Institution: University of Oxford

Unit of Assessment: 14 – Geography and Environmental Studies

Title of case study: Planning Infrastructure Systems to Support Sustainable Development through the United Nations

Period when the underpinning research was undertaken: 2011-Dec 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:
Professor Jim Hall	Professor of Climate and Environmental Risks, ECI	2011-present
Dr Matt Ives	Senior Researcher	2014-present

Period when the claimed impact occurred: 2016-Oct 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

The long-term and integrated planning of energy, transport, water, waste management and digital communications infrastructures is crucial for sustainable development. The Infrastructure Transitions Research Consortium (ITRC), led by Hall, has created a system-of-systems method for such planning, underpinned by the globally unique suite of models and tools called NISMOD (National Infrastructure Systems MODel). NISMOD enables a paradigm shift in infrastructure planning by national governments, towards cross-sectoral, long-term and resilience-oriented thinking. The NISMOD approach has been adopted by the United Nations Office for Project Services (UNOPS), and this has changed the infrastructure-related understandings, modelling capabilities, assessment approaches, and support it offers to partner countries. For instance, the small (and particularly vulnerable) developing island state of Curaçao has transformed its analysis and planning of infrastructure systems. The success of the work in Curaçao has subsequently inspired the government of Saint Lucia to develop its own national assessment of infrastructure, supported by ITRC and UNOPS.

2. Underpinning research (indicative maximum 500 words)

The underpinning research began with the creation of the UK Infrastructure Transitions Research Consortium (ITRC) in 2011, with an EPSRC grant of 4,600,000 GBP (PI Hall). The initial phase of ITRC produced the first version of the National Infrastructure Systems Model (NISMOD) and analysis which was used by the National Infrastructure Commission for the UK's first National Infrastructure Assessment, published in 2018.

NISMOD enables national governments to make informed decisions on how to create sustainable, efficient, and resilient infrastructure systems, integrating energy, transport, water, waste management and digital communications. The approach, known as a System-of-Systems (SoS) analysis [**R1**], is ever-more necessary owing to the growing interdependencies between sectors, for instance because the electrification of transport places increasing demands on electricity grids. NISMOD is a world-first because it models and simulates interdependent infrastructure systems as spatial networks at the national scale while accounting for both capital and operational costs over the lifecycle of infrastructure assets. The recommendations arising from the analysis include optimal locations for assets and priorities for investment in network resilience. The second ITRC Programme Grant (EPSRC, GBP5,400,000, 2016-2020) was designed with the United Nations Office for Project Services (UNOPS) and developing country partners, and developed a new version of NISMOD for international development contexts. Its first application was in the occupied Palestinian territories [**R2**]. The revised model also analyses climate risks to infrastructure networks and allows vulnerabilities to be identified and adaptation actions to be prioritised. The

team has produced a sequence of papers describing this research with an empirical focus on the UK, China, or the whole world [e.g. **R3**].

In **R4** NISMOD has been used to conduct the first global, comprehensive and systematic analysis of the impacts of infrastructure development on the realisation of the Sustainable Development Goals. The SDGs were adopted by the UN in 2015 as a blueprint to realise a more sustainable future for all of the world's inhabitants by 2030. **R4** highlights the multiple effects of interdependent infrastructure systems on the SDGs: 68% of the 121 SDG targets impacted by infrastructure are influenced by multiple infrastructure sectors.

Most of the research using NISMOD has focused on small island developing states, and Curaçao and St Lucia in particular [**R5**, **R6**]. This orientation reflects the very specific and urgent challenges these states face in achieving the SDGs, including low income, remote geography, reliance on the pressures of tourism, and particular exposure to the impacts of climate change and extreme weather events. **R5** and **R6** demonstrate how SoS modelling of infrastructures, together with local stakeholder engagement, can be used to assess the effectiveness of different interventions to address challenges in energy provision, water supply and waste management in Curaçao. The analysis reinforces the findings about interdependencies between infrastructures from **R4**. It also highlights the importance of considering uncertainty in the demand for infrastructure services and the need for iterative assessment and flexibility in long-term infrastructure planning.

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

R1: Hall, J.W., Tran, M., Hickford, A.J. and Nicholls, R.J. (eds.) (2016) *The Future of National Infrastructure: A System of Systems Approach*. Cambridge: Cambridge University Press. Available at: https://www.cambridge.org/core/books/future-of-national-infrastructure/7D4DF0295A9D8A7304E6C87204BAA0EA [output type: A]

R2: Ives, M., Sway, T., Thacker, S., Jones, R., O'Regan, N., Abu-Ayyash, M., Nicholls, R.J., Adshead, D., Hickford, A. and Hall, J.W. (2019) A systems-based assessment of Palestine's present and future infrastructure requirements. *Journal of Environmental Management* 234: 200-213. http://doi.org/10.1016/j.jenvman.2018.12.058 [output type: D]

R3: Koks, E.E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousdoukas, M., Fraser, S.A., Hall, J.W. and Hallegatte, S. (2019) A global multi-hazard risk analysis of road and railway infrastructure assets. *Nature Communications* 10(1): 2677. http://doi.org/10.1038/s41467-019-10442-3 [output type: D]

R4: Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J. and Hall, J.W. (2019) Infrastructure for sustainable development. *Nature Sustainability* 2: 324-331. http://doi.org/10.1038/s41893-019-0256-8 [output type: D]

R5: Adshead, D. Thacker, S., Fuldauer, L.I and Hall, J.W. (2019) Delivering on the Sustainable Development Goals through long-term infrastructure planning *Global Environmental Change* 59: 101975. http://doi.org/10.1016/j.gloenvcha.2019.101975 [output type: D]

R6: Fuldauer, L.I., Ives, M.C., Adshead, D., Thacker, S. and Hall, J.W. (2019) Participatory planning of the future of waste management in small island developing states to deliver on the Sustainable Development Goals. *Journal of Cleaner Production* 223: 147-162. http://doi.org/10.1016/j.jclepro.2019.02.269 [output type: D]

Funding: PI: Hall, Infrastructure Transitions Research Consortium, EPSRC, GBP4,780,610 (whole consortium), 2011-2016; PI: Hall, MISTRAL: Multi Scale Infrastructure Systems Analytics, EPSRC, GBP5,374,638 (full consortium), 2016-2021

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

NISMOD's System-of-Systems (SoS) approach to cross-sectoral, long-term and resilient-oriented infrastructure planning has created a cascade of changes at two levels of governance. At the supranational level, the approach has transformed understandings, modelling capabilities and

assessment approaches within UNOPS. This has allowed this organisation to offer better advice to multiple countries on how to plan for and invest in infrastructure development. This case study however focuses on Curaçao and Saint Lucia because these small island developing states have seen the most comprehensive changes in data availability, modelling capabilities, long-term infrastructure planning, and implementation of immediate interventions in infrastructures as a result of the ITRC/UNOPS collaboration.

Improving the understanding of infrastructure at UNOPS

The ITRC's SoS approach [**R1**] has resulted in new understandings of infrastructure within UNOPS, as a video on its website attests: "From working with ITRC we have come to understand that infrastructure is more than just physical assets. It includes knowledge, and the institutions involved in the planning and governance of those assets. Infrastructure exists as a highly linked interdependent system of systems across cities, regions and countries" [**E1**]. UNOPS' technical modelling capabilities have also improved, especially with the appointment of one of Hall's researchers, Dr Thacker, as senior UNOPS/ ITRC Analyst to lead a team of 5 UNOPS-funded PhD students and postdocs, based in Oxford but working on NISMOD applications around the world.

UNOPS' Under-Secretary-General and Executive Director has endorsed the culture change produced by the research by Hall and colleagues: "[o]ur collaboration with the University of Oxford has made a seminal contribution to taking forwards the thinking and positioning of UNOPS in relation to sustainable and resilient infrastructure. We have worked together to map out the relationship between infrastructure and the SDGs and have promoted the use of NISMOD widely within UNOPS ... I would describe this as being no less than a culture change within our organisation" [**E2**, emphasis added]. During an interactive discussion following a UNOPS Executive Board meeting in late 2019, she explained that understanding the importance of infrastructure to attaining the SDGs and the costs involved (especially the long-term costs of poor decisions) [**R4**] had caused UNOPS to work more systematically with academia and to adopt a scientific approach, stating that "the deep cooperation we have had with the University of Oxford and with Jim Hall has taken us a huge step forward in the thinking [of the UNOPS EBI strategy]" [**E3**].

The changes are not only internal to UNOPS as the ITRC/UNOPS collaboration has helped to shift the relationship between UNOPS and the governments of the countries it serves. UNOPS' stated goal is to help national governments develop capacity for long-term evidence-based planning, design and operations of infrastructure systems in order to enhance resilience to short-term shocks and robustness to long-term changes [**E1**]. The organisation does this by encouraging the adoption of best practices, institutional structures and analytical tools. The embedding of NISMOD in UNOPS' approach to national-level capacity building is recognised in the midterm review of the UNOPS strategic plan 2018-2021, published in July 2020 [**E4**]. This document states that, "[t]hrough the [NISMOD-enabled] evidence-based infrastructure approach, UNOPS can enable governments to 'spend better' when investing in infrastructure" [**E4**]. This approach, it continues, "can empower government partners to plan, deliver and manage their infrastructure systems and optimize the impact of their investments while keeping a sharp focus on sustainability and resilience" [**E4**]. In a testimonial letter the UNOPS Under-Secretary-General and Executive Director of UNOPS adds that

> "[t]hanks to our collaboration we [UNOPS] have progressed on our journey to becoming a proactive partner in the delivery of quality infrastructure. The methodologies and data embedded in the NISMOD tool have helped us to empower government partners to plan, deliver and manage their infrastructure systems and optimise the impact of their investments while keeping a sharp focus on sustainability and resilience. This has helped partner governments to establish a comprehensive and realistic understanding of future needs, and project gaps for an uncertain future, marked by population growth, urbanization and the effects of climate change" [UNOPS' Under-Secretary-General, **E2**].

Improving infrastructure assessment and implementation in Curaçao

In 2016, the ITRC/UNOPS partnership began working with the Government of Curaçao to undertake a comprehensive assessment of Curaçao's infrastructure needs. This analysis led to

the creation of a detailed spatial infrastructure asset database for Curaçao and enhanced the island's capabilities for cross-sectoral, long-term and resilient-oriented infrastructure assessment. Oxford ITRC researchers trained 15 senior civil servants and analysts from the Ministry of Traffic, Transportation and Urban Planning in the use of NISMOD and EBI. The 'Evidence-Based Infrastructure: Curaçao' [**E5**] report was jointly released by the Curaçao Ministry of Traffic, Transportation and Urban Planning, UNOPS and the University of Oxford in May 2018. The report is the first ever long-term strategy for infrastructure provision in Curaçao. UNOPS' Under-Secretary-General confirms that "[t]he report specified a set of priority actions, including improvements to waste water treatment and transport, which I am pleased to say are being taken up in practice, thus benefiting the 160,000 people of Curaçao" [**E2**].

On 8-9 May 2018, the EBI recommendations, based on Oxford-led ITRC research, were presented at the Resilient Infrastructure Conference in Curaçao to delegates from many Caribbean island states. Curaçao's Minister for Traffic, Transport and Urban Planning declared that:

> "[o]ur infrastructure is vital for the functioning of Curaçao today and its future success. Therefore, it should be optimised, efficient and resilient. In that context, cross-sectoral long-term planning is essential for maximising the full potential of our island for the benefit of all its people… [**E6**].

The Minister has subsequently reiterated the importance of the EBI approach:

> "In 2016, we embarked on a journey of sustainable and resilient infrastructure planning using the Evidence-Based Infrastructure framework. We went on this journey with the help of UNOPS and ITRC, headed by the University of Oxford" [**E11**]

The NISMOD-facilitated EBI analysis [**E2**] has had two subsequent impacts. First, the Curaçao government produced and approved a Road Map for the Implementation of the SDGs in 2018. The Road Map document cites the EBI recommendations on road networks, wastewater management and community resilience: "The risk assessments performed by UNOPS [which draw on **R3**] are a good step towards improving community resilience, as they allow for determining which communities on the island are most vulnerable to risks. In addition, the implementation of social protection systems, safety nets and contingencies can strengthen community resilience" [**E7**]. Second, the European Development Fund has endorsed the EBI analysis, using it to prioritise financial investments in infrastructure in Curaçao, which amounted to EUR16,950,000 in 2019 [**E2**, **E8**].

Changes in infrastructure assessment and implementation extending to Saint Lucia

The government of Saint Lucia created the National Integrated Planning and Programme Unit (NIPP) within its Department of Finance to provide evidence-based assessments for national infrastructure planning across all government agencies in August 2018. In May of 2018 a delegation from Saint Lucia had attended the Resilient Infrastructure Conference in Curacao, and the Director of the NIPP confirms that it was this "first hand experience" of a successful intervention and "great interest in the EBI approach" that inspired an approach to the UNOPS office in Castries and subsequent commissioning of an EBI [**E9**]. By December 2020, the UNOPS/ITRC team had trained 19 members of the NIPP and officials from key government departments in the use of an asset database and long-term planning model. The Director of the NIPP writes that the government of Saint Lucia consider the transfer of open-source modelling capabilities to local stakeholders of key importance, as previously they had to rely on for-profit consultants from overseas [**E9**].

Collaborating with ITRC and UNOPS, the Saint Lucia NIPP has developed the National Infrastructure Assessment (NIA) [**E10**]. This involved data collection and analysis of future infrastructure needs for energy, wastewater, water and solid waste services as well as analysis of climate change driven hazards to various infrastructure. It also involved long-term strategic planning and adaptation planning, and offered the Government specific guidance on how to plan and locate sustainable and resilient infrastructures. The NIA was launched on 7 October 2020 by the Prime Minister who, according to the Director of the NIPP, "was desirous of an outcome that was not simply a report but a roadmap that would lead to tangible solutions to the many problems facing the island's national infrastructure systems …. The work of the Oxford led ITRC was well

received and considered of great value as such an approach to infrastructure assessment had never been done in Saint Lucia or the English speaking Caribbean before" [**E9**].

The NIA has entered the implementation phase. The Government has identified a priority set of infrastructure investments for which it was seeking funding in December 2020 [**E9**]. In the short time since its launch, the NIA has had two immediate impacts. A plan has been developed to tackle solid waste challenges and loss of non-revenue water through a new wastewater treatment plant in Castries, the island's capital. Together with Saint Lucia's Disaster Management Organisation, the NIPP has begun to address flood-related vulnerabilities identified in the NIA, using data created during the NIA to identify evacuation routes in the event of flooding from storm surge or flash flooding. The Director of the NIPP affirms that:

> "[t]he immediate changes have been the initiation of discussion on the definitive way forward with the current solid waste challenges and loss of non-revenue water. One of the most important aspects of the NIA that redefines our infrastructure agenda is the timeline associated with the long-term planning component- never before have we been able to decide when (the year) we need to increase our capacities across the 4 sectors analyzed. [drawing on **R3** and **R4**]. Additionally, the National Emergency Management Organization has begun work with the NIPP Unit to assist with disaster risk and vulnerability" [**E9**].

The impact of Hall's research is set to continue with a new collaboration underway in Ghana (since August 2019) and an agreement to begin working in Jamaica (project scope decided in December 2020 and formally signed January 2021).

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

E1: Video: UNOPS (2016) The system of systems approach to infrastructure, available at: https://www.unops.org/news-and-stories/news/the-system-of-systems-approach-to-infrastructure

E2: Letter from Under-Secretary-General and Executive Director of UNOPS.

E3: Video: Executive Board of UNDP, UNFPA and UNOPS - Second Regular Session, 3-6 September 2019 (7th meeting), at 0:59:00, available at: http://webtv.un.org/watch/executive-board-of-undp-unfpa-and-unops-second-regular-session-3-6-september-2019-7th-meeting/6084133919001/

E4: Report: United Nations (2020) Midterm review of the UNOPS strategic plan, 2018-2021.

E5: Report: Ministry of Traffic, Transport and Urban Planning, UNOPS and ITRC (2018) Evidence- Based Infrastructure: Curaçao.

E6: Newspaper report of Resilient Infrastructure Conference.

E7: Report: UNOPS (2018) A Roadmap for SDG Implementation in Curaçao.

E8: Terms of Reference: European Commission (2020) Specific Terms of Reference: Technical assistance to the Government of Curaçao for the Programming of the 11th EDF Building Resilient & Sustainable Communities.

E9: Letter from Director, National Integrated Planning and Programme Unit, Department of Finance, Government of St Lucia.

E10: Report: UNOPS, Government of Saint Lucia and ITRC (2020) Saint Lucia: National Infrastructure Assessment.

E11: Report: UNOPS, Hidden Champions.