Research Assessment Exercise 2020 - Impact Case Study

University: The University of Hong Kong
Unit of Assessment (UoA): 18 – Planning and Surveying (land and other)
Title of case study: Spatial Design Network Analysis (sDNA): improving design analytics for evidence-based planning and design

(1) Summary of the impact

More pedestrian- and walking-oriented space will make cities more sustainable, energy efficient, healthy and liveable. The next generation Spatial Design Network Analysis (sDNA) software of HKU Faculty of Architecture (FoA) has been used by urban designers in Shanghai, Paris, London and Hong Kong (HK) to generate analytical evidence in arguing for more pedestrian- and walking-orientated space in their designs. The FoA team estimates that sDNA-enabled projects have benefitted up to five million residents by offering viable, well-planned alternatives to car use. In another domain, sDNA has been applied in innovative public health analytics. It has enhanced the modelling power of the UKBiobank, a flagship epidemiological resource, by adding 700 high resolution, objectively measured built environment (BE) metrics for each of the cohort's half a million subjects. The UK Biobank is now the only national-level cohort study to have a wide range of measures covering all four pathways to disease impact and prediction: genome, built environment, natural environment, and social environment. FoA research has generated a platform that for the first time allows public-health analysts to build standardised measurements of the BE into their models of healthy cities. sDNA exists as an open source standalone analytical tool, or a free plugin for proprietary software.

(2) Underpinning research

This comprises two categories: (i) research into the relationship between network analysis and urban performance; and (ii) computation and technical research that implements models of urban network analysis suitable for scientific and professional use. These are elaborated as follows.

(2.a) Underlying urban science. sDNA quantifies and compares the relative efficacy of urban network layouts for pedestrian, cycle, road or rail movements. FoA researchers have established strong statistical associations between a city's socio-economic performance and the configuration of its urban road and pedestrian movement grids **[a-f]**. They have used large-number studies (for statistical power) to show the associations between network design and individual health **[d-e]**, property prices, housing sub-market formation **[a]**, street walkability, social and transactional opportunities **[f]**, traffic externalities **[c]**, three-dimensional urban design performance **[b]**, and the effectiveness of green spaces on walking choice and health **[e]**. These studies have shown that the geometric and topological information that sDNA measures can be used as a proxy for urban socio-economic performance on these various dimensions. The team has published papers in leading science journals such as Lancet Planetary Health, for example, on the influence of urban design on Type II diabetes, obesity, mental health and, cardio and pulmonary disease; and also to publish in top urban journals on the influence of sDNA-measured network design on people movement, land values and the use of the tool predictively to analyse urban plan performance. This underlying research (2015-present), provides the scientific credentials of sDNA for its users.

(2.b) Second is the **computational and technical research** behind sDNA. The research team's contribution is significant in the world of urban design and transport analytics because it improves upon the three-decades old established market-leader, UCL's successful Space Syntax software. Space Syntax was built to support architectural urban design work. It was lacking transparency in its code, scientific credibility, industry-standard representation methods, advanced geometric analysis features, suitability for 3D analysis and so on. **sDNA was built to address such issues and provide a brand-new approach to urban design analytics while at the same time producing a scientifically credible tool to use in the fast-growing interface between urban design and public health.** An early version of sDNA was released in 2012, when three of the HKU team were at Cardiff University. The team moved to HKU between 2013 and 2016 and began releasing innovations in November 2014. These include the following. **(i)** An **innovative algorithm for measuring movement friction and centrality in a network,** combining Euclidean and geometric measures, which outperform

previously used network friction metrics empirically [b] and **is more consistent with behavioural wayfinding theory. (ii)** An innovative **true-3D data representation and analytical algotithms,** developed and empirically tested [b], which is important in under-researched multi-level Transit Oriented Development (TOD) urban design schemes, increasingly used as a transport and planning strategy across the world. **(iii)** Use of **industry standard data structures** and mapping representation [c] facilitating use by researchers and professionals across urban, transport planning and design domains. **(iv)** These developments were shaped by multiple consultations with user communities including: at a three-level transport analysis workshop with industry professionals at the Annual UK Transport Practitioner Meeting, Birmingham (2013), London (**2014, 2015**); at the international conference Walk 21, Munich (**2014**), Vienna (**2015**) and HK (**2016**); and at the European Transport Conference Frankfurt (**2014**) with more than 500 delegates from health, transport and planning professions. **(v) sDNA scaling-up to support a city-wide digital data platform was tested in the building of a 2D/3D** pedestrian route model for the whole of Hong Kong [b] co-produced with HK Government's Lands Department and adopted by them in 2019 as the model for active travel planning in HK. **This is the first industry-standard 3D pedestrian network of an entire city anywhere in the world.**

(2.c) Staff at HKU (**Webster C**, Chair Professor in Urban Planning and Development Economics, HKU 2013-present, Cardiff University 2000-13; **Chiaradia AJF,** Associate Professor in Urban Design, HKU 2016-present, Cardiff University 2010-16, UCL 2000-09; **Sun G**, Assistant Professor, HKU 2016-present; **Sarkar C,** Assistant Professor of GIS, Urban Health and Environment, HKU 2014-present, Cardiff University 2010-14) have conducted a series of competitive externally and internally funded research projects structured within the team's original economic theory of accessibility and its own original spatial epidemiology and public health theory of accessibility [e]. This research, which commenced at Cardiff University in 2010, received funding from an Economic and Social Research Council (ESRC) Transformative Research grant (2013-14), administered from HKU, and has since been developed in collaboration with Cambridge, Oxford, Shenzhen, and Tongji Universities, and with planning and transport consultants including WSP and ARUP UK and HK, Civic Exchange, and HK Government departments (Lands, Planning and Transport).

(3) References to the research

[a] Xiao, Y., Orford, S., and **Webster, C**. (2016) **'**Urban configuration, accessibility, & property prices: a case study of Cardiff, Wales', *EPB: City Science & Urban Analytics*, 43(1): 108-129. [DOI: 10.1177/0265813515600120]

[b] Zhang, L. and **Chiaradia, A**. (2019) 'Three-dimensional Spatial Network Analysis and Its Application in a High-Density City Area, Central Hong Kong', *Urban Planning International*, 34(1): 46-53. [DOI: 10.22217/upi.2018.513]

[c] Wedderburn, M. and **Chiaradia, A**. (2014) 'Network, Network, Network: New Techniques in Pedestrian Movement Analysis', *In 42nd European Transport Conference, Association for European Transport (AET)*, 29 Sept- 01 Oct*, Frankfurt,* 1-13.

[d] **Sarkar, C.**, Gallacher, J., and **Webster, C.** (2015) 'UK Biobank Urban Morphometric Platform (UKBUMP) – a nationwide resource for evidence-based healthy city planning and public health interventions', *Annals of GIS*, 21(2): 135-148. [DOI: 10.1080/19475683.2015.1027791] **2014 RTPI Research Excellence Award.**

[e] **Sarkar, C.** and **Webster, C.** (2017) 'Healthy Cities of Tomorrow: the Case for Large Scale Built Environment–Health Studies', *Journal of Urban Health*, 94(1): 4-19. [DOI: 10.1007/s11524-016-0122-1]

[f] **Sun, G., Webster, C., and Chiaradia, A.** (2017) 'Ungating the city: a permeability perspective', *Urban Studies*, 55(12): 2586-2602. [DOI: 10.1177/0042098017733943]

Research grants awarded: Chiaradia A. (Co-I), *Strategies for Enhancing Walkability in HK via Smart Policies, Strategic Public Policy Research Fund*, 2017-2020 (HK$ 3.5 million).

(4) Details of the impacts

sDNA, is being used to provide analytical evidence globally in support of policy and design that is more friendly to the environment, healthier for city inhabitants, economically more beneficial for

commerce and home-owners, and more consistent with lively, viable urban streets and spaces. Since releasing sDNA for open source Geographical Information System QGIS at the beginning of 2016, **the annual rate of new licence registrations tripled between 2014 and 16. By 2018, the number of sDNA-QGIS software/license downloads had increased 20-fold to ≈ 12,000** compared to 17,500 for its long-established competitor Space Syntax. The geographical split of downloads is: Europe (22%), China (16%), North America (6%), with the remaining 56% spread globally.

(4.a) Examples of Hong Kong impact. HK has one of the highest metro ridership rates in the world and has given the world its famous model for land-based transit investment finance through high density TODs; both made possible by its highly dense pedestrian network. **Until 2017, however, HK was without a pro-walking policy or an underlying data-platform to support such a policy. FoA's walkability team, using sDNA technology, has provided that platform**. In 2016, the international conference Walk21 promoting walkability worldwide was organised in HK and attended by the Government Chief Executive, who made a policy pledge on Walkability [1]. **The sDNA-enabled WalkableHK project, the world's first 3D digital pedestrian route-map for an entire city, won the Walk21HK CityTech Award**. In 2017, the Chief Executive committed to improving walkability across HK. This was followed by a range of walkability consultancy commissions. The FoA team, in partnership with HK Lands Department (LandsD), with a HK$ 1.4 million contract, developed a 3D integrated outdoor-indoor pedestrian network map for healthy city modelling for the whole of HK. **This geo-database, handed over by the HKU team to government LandsD in early 2019, is now the *de facto* pedestrian digital standard infrastructure for HK government's Transport (TD) and Planning (PlanD) Departments' walkability initiatives** and will benefit the whole of HK for many years to come [2]. Relatedly, transport consultancy MottMac (HK$ 14 million project) and ARUP HK (HK$ 7 million project) were commissioned by TD and PlanD to formulate a planning and design standard based on pedestrian-first principles for developing HK into a more walkable city. These are using FoA's 3D sDNA-enabled pedestrian network model of Central HK to prototype and test the following. 1) walkability improvements impacting daily on more than one million people as part of a three-year HK-wide walkability programme and alternative option by Benoy. 2) a Pedestrian Connectivity Analysis Application for the Built Environment Application Platform to appraise all future pedestrian projects [3]. At another scale, HKU's sDNA team collaborated with Cistri [4] on the first "Places Impact Report" (2019) of Swire Properties, a leading international property developers and global sector leader in Global Real Estate Sustainability Benchmarking [5]. The study focused on office-led TODs in Taikoo Place areas in HK (100,000 residents + commuters) and as a pilot impact methodology, it is guiding Swire Properties future 'place developments' in HK and worldwide [6].

(4.b) Examples of Mainland China impact. sDNA is being used across Mainland China. The attraction of sDNA to China's urban planners is its ability to predict urban system performance, including pedestrian and car traffic volumes, land use demand at different points in an urban grid, land values, and urban health outcomes. sDNA analysis provides the "proofing" of strategic plans from early in the process of planning and design to modifications at the time of consultation and implementation. *Tongji University Planning and Design Institute (TJUPDI Shanghai)* and *Shenzhen University Design Institute* consultants, for example, are currently using sDNA to evaluate accessibility and economic performance of TODs [7]. **As a result, many implemented urban master plans have included urban grids that are sDNA-proofed for greater walkability. The impacts will remain in China's cities for decades if not centuries to come.** These two institutes are huge players in Chinese master planning, with TJUPDI (established in 1996 as a practice based platform of Tongji University) having over 200 full-time urban planners and designers who have prepared about 40% of the master plans for China's major cities. Tongji University has co-funded some sDNA technical refinements for 3D urban design. **Thus, FoA has provided a scientifically validated urban analytics tool kit for one of the most prolific and respected master planning agencies in the world and sDNA has led to the hard wiring of walkable, sustainable, healthy environments into Chinese cities for generations to come**.

(4.c) Example of EU & US Impact: in 2014 consultants BRS (France) and dEp (UK) completed a study contracted by the Planning Authority of St Quentin-en-Yvelines [8] (230,000 inhabitants, 145,000 workplaces), to appraise walking and cycling investment plans. The sDNA-3D enabled applied research created a 1,400km pedestrian network map as a basis for a road-transport community severance study. **An sDNA-enabled routing app was also developed for impaired people (visual, physical or cognitive), which won the 2014 Paris-based Mobility Award** [9]. The 15- year investment plan aimed to reduce urban rail infrastructures severance around TODs for pedestrians and cyclists. sDNA analysis showed that the compounding of cycling and walking investments was not effective for pedestrians. **sDNA analysis prevented the construction of ineffective pedestrian infrastructure** and prevented the wasting of resources for this major redesign of part of one of the world's great cities. **For UK and US see [10]**

(4.d) sDNA's impact on Public Health analytics: sDNA has been used by the *UK Biobank* project based at Oxford University to develop innovative objective and standardised BE indicators. **Through the many studies that have now used the public–domain sDNA-enhanced UK Biobank (UKBUMP – or UK Biobank Urban Morphometrics Platform), sDNA metrics have been adopted into analytical epidemiological models and public health and wellbeing debates worldwide.** The UK Biobank, an independent non-profit organisation, is a major national and international health policy and science resource. It aims to improve the prevention, diagnosis and treatment of a wide range of serious and life-threatening illnesses through data on 500,000 people. A UK Biobank grant (**2013-2017**), run from HKU FoA, enabled the sDNA-based production of a uniquely accurate set of new BE metrics (epidemiology programme standard quality) for each of the Biobank's 500,000 cohort members. According to Nature, UK Biobank creates an "unprecedented open access database that has enabled order of magnitude larger studies on genetic and epidemiological associations for an extensive range of health related traits" and opens "a new era of health research". **The sDNA team has converted the UK's flagship national epidemiology cohort study into a full gene-environment (built, natural, and social environment) platform.** This is something of a holy grail for public health and healthy city analysts, practitioners and policy makers, since it covers the four principal pathways to health/poor health. **No other study globally has this quality of BE data in a form that can be matched with individual health records and subjects' personal DNA.** Since there is no way to prove the end user impact of the sDNA-enabled UK Biobank platform on health, we can only point to the intermediate impact and claim that HKU's sDNA researchers have made it possible for the UK Biobank to support four-pathway epidemiology studies, with sDNA-enabled BE epidemiology models having been used by healthy city analysts and practitioners as reported in leading health journals, such as the American Journal of Epidemiology, British Medical Journal and Lancet Planetary Health.

(5) Sources to corroborate the impact

[1] Walkability a shared vision, Hong Kong's Information Services Department, 3 October 2016. [https://bit.ly/2mnxZY9]

[2] HK SAR Lands Department contract

[3] Testimony of ARUP HK and Benoy Urban Design.

[4] Shaping Cities and Communities, CISTRI [https://cistri.com]

[5] Swire Properties Joins Dow Jones Sustainability World Index (DJSI World), Swire Properties, 21 September 2017. [https://bit.ly/2lTBENc]

[6] Swire/Cistri scope of work KE contract.

[7] Testimony from Shanghai Tongji Design Institute (TJUPDI) and Shenzhen Design Institute (SUIAUPDR) confirms the use of sDNA for proofing strategic spatial planning in China.

[8] Testimony from St. Quentin en Yvelines Planning Directorate, confirms the use and usefulness of sDNA in planning and urbanism projects in Paris

[9] Découvrez les lauréats des Trophées 2014, Plan de déplacements urbains Île-de-France, 2014. [https://bit.ly/2lWzxbr]

[10] Testimony of transport and urban design professional, Wedderburn, ARUP UK sDNA license, Foster and Partners use sDNA for sustainable transport planning and design (UK, US & Japan).