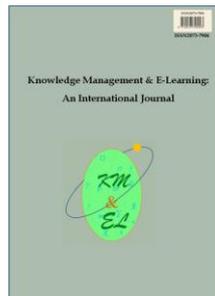


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### **Our building is smarter than your building: The use of competitive rivalry to reduce energy consumption and linked carbon footprint**

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## **Our building is smarter than your building: The use of competitive rivalry to reduce energy consumption and linked carbon footprint**

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**Abstract:** This research is located within the smart city discourse and explores the linkage between smart buildings and an intelligent community, employing the University of Cape Town as a case study. It is also situated within the research stream of Green Information Systems, which examines the confluence between technology, people, data and processes, in order to achieve environmental objectives such as reduced energy consumption and its associated carbon footprint. Since approximately 80% of a university's carbon footprint may be attributed to electricity consumption and as the portion of energy used inefficiently by buildings is estimated at 33% an argument may be made for seeing a campus as a "living laboratory" for energy consumption experiments in smart buildings. Integrated analytics were used to measure, monitor and mitigate energy consumption, directly linked to carbon footprinting. This paper examines a pilot project to reduce electricity consumption through a smart building competition. The lens used for this research was the empirical framework provided by the International Sustainable Campus Network/Global University Leadership Forum Charter. Preliminary findings suggest a link between the monitoring of smart buildings and behaviour by a segment of the intelligent community in the pursuit of a Sustainable Development strategy.

**Keywords:** Smart buildings; Green information systems; Energy; Carbon footprint; Sustainable development

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## **1. Introduction**

Cape Town, which is one of three smart cities in Africa (Nam & Pardo, 2011) is the setting for this case study, which investigates how to use a university as a laboratory for experiments in developing a smart campus. This links to the broader global research project for the development of an intelligent community site, which has five indicators, namely broadband connectivity, a knowledge workforce, innovation capacity, promoting digital inclusion and marketing of its vision (Nam & Pardo, 2014). Of these, innovation capacity is the most influential indicator, in this case study, as universities are in the process of evolving from knowledge factories to innovation incubators (Youtie & Shapira, 2008). This research is also aligned more broadly to the notion of Sustainable Development (SD) which has been defined as development which “meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (United Nations, 1987). This research is thus a response to the global challenge of the excessive consumption of energy from fossil fuels and other finite resources thus create a challenge for future generations and placing the planet in peril, arguably one of the greatest challenges of our time (Hansen, 2011).

Universities have a key role to play in developing a knowledge workforce, another Smart City indicator, and many institutions of higher education recognise that they have a leading role to play in creating a sustainable future and have begun to institutionalize SD into their research, curricula, operations and reports (Cortese, 1992). The University of Cape Town in South Africa was one of the founding signatories of the Talloires Declaration (Adlong, 2013) which represents a commitment to sustainability, yet in the researchers’ views, thus far has made limited progress towards developing an integrated and synergistic intelligent community.

This failure calls for a response which is synergistic, holistic and trans-disciplinary (Lozano, 2010). A gap in the smart city literature has been identified as a failure by academics to go beyond conceptualisation research and to undertake practical, impactful research (Nam & Pardo, 2011).

This paper represents an exploratory attempt at filling this gap within the African context. The research question is: How can a segment of an intelligent community be galvanised to effect behavioural change in smart buildings?

The empirical framework of this paper is based on the three principles of the International Sustainable Campus Network/Global University Leadership Form Charter which embraces three principles linked to buildings, master planning and integration of research and education into a “living laboratory” for sustainability (ISCN, 2010). The

first principle, which focuses on buildings, is particularly apt, as it has been found that 33% of electricity consumption in buildings elsewhere in the world is inefficient (Nadel, Shipley, & Elliott, 2004).

This paper is organized as follows: The authors begin with a review of the literature as well as the contextual framework. This is followed by a description of the project and some of the results. The constraints and limitations as well as the way forward are then explored.

## **2. Relevant literature**

The concept of a smart city relates to the use of computing technologies to enable more efficient, more intelligent, interconnect services in a city, such as education, administration, healthcare, safety, real estate, transportation and utilities (Washburn et al., 2009).

The smart campus notion is strategically aligned with this, and cascades down from the smart city, in our view. Thus a smart campus at the University of Cape Town is a smaller version of Cape Town's smart city, with a similar commitment to increasing connectivity (free Wi-Fi on campus, is in fact ubiquitous on campus, although sporadic in the city at large).

The argument for a university as innovator has some support in the literature (Youtie & Shapira, 2008) as well as the intertwined linkages of technologies and standards as drivers of innovation (Klett, 2010).

It needs to be borne in mind that the smart campus notion may also be mapped to the research theme of Green Information Systems, (Green IS) which we define as the confluence of people, smart computing technologies, data and processes in order to achieve sustainability objectives. This aligns with the description of Green IS which views a combination of social and technical processes to enable the achievement of sustainability objectives (Melville, 2010). The challenge of sustainability is a persistent and ubiquitous issue, which was raised by the United Nations more than two decades ago (United Nations, 1987). The subsequent international failure to develop and implement holistic solutions, in spite of the awareness that environmental issues are amongst the most pressing of our time, has been described as Giddens' Paradox (Giddens, 2009). This issued has led to the development of a range of research agendas and this paper represents a pilot study for a larger research project to fill some of the gaps.

The importance afforded to this topic by institutions of Higher Education is borne out by the development of numerous declarations and charters which provides frameworks for sustainability at universities. The University of Cape Town recently became a signatory to the International University Sustainability Network/Global University leadership Forum Charter, which requires it to monitor and report on sustainability issues on an annual basis. In this regard, the Department of Information Systems at UCT has been asked to measure the university's Carbon Footprint - a unique opportunity to develop an integrated SD research and learning agenda. This enables an institution of Higher Education to become a living laboratory to iteratively test database models, with all the challenges of managing people as well as technology.

### **3. Intervention**

The University of Cape Town was established in 1829 and is committed to innovative research and teaching, aimed at engaging with the key issues of the natural and social worlds. (UCT, 2014). In 2012 the university educated 25 694 students and provided employment for the fulltime equivalent of 4 884 staff members. The number of graduates that year was 6 858. Attempts to incorporate sustainability into its many facets started in 1990 with regular self-audits of its progress (Rippon, 2011). In 2009 Andre Theys, manager of Engineering Services in the Properties and Services division, investigated a range of metering technologies for analysing electricity consumption, however the high capital cost of equipment was seen as a barrier. The following year a web-based energy management system (Power-Star) was purchased, enabling the delivery of real-time energy consumption data via wireless meters installed in buildings, including a monthly subscription cost for data reporting. By 2012 a total of 33 smart meters had been installed at transformer level on the Upper Campus, enabling real-time analysis of consumption of electricity.

In 2012 UCT produced its first report for the International Sustainable Campus Network/Global University Leadership Forum. In terms of this charter, it is required to develop three principles. Firstly, “to demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation, and operation of buildings on campus” (ISCN, 2010). The second principle refers to campus-wide master planning and target-setting, while the third principle requires that “sustainable development, facilities, research, and education should be linked to create a ‘living laboratory’ for sustainability” (ISCN, 2010).

Since 2011 the IS department has responded to the third principle, by integrating sustainability issues into the curriculum and in 2012 an experiment, suggested by the power utility, Eskom, was conducted aimed at assessing the impact of behavioural changes on energy consumption within buildings on campus. This was conducted as a competition between building complexes, with the aim of raising awareness of sustainability issues on an extra-curricular level. Data from six buildings was collated, and compared with consumption and peak demand for comparable periods the previous year.

Mobilisation of energy awareness and competitive rivalry was engineered by students belonging to the Green Campus Initiative, an environmental lobby group on campus which has grown from a membership of 570 in 2008 to a membership of 1600 in 2011 (UCT, 2014).

### **4. Results and analysis**

Data was collected for three building complexes on the upper campus using the Power Star system, a Green Information System which provides consumption in kWh and demand in kVA. The first group consisted of Leslie Commerce TRX, Leslie Social Sciences TRX 1 and Leslie Social Science TRX 2. The second group had digital meters at Beattie TRX1 and Beattie TRX2. The third building complex was metered at Engineering Sub TRX. Consumption and Peak Demand was captured by smart meters for the first eight days in August 2011 as the benchmark and the first eight days in August 2012 for each of the building complexes in the intervention. The results are shown for the first period in August 2011 compared with the same time period in 2012.

The results of the competition showed that the “Smartest building” was the Leslie Commerce and Leslie Social Sciences complex which effected a saving of 10.61% in peak demand (kVA). The cost of the electricity consumption for the first eight days of the experiment was given R114 898.

Exploration of the software by the researchers disclosed that the Power Star system created linked reports for carbon footprints – enabling embedded algorithms to work out the equivalent carbon emissions per building complex.

**Table 1**  
Electricity consumption data for smart buildings on campus

Group	Electricity consumption data		
	Building complex	2011 (kWhr)	2012 (kWhr)
1	Leslie Commerce TRX	66135	65459
	Leslie Social Sciences TRX 1	12831	11452
	Leslie Social Science TRX 2	5477	4588
2	Beattie TRX 1	36009	36515
	Beattie TRX 2	41578	39376
3	Engineering Sub TRX	49431	48832

Data for the Leslie Commerce TRX for 2012 is shown graphically below in Fig. 1 as well as the linked environmental report (Fig. 2) showing the reduction in carbon emissions from 58 326 kg for eight days in 2011 to 57 473 kg in the same period in 2012.



**Fig. 1.** A screen grab of the dashboard showing energy data for eight days



**Fig. 2.** A screen grab of the Leslie Commerce carbon footprint for eight days

## 5. Comments

The research objective of this study was to ascertain how basic building blocks of a smart city (smart buildings and a segment of an intelligent community) could be galvanised to achieve environmental objectives, namely reduction of both energy consumption and Greenhouse Gas emissions. One segment of the intelligent community – students – were nudged into behavioural changes through a competitive game between faculties.

This pilot project tested the analytical tools for measuring real-time energy consumption on buildings fitted with sensors to monitor usage, and moderate success was observed with a saving of 10%. However, the study created more questions than answers. New questions which arose included the following: How should an intelligent community be segmented, and should each segment be galvanised in a customised manner? If stakeholders include executives, administrative staff, academic staff and students (among others), how should each segment be nudged towards behavioural (or policy) changes with regard to energy consumption? Can members of an intelligent community feel a sense of belonging to the buildings in which they study and/or work? How can this be nurtured?

How can feedback of energy consumption be given to stakeholders? Should this be through public displays (Eisenberg, Basman, & Hsi, 2014) or private displays, such as social media? Or both?

A limitation of this study is that although there are 177 buildings on campus, only 33 qualify as being smart, with digital meters and only six were monitored for this research project.

Another weakness is that unscheduled maintenance occurred during the intervention, with Leslie Social Sciences TRX 1 and 2 switched off for maintenance during the second week of the experiment, hence data was restricted to the first week of the experiment. A further weakness was that the behavioural changes were not conducted in a controlled manner. This creates an opportunity for more rigorous experiments in future research, isolating individual behavioural changes in order to understand the linkages between behaviour changes and energy conservation, as well as reduced carbon footprints.

## 6. Conclusion

This pilot study was an attempt to fill the practical research gap relating to the discourse of smart buildings and in particular to move beyond conceptual studies to designed interventions with a view to impactful research. The core components of the smart city concept were employed in synergy in this case study, namely technology factors, human factors and institutional factors (Nam & Pardo, 2011). This relates to the research domain of Green IS, which combines technology, people, data and processes within an organisational context (Melville, 2010).

Using the ISCN-GULF empirical framework, which focuses on buildings as its first principle, this exploratory research was to test the concept of an energy challenge between smart buildings and their daytime occupants. The research shows that students have the capacity to effect energy conservation – and reduce the carbon footprint – of buildings where they work and study. A saving in excess of 10% in peak demand was achieved, plus a reduction in the carbon footprint of 853 kg.

Future experiments are planned with a more structured engagement to encourage behavioural change by staff and students, including feedback from Green Information Systems to inform them of their progress and inspire sustainable changes. In future smart cities, it has been predicted that fine-grained information with respect to energy behaviour needs to be given to energy consumers (Karnouskos & Nass de Holanda, 2009) and future research needs to address this issue.

In addition, more comprehensive evaluations of interventions of this nature are required, to assess the effectiveness of various smart city indicators, such as broadband connectivity, a knowledge workforce, innovation capacity, promoting digital inclusion and marketing of its vision.

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