNA has provided the methodological basis for several major funded research projects closely linked to policy making agencies, with several others under discussion. For example, in July 2013 the Turkish Government awarded a significant grant to a team based at Gazi University Ankara, Istanbul City University, Cardiff University and Hong Kong University to study the optimal timing sequence of residential and retail development by the municipality of Ankara and Istanbul using

sDNA **[5]**. This project will help guide the work of Istanbul's powerful new Urban Transformation development agency as it sets about spatially re-configuring a massive 75% of the city's fabric. Istanbul has 14 million inhabitants and this is the largest ever application of the tool of land readjustment (temporary expropriation, redevelopment, reorganising property rights and reallocation pro-rata less a fraction to cover cost of redevelopment).

g. In 2013, sDNA was presented within a suite of three–level walking modelling framework by an independent transport planning consultant to a network with over 300 industry professionals from the UK and Ireland at the 11th Annual UK Transport Practitioner Meeting, Birmingham and at the international conference Walk 21, Munich, with 500 delegates from health, transport and planning professionals who are working increasingly together throughout the world to deliver more liveable and successful places. On both occasion the audience consisting of transport modellers and other practitioners who work with modellers found the three-level framework useful as a way of conceptualising different stages of analysis in a design and planning process. The audience was very receptive and appreciative of the framework and of sDNA capacities **[**Error! Reference source not found.**]**.

h. Following advice from transport professionals Welsh Government funding (£5k) has been secured by Cardiff University's Research, Innovation & Enterprise Services to support market research targeting sustainable transport professionals which will direct the further development of sDNA software. This is not published on website due to the sensitive nature of these commercial projects.

i. sDNA has been competitively selected to be used by iSolve 2013-14, a programme developed first at MIT in Boston and then extended to Cambridge University, this exciting concept has now been successfully developed at Cardiff University. iSolve allows entrepreneurial postgraduates and researchers to work with real inventions in order to determine the best route for their further commercialisation and impacts **[7]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Testimony from the Director at Renew A+P Consultants (Architecture and Planning), confirms the use and usefulness of sDNA for proofing strategic spatial planning in China.
2. Testimony from a Partner at BRS, confirms the use and usefulness of sDNA in planning and urbanism projects in France.
3. Testimony of the Urbanism and Landscape Leader, Arup confirms the use of sDNA to appraise and evaluate strategic spatial planning options in the UK.
4. Testimony of the CEO, Royal Town Planning Institute, confirms the transformative nature of approaching planning from health afforded by the use of sDNA.
5. Confirms the use of sDNA by large local planning authority, the Municipality of Ankara and the Municipality of Istanbul. http://websitem.gazi.edu.tr/site/bozuduru/posts/view/id/84013
6. Testimony of an independent transport professional, confirms the wide transport professional interests for sDNA for sustainable transport planning and the use of sDNA in sustainable transport planning in the UK.
7. http://sites.cardiff.ac.uk/cuenterprise/about-2/isolve/current-projects/ confirms the selection of sDNA for iSolve