Impact case study (REF3)

Institution: Brunel University London
Unit of Assessment: 11-Computer Science
Title of case study: Developing National Research and Education Services in Africa
Period when the underpinning research was undertaken: 2009-2019

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:
a) Professor Simon J E Taylor	a) Reader/Professor	a) 01/1995-present
b) Dr Anastasia Anagnostou	b) Research Fellow/Lecturer	b) 03/2012 - present

Period when the claimed impact occurred: August 2013 to December 2020
Is this case study continued from a case study submitted in 2014? N

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

Prof Taylor and Dr Anagnostou at Brunel have supported National Research and Education Networks (NRENs) in at least 6 African countries to develop network services for at least 300 Universities, improving the experience of around 3,000,000 students and faculty. Their service development roadmaps have helped deliver national education policies in at least 11 countries leading to digitally enhanced student experience. Through this work students are saving annually in excess of GBP81,700,000 in broadband costs and are contributing an estimated GBP98,000,000 annually additional GDP as a result of a digitally enhanced education across the countries Brunel have worked with.

2. Underpinning research (indicative maximum 500 words)

In over 120 countries, public universities have joined together to organize Internet access/connectivity, via centralized organizations called National Research and Education Networks (NRENs). These have been hugely impactful by achieving cheaper Internet access, software, systems and services through national economies of scale and have enabled worldwide scientific collaboration and digital education. Prior to 2008, Sub-Saharan Africa (SSA) had little in terms of these. In 2008 the European Commission commissioned the FEAST study to roadmap strategies to creating both physical communication networks, African NRENs and network links to Europe. The EC in partnership with the African Association of Universities and African Nations have made major investments in undersea cables and national infrastructures. These led to the emergence of SSA NRENs and the Regional Research and Education Networks coordinating and leading efforts between the emerging SSA NRENs (Ubuntunet Alliance (East and South SSA) and WACREN (West and Central Africa)). In parallel with these developments, our research has studied and supported the developed of NRENs and their network services in SSA.

In 2009, Taylor led the FP7 ERINA4Africa project (2009-2011) that established the impact of e-Infrastructures network services in Africa in terms of the Millennium Development Goals (now the Sustainable Development Goals) by creating several innovative African-based demonstrators. Results identified that advanced network services (e.g. e-Infrastructures) had major potential for Africa and emerging African NRENs had a significant role to play in terms of emerging African economies. For example, our e-Health application survey identified funding dependency, the provision of suitable communication networks and use of unsupported technologies as major factors in health project failure (**REF1**). However, the diversity of network service technologies and architecture and speed of technological change makes baseline

innovation difficult to develop (e.g. which security architecture to use, how to store and access data, software, etc.) Work carried out by Taylor/Anagnostou in industry as part of the FP7 CloudSME project recognised that end user access to complex networked software and services could be simplified by creating sophisticated web-based front ends (science gateways) where appropriate supporting network services existed (**REF5**). In the FP7 eI4Africa project (2012-2014), in East and Southern Africa with the Ubuntunet Alliance Taylor/Anagnostou proposed a reference architecture for African network services that assisted emerging NRENs in understanding network service provision to Universities on a national scale (**REF4**) resulting in 6 African NRENs developing/expanding their services (Kenya, Malawi, Nigeria, South Africa, Tanzania and Zambia) and 24 scientific communities adopting their own science gateways linked to African network services (**REF3**). Based on this, in the H2020 TANDEM project (2015-2017) Anagnostou/Taylor worked with WACREN in West and Central Africa to develop their NREN Network Service Roadmap which is being used to develop network services in the region and deliver national education policy (ranging from email to cloud services – **REF2**). Following the emergence of Open Science, in our H2020 Sci-GaIA sister project (2015-2017) Anagnostou/Taylor co-developed the FAIR Open Science Platform network service to support all aspects of open science ("FAIR" is the sense of FORCE11 principles of Findable, Accessible, Interoperable, Re-usable data). This facilitates the development of key Open Science components including Open Access Repository, Science Gateways and e-Infrastructure network services technologies. Multiple new Open Access Repositories and applications were created through Hackfests in 6 African countries. Overall, our research has had a major impact realising the educational policies of African nations by establishing African NRENs and enabling them to deliver their own impact on African education.

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

REF1: Jahangirian, M. and Taylor, S.J.E. (2015). Profiling e-Health projects in Africa: trends and funding patterns. Information Development. 31(3): 199-218. (doi:10.1177/0266666913511478 – 16th December 2013).

REF2: Kashefi, A., Taylor, S.J.E, Abbott, P., Anagnostou, A., Tessa, O.M., Oaiya, O., Barry, B. and Alline, D. User Requirements for National Research and Education Networks for Research in West and Central Africa. Information Development, (May 2018). doi:10.1177/0266666918774113.

REF3: Ogunleye, O.O, Fadare, J.O., Eriksen, J., Oaiya, O, Massele, A., Truter, I., Taylor, S.J.E., Godman, B. and Gustafsson, L.L. (2019). Reported needs of information resources, research tools, connectivity and infrastructure among African Pharmacological Scientists to improve future patient care and health. Expert Review of Clinical Pharmacology, 12(5): 481-489 https://doi.org/10.1080/17512433.2019.1605903.

REF4: Spyridonis, F., Taylor, S.J.E., Abbott, P., Barbera, R., Nungu, A., Gustafsson, L.L., Pehrson, B., Oaiya, O. and Banda, T. (2015). A study on the state-of-the-art of e-Infrastructures uptake in Africa. Palgrave Communications 1, Article number 14007 (doi:10.1057/palcomms.2014.7 – 20th January 2015) http://www.palgrave-journals.com/articles/palcomms20147.

REF5: Taylor, S.J.E., Kiss, T., Anagnostou, A., Terstyanszky, G., Kacsuk, P., Costes, J., Fantini, N. (2018). The CloudSME simulation platform and its applications: A generic multi-cloud platform for developing and executing commercial cloud-based simulations. Future Generation Computer Systems, 88: 524-539.

GRANT 1: Simon Taylor (PI) European Commission (654237) 1 May 2015 – 30 April 2017, Energising Scientific Endeavour through Science Gateways and e-Infrastructures in Africa (Sci-GaIA), GBP1,190,549.08

GRANT 2: Simon Taylor (PI) European Commission (654206) 1 May 2015 – 30 April 2017, TransAfrican Network Development (TANDEM), GBP1,082,902.60

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

Equitable access to education and research is vital to development in Africa and is a major priority for African Nations. For example, the African Union Agenda 2063's Call to Action commits to speeding up actions to (c) "Catalyse education and skills revolution and actively promote science, technology, research and innovation…" This aligns with Sustainable Development Goal 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all). As noted by the World Bank, National Research and Education Networks (NRENs) are a major factor in enabling this – as demonstrated in over 120 countries, NRENs organize centralised public university Internet access/connectivity, offer additional software, systems and services through common standards to enable worldwide scientific collaboration and digital educational resources, and, through economies of scale, drive down prices of these. In Africa emerging NRENs are having a major impact on public Universities (e.g. cutting Internet costs from GBP3,000 to GBP4,400 per megabit per second (Mbps) per month to under GBP73 per Mbps). However, African universities cannot realise the full benefit of these reduced costs without networked services supporting education and research. Taylor and Anagnostou have worked with emerging African NRENs to develop these services and to accelerate significantly their maturity. This has had a major knock-on effect to their user community, the staff and students of African universities. Taylor and Anagnostou have identified two main examples of impact.

(i) African Network Service Development. Network service deployment is extremely complex. For example, services supporting access and collaboration need a portfolio of services Authentication and Authorization Infrastructures (AAIs). These allow NRENs and their universities to establish trusted user identities and to authorise home institution access to internal networks and digital resources. Importantly, it allows home users to be authenticated at other partner NRENs and universities across the world (e.g. via eduroam). There are multiple complex routes to deployment (federated single sign-on, e.g. Shiboleth, eduGAIN, etc.) which required a highly skilled technical team. Taylor led consortia and worked with the RENs Ubuntunet Alliance and WACREN to investigate of the most effective route to service deployment of this and other associated services (e.g. Science Gateways) based on a novel e-Infrastructure Reference Architecture (**E1**). From this, Taylor led the development of training materials delivered by the RENs to their NRENs. This work was adopted by both these associations as well as at least 6 NRENs (Kenya, Malawi, Nigeria, South Africa, Tanzania and Zambia) supporting approximately 160 Universities and 1,800,000 students (**E2**). Our work was instrumental in initiating several NRENs including the Lagos State-based Eko-Konnect cluster of the Nigerian NREN (NgREN) that serves 176 Universities and around 2,000,000 students. (**E3**). Taylor/Anagnostou also worked in the H2020 TANDEM project with WACREN to create a NREN Service Roadmap used to guide the development of NRENs in 11 African Nations in West Africa (**E4**). These NRENs form a formal part of education policy in these countries – this work has therefore directly contributed to the educational policies of at least 17 African Nations (**E5**).

(ii) The OECD, UNESCO and the World Bank have indicated the value and benefits of Open Science in developed economies (e.g. over a billion USD in 10 years in the USA, wider innovation in SMEs, citizen science, etc.) In developing economies further benefits are possible (e.g. access to African research outputs, access to research by research institutions, significantly reduced costs of data access/use, etc.) (**E6**) With the Ubuntunet Alliance and WACREN, Anagnostou/Taylor used the FAIR Open Science Platform (OSP) (co-developed by Brunel and UNICT (Italy)) to demonstrate how Open Science could be adopted by NRENs and used to support their Universities. Again with UNICT, Anagnostou/Taylor ran several hackfests (2016/7) to jump start several African Open Science projects.   This resulted in 35 scientists from 6 African countries developing 49 applications servicing 24 scientific communities (ranging from

bioinformatics to healthcare). It also enabled several NRENs to begin to create Open Access Repositories (Ethiopia, Nigeria, Somalia, Tanzania and Uganda) that are servicing their scientific communities (e.g. this has enabled the Africa Centre of Excellence in Phytomedicine and Research Development (ACEPRD) at University of Jos (Nigeria) to create a repository of over 200 local plant species) (**E7**). The most successful of these formed the basis of the National Academic Digital Repository of Ethiopia (NADRE - https://nadre.ethernet.edu.et//) with EthERNet (Ethiopia's NREN). 47 public Universities are able to use this service to openly publish their work, data and theses. Academic end users benefit from this national NREN service (including many now using ORCIDs for the first time). This overcame the problems with maintaining institutional ones (around 10 repositories with only three working) (**E8, E9**). In 2019 this led to the Ethiopian Ministry of Science and Higher Education mandating Open Science and the free access to all outputs from publicly-funded research.

The only report on the economic benefits of a NREN to its host nation (Canada) estimated an annual 5% increase in GDP through enhanced digital service provision and reduced Internet bandwidth costs for universities (**E10**). These facilitated increased research productivity and higher numbers of highly qualified graduates entering the national economy. There is no recent data on graduates and their employment. However, as evidenced above, 3,800,000 students have received digitally enhanced education provided through digital educational platforms and services (access made possible through Brunel's research) and have saved annually at least GBP81,700,000 in broadband costs (**E11**). Finally, given that NRENs that Brunel has worked with are some of the most mature in Africa, if we estimate their effect on national economies to be 0.01% rather than 5% (limited by other factors such as high graduate unemployment (**E12**)), then these NRENs and the services that Brunel researchers have enabled will have in 2019 contributed to an additional approximate GDP of GBP98,000,000 annually across Kenya, Nigeria, South Africa, Tanzania and Zambia (Malawi is still developing) (**E13**).

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

E1: Establishment of e-Infrastructure Services and Identification of e-Infrastructure Priorities – Final Report (e-I4Africa) (eI4Africa_D6.3))

E2: Corroborating letter from Ubuntunet Alliance

E3: Corroborating letter from CEO WACREN

E4: D3.4 TANDEM-WACREN roadmap recommendations

E5: Foley, M. (2016). The Role and Status of National Research and Education Networks (NRENs) in Africa. World Bank Education, Technology & Innovation: SABER-ICT Technical Paper Series (#05). Washington, DC: The World Bank. http://saber.worldbank.org

E6: OECD (2015-10-15), "Making Open Science a Reality", OECD Science, Technology and Industry Policy Papers, No. 25, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jrs2f963zs1-en.

E7: Energising Scientific Endeavour through Science Gateways and e-Infrastructures in Africa Final Report (Sci-GaIA)(D5.4_Final Report_Sci-GaIA)

E8: Corroborating letter from Ethiopian Education and Research Network (ETHERNET), Ethiopia

E9: Corroborating letter from Higher Education Strategy Centre, Ethiopia.

E10: Nordicity and Bytown Consulting (2014), Analysis of the Economic Benefits of CANARIE. https://www.canarie.ca/wpdm-package/canarie-economic-benefits-analysis-2014/

E11: ITU Broadband prices (2019, 5GB). https://www.itu.int/net4/ITU-D/ipb/ Costs estimated at GBP21.5 for 5GB access.

E12: Can higher education solve Africa's job crisis? British Council. https://www.britishcouncil.org/sites/default/files/graduate_employability_in_ssa_final-web.pdf

E13: GDP figures from https://data.worldbank.org/