Institution: Manchester Metropolitan University

Unit of Assessment: D32 Art and Design: History, Practice and Theory

Title of case study: A methodology for complex sustainable futures: disruptive technologies in urban transformation

Period when the underpinning research was undertaken: 2013-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Pok Yin (Eric) Cheung	Senior Research Associate	2016–present
Solon Solomou	Research Associate	2017–present
Sigita Zigure	Research Associate	2017–present
Mahmud Tantoush	Research Associate	2018–present
Robert Hyde	Senior Lecturer	2012–present
Ulysses Sengupta	Reader	2013–present

Period when the claimed impact occurred: 2013–2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

The CPU Lab develops system-level approaches and computational models to assess implications of disruptive technologies in urban transformation to inform 'ex-ante' strategic policy formulation. In collaboration with public bodies and civic leaders, the Lab utilises technologically advanced data modelling and simulation to understand and explore urban transformation, enhance the ability of policy makers to undertake data-led smart city planning, and co-create citizen choice for future mobility strategies. Funded collaborations with partners in the North West have shaped strategic policy formulation that 1) informed the development of Manchester's digital strategy; 2) incorporated IoT data in Smart City mobility planning; 3) integrated Connected Autonomous Vehicles into TfGM's Future Mobility Strategy; and 4) guided the sustainability agenda of one of the largest regeneration projects in the UK (the Northern Gateway Strategic Regeneration Programme) through new forms of technology-driven architectural design practice via CPU-Ai. Supported by an interdisciplinary network in Brazil, China, Japan and the UK, the Lab ultimately co-produces intelligent decision making towards sustainable and liveable cities.

2. Underpinning research

Established by Hyde and Sengupta, Complexity Planning and Urbanism (CPU) encompasses the CPU-Lab, an externally funded research laboratory, and the linked CPU-Ai Master of Architecture Atelier. Based in Manchester School of Architecture (8th in QS World Rankings, 2020), the Lab explores urban transformation through the development of innovative digital tools based on complexity theory. Complexity theory allows simulation of, and experimentation with, previously impracticable temporal urban phenomena. Sengupta has developed a body of knowledge in urban studies aimed at understanding real-world phenomena characterised by temporal change, unpredictability, adaptation and evolution **[1]**. By synthesising multiple concepts and terminology from the complexity sciences into an effective conceptual framework for the urban context, Sengupta establishes insight through methodological experimentation thereby expanding the frontier of the field **[2]**. Research identifies patterns and mechanisms of change, linking cities and diverse socio-technical and social-ecological systems. Through CPU-Ai it also involves the design of new forms of intervention towards sustainable future cities. The research impacts on the co-evolution of governance and design practice in relation to Future Cities; Smart Cities; the Internet of Things (IoT); agile governance and cities as complex adaptive systems.

The EU H2020 funded (EUR22,000,000) *Synchronicity* project elucidates the pitfalls of technological surveillance, control, exclusion and corporate control over private data, while exploring new models of agile governance enabled new developments in urban ICT, Big Data and an urban Internet of Things. Sengupta's underlying research examines the potential for ICT technologies to contribute towards new processes of participation and co-evolution supporting citizen agency in cities **[3]**.

Future possibilities of Connected Autonomous Vehicle (CAV) integration into cities is a particular research focus through computer simulation and computational discourse analysis based on socio-technical transitions and emergence. Alternative trajectories and related impacts of new mobility services enabled by CAVs are examined in terms of advantages and disadvantages to different stakeholders (government, citizens, mobility service providers). The Innovate UK funded *Synergy* project (GBP5,000,000) has enabled Solomou, Zigure and Sengupta to determine potential impact of CAVs on cities **[4]** and has contributed directly to Greater Manchester's (GM) strategic transport policies.

With the growth of ICT technologies and multi-player online games, urban planning and future city research has seen an increasing interest in urban games for citizen participation and engagement. However, there is a growing critique on (i) engagement based on the limited game design experience of 'serious game' designers; (ii) the growth of GIS embedded Location-Based Mobile Games (LBMG) blurring distinctions between virtual and 'real' urban space and creating a more fluid 'hybrid reality'. The complexity paradigm informed research by Sengupta, Tantoush and Cheung into the LBMG *Ingress* (over 20 million global players) resulted in the first published research which pioneers a new methodology cross-referencing Mechanics-Dynamics-Aesthetics analysis (game studies) and a hybrid realities theoretical framework (urban studies) to identify key mechanisms affecting gameplay, leading to altered practices in the city **[5]**.

Historic urban planning and spatial design practices have limitations when addressing complex spatio-temporal aspects of our cities. Research on methods to address urban transformations is evidenced through collaboration with the Association of European Schools of Planning (AESOP), the International Federation for Housing and Planning (IFHP), the European Council of Spatial Planners and the International Society for City and Regional Planners. Led by Sengupta, the findings **[6]** demonstrate the development and potential use of non-deterministic computational modelling (BBB Generator) in simulating urban territories (Bromley by Bow, London) in states of rapid change to comprehend and test the possibilities of spatial and policy interventions. The digital tool introduced young planners to complex systems and digital tool-based approaches in the Third European Urban Summer School: Times of Scarcity, London.

3. References to the research

1. **Sengupta, U**., 2017. 'Complexity Theory: The urban is a complex adaptive process'. In Iossifova, D., Doll, C. and Gasparatos, A. (eds.) *Defining the Urban*, Routledge. ISBN 9781472449528
2. **Sengupta, U**., Rauws, W., De Roo, G., 2016. 'Planning and Complexity: Engaging with temporal dynamics, uncertainty and complex adaptive systems', *Environment and Planning B: Planning and Design*, 43(6):970-974. In **Sengupta, U.,** Rauws, W., De Roo, G. (eds.) 2016, 'Planning and Complexity'*, Environment and Planning B: Planning and Design* 2016, Vol. 43(6). https://doi.org/10.1177/0265813516675872
3. **Sengupta, U**., 2017. 'ICT, Open Data and the Internet of Things: Potential future trajectories in urban planning'. In De Roo, G., Yamu, C., Dewisch, O. and Poplin, A. (eds.) *The Virtual and the Real in Planning and Urban Design: Perspectives, Practices and Applications*, Routledge. ISBN 9780367208509
4. **Solomou, S**., **Zigure, S**., **Sengupta, U**. et al. 2018-20. Synergy – Connected Autonomous Vehicles selected reports. D7.2 Discourse Analysis Report: Autonomous Vehicle Concerns; D7.3 & D7.4 Urban Simulation: Resource Competition and Service Performance Model.
5. **Sengupta, U., Tantoush, M**., Bassanino, M., & **Cheung, E**. (2020). The Hybrid Space of Collaborative Location-Based Mobile Games and the City: A Case Study of Ingress. Urban Planning, 5(4), 358-370. doi:http://dx.doi.org/10.17645/up.v5i4.3487

6. **Sengupta, U.**, Cheung, E., 2013. 'Acknowledging Complexity in Continuous Urban Change'. In Iossifova, D. ed. *Architecture and Planning in Times of Scarcity: Reclaiming the Possibility of Making the City*, p. 221-229. Softgrid Limited in association with AESOP & IFHP.

Funding (full project values):

G1. ESRC Strategic Network: Data & Cities as Complex Adaptive Systems DACAS GBP100,799
G2. EU H2020 funded project *Synchronicity* EUR22,000,000
G3. Innovate UK funded project *Synergy* GBP5,000,000
G4. Innovate UK funded project *CityVerve* GBP16,000,000

4. Details of the impact

Drawing on the complexity sciences as a cross-disciplinary theoretical base for its research, the CPU-Lab harnesses the potential of computational modelling to explore the impact of disruptive technologies in urban transformation, Smart Cities and Future Cities. The research has direct impact on urban policy makers at the strategic policy formulation stage (ex-ante) and innovative design practitioners, working towards more sustainable and liveable future cities.

A complexity approach to smart and sustainable cities of the future: As founding members of the ESRC-funded Data and Cities as Complex Adaptive Systems (DACAS) strategic network (GBP100,799) with the University of Tokyo, Imperial College London, University of Aberdeen, Wuhan University, University of Sao Paulo and University of Manchester, the Lab has generated agenda-setting impact on researchers and policy makers for sustainable development through promotion of a transdisciplinary approach to urban transformations. DACAS has established enduring connectivity with public bodies and civic leaders including Manchester City Council (MCC), RIBA, Future Cities Catapult (now CPC), Transport for Greater Manchester (TfGM) and government stakeholders in Brazil, China and Japan. As one of the most respected global policy brief publishers on issues of sustainability, collaboration with the United Nations – Institute of Advanced Studies led to the production of the international policy brief 'Sustainable Smart Cities: Applying Complexity Science to Achieve Urban Sustainability' co-authored by Sengupta and Hyde. This engages critically with technology provider-led implementation strategies for Smart Cities and identifies practical policy steps for government actors to empower citizen-led, bottom-up sustainability agendas. It is the most viewed and second most downloaded (across three languages) UN policy brief in the series **[A]**.

Informing the development of Manchester's digital strategy: In the *Synchronicity* project, the Lab worked collaboratively with MCC and Bronze Labs (a technology SME) to test integration of the use of IoT/urban data for agile local governance and strategic policy formulation. Within Manchester, the Lab reported on the low data availability and integrity via the existing *CityVerve* legacy city data platform and supplementary data sources. A collaborative approach exploring new use cases involving multiple MCC service teams identified barriers and opportunities for data from connected technologies towards greater agility and responsiveness in local governance. MCC's Principal Resource and Programmes Officer has attested that CPU-Lab played a direct role in MCC committing to and commissioning the new Manchester Digital Strategy (Creating an Inclusive, Sustainable and Resilient Smart City): 'Since the end of the project we're further exploring the idea that decision making can be better informed by better data. The work with Ulysses identified the digital schema that could work and created awareness raising amongst our client base, which were council employees and staff. In September 2019 towards the end of *Synchronicity* we had a workshop for 40 stakeholders, mostly from the city council. 18 months before no one had wanted to attend, but now people felt that they wanted to be part of it. The ongoing engagement with Lab over the previous 2 years was key to this shift' **[B]**. In the most recent annual report published by the council *State of the City* (2019), CPU research has been acknowledged for its current and projected wider impact on the new Manchester Digital Strategy and attraction of additional IoT funding **[C]**.

Embedding IoT data in smart city mobility planning towards more sustainable journey choices: Located in Manchester, *CityVerve* was one of three Innovate UK funded Smart City demonstrators. In a R&D space dominated by technology providers, the Lab adopted a people-

centric approach to prototyping the 'Green Travel Planning' web application to demonstrate the potential use of close to real-time ICT data to enable sustainable travel choices. Focussing on understanding user behaviours, an analysis of existing applications informed the development of an innovative new travel planning application highlighting the environmental implications of travel choices. The innovative digital interface also allowed the collection of data to inform infrastructure and mobility service planning within the city. The findings were published in seven reports and a short film demonstrating functionality **[D]**. Key insights were disseminated through a series of incremental round tables with MCC, TfGM and technology consortium partners, before being publicly released for the benefit of local authorities and SME's working with ICT. MCC's Principal Resource and Programmes Officer has attested that the project 'makes people think about what a sustainable journey is, taking into account the human complexity involved, and the data gathered can also be used in a very real way to inform planning decisions' **[B]**.

Integrating Connected Autonomous Vehicles into TfGM's Future Mobility Strategy: Through collaboration with multiple industry and implementation stakeholders as part of the *Synergy* project, the Lab used computational modelling to shape understandings of the potential of CAV services to augment or replace other motorised public transport services. This has included contributing to GM's CAV Policies and Strategy in support of GM's 2038 Net Zero ambition, with implications for the 6 million daily trips undertaken in the city region. The Transport for Greater Manchester (TfGM) commissioned the report 'Connected and Autonomous Vehicles: The Opportunity in Greater Manchester' **[E]**, into which the Lab had direct input, marking a turning point in future mobility strategic planning by identifying use cases for CAV deployment in Greater Manchester. The report has resulted in the policy document 'A Principles-Based Strategy for Connected and Autonomous Vehicles in Greater Manchester' produced by the TfGM policy team, on which again the Lab was directly consulted **[F]**. The Lab are formally acknowledged in both the report and the policy document and continue to be involved as a core partner with TfGM in co-producing and monitoring objectives for GMs CAV policies. TfGM have acknowledged the Lab for 'support in shaping TfGM's CAV Agenda in the last two years through your involvement on the Synergy project [you] have helped in making GM's 2040 Transport Strategy more innovative and have placed Manchester high in the ranks on future mobility' **[G]**. Wider reach has been achieved through the agenda-setting 'Future Mobility Symposium 2020' at Manchester Met which brought together 60 future mobility service stakeholders (including the Manchester Airport Group, TfGM (co-organiser), Connected Places Catapult, Law Commission, Atkins, Oxfordshire County Council, Highways England, Innovate UK, RIBA and Jacobs) to co-develop a forward-looking agenda and public report **[H]**.

Guiding the sustainability agenda of Manchester's largest regeneration project: Led by Hyde and Sengupta, CPU-Ai is a cutting-edge research-led Atelier on the two-year MArch Master of Architecture programme informed directly by the Labs research expertise. CPU-Ai employs design science to develop theoretical approaches and computational tools for the design, management, governance and understanding of future cities. Since 2018, ca.60 students in CPU-Ai have engaged with the planners in The Northern Gateway (NG) Strategic Regeneration Framework (SRF), a major (150ha) regeneration and development programme aiming to deliver 15,000 new homes in NE Manchester. The 25-year development is on the scale of a new town incorporating transport, green and wider place based social and community infrastructure. The Northern Gateway Strategy and Co-ordination Lead acknowledges the positive impact of working with CPU-Ai on their ongoing sustainability policy in four key areas: 1) Urban design in the form of 'insight into [impact of] urban design strategies for the Northern Gateway'; 2) Raised awareness of the UN Sustainable Development Goals through 'the research which mapped out the UN-SDG's against our strategic ambitions. We now acknowledge that a lot of our work should engage with these goals'; 3) The use of scientific methods for innovation in design noting 'The CPU complexity and design science design methods for futures helps us change and refine our thinking about the built environment. We are behind the curve of innovation, and we work with you to inform our approaches'; and 4) Changed strategic policy as demonstrated in 'The SRF – is now moving to a greater level of detail. We have taken some of your student-led research to inform how that is going to come forward, for example, on the green infrastructure, climate resilience, biodiversity, water retention,

etc. We have also been influenced by your design options to develop more detailed strategies and plans around transport and movement related to locations and routing of certain options for transport. These have been incorporated into multiple policies such as Sandhills Metrolink options appraisal by TfGM and MCC, Rochdale Road design options by TfGM and ARUP and MCC and Green Infrastructure issues within the City River Park Vision document with Planet. This will impact on 35,000 people in the regeneration area' **[L]**.

New forms of technology-driven architectural design practice: The cutting-edge CPU-Ai Atelier curriculum combines design acumen with the development of bespoke computational tools to address complex problems through systems thinking. This combination of design skills and systemic thinking has resulted in a highly innovative teaching agenda (*#architectsthatcode*). The desirability of CPU-Ai graduates has resulted in high-demand in R&D roles prioritising the development of new approaches for an evolving profession. These include the UK Building Information Modelling (BIM) leader Bryden Wood, who state 'your graduates have a direct impact on our ways of working in the office and especially in our specialist CT [Creative Technologies] team by bringing in the latest digital workflows. Your graduates learn to code and expand their design approaches beyond traditional software and form based digital design. They are aware of interdisciplinary approaches and requirements for design based on a broad theoretical familiarity. The capacity to grow the CT team at Bryden Wood was partially due to the existing knowledge and skills of CPU-Lab graduates' **[I]** and the largest global architecture practice Gensler who state that the CPU-Lab graduate employed there 'introduced us to new computational tools for the understanding the performance of the building envelope of a project which has just recently gained planning approval. This is a high-profile project with very ambitious energy targets. These targets have been achievable partially due to the use of these new tools that [the CPU-Lab graduate] brought with him' **[J]**. The ongoing change in attitudes, processes and practice is reflected nationally in industry and RIBA as attested to by its President Alan Jones, who states 'at CPU-Lab you are developing new methods with your students based on functionality and evidence by expanding their education into areas of computer science, data analysis and urban simulation. The CPU design science-based approach is playing an important part in the changing trajectory of the profession' **[K]**.

5. Sources to corroborate the impact

A. United Nations-Institute of Advanced Studies (Policy Brief statistics): Web link to UNU-IAS ''Sustainable Smart Cities: Applying Complexity Science to Achieve Urban Sustainability' https://collections.unu.edu/collection/UNU:5478

B. Testimonial: Manchester City Council Policy, Partnerships and Research, Adrian Slatcher, Principal Resource and Programmes Officer.

C. https://www.manchester.gov.uk/downloads/download/7121/state_of_the_city_report_2019_whole_document

D. Cheung, P., Sengupta, U. 2017. CityVerve – Greener Journey Planner. Seven sequential industry focused public reports; CityVerve prototype Web Application Demo 2018:, http://www.complexurban.com/video/cityverve-research-journey-planner-to-enable-greener-travel/

E. Connected Autonomous Vehicles report commissioned by Transport for Greater Manchester (TfGM). 'Connected and Autonomous Vehicles: The Opportunity in Greater Manchester'.

F. Connected Autonomous Vehicle policy in Transport for Greater Manchester Policy Report: 'A Principles-Based Strategy for Connected and Autonomous Vehicles in Greater Manchester'

G. Testimonial: Transport for Greater Manchester, Anna Craciun, Innovation Officer, TfGM

H. Future Mobility Symposium Public Report 2020: http://www.complexurban.com/wp-content/uploads/2020/06/fms2020_report_web_june.pdf

I. Testimonial: Bryden Wood, Filippos Filippidis, R&D Project Leader

J. Testimonial: Gensler (Benjamin Minton, Senior Associate)

K. Testimonial: Royal Institute of British Architects (RIBA), Alan Jones, RIBA President

L. Testimonial: Manchester City Council - Northern Gateway Development, Matt Doran Northern Gateway Strategy and Coordination Lead