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Diffusion Theory and the Sustainability of IS Innovations: A Greener Earth beneath the Clouds

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Abstract
Our world is increasingly conscious of environmental issues. In IT, one concern is that of the legacy IT infrastructure and the need to improve its sustainability. In this paper we argue that the sustainability of any IS innovation will be formally assessed as organizations and individuals consider such innovations for adoption. Therefore we propose an addition to the classic diffusion of innovation factors of a sixth factor, Relative Sustainability. Relative Sustainability can be initially operationalized using the three eco-goals identified by Watson et al, 2010: 1. Eco-efficiency measures whether an IT good or service reduces ecological impacts and resource use and is competitively priced. This expands our traditional focus on economic efficiency, since it also focuses on how an IT good or service meets ecological pressures. 2. Eco-effectiveness measures how well an IT innovation has been designed from the beginning to be sustainable. This often requires transformational thinking, the focus being working on the right products and services and systems instead of making the wrong things less bad (McDonough and Braungart, 2002, p. xxx). 3. Eco-equity, which measures how well the IT good or service will result in a fair distribution of resources within and between generations. This measure is based on our social responsibility for the future generations who will bear the consequences of excessive consumption of scarce resources and environmental degradation (Watson et al., p. 28). Measuring eco-equity will require predictions about both initial resource use of an IT innovation (e.g., energy consumption), but also longer-term resource issues, such as final disposal of an IT product (are IT components recyclable or biodegradable, or will they pollute the environment?). We consider the case of the diffusion of cloud computing, in particular the establishment of data centers for private and public clouds. Cloud computing is selected because it represents a transformational change in how computing is done on many levels. The replacement of distributed data centers with fewer, centralized data centers delivers eco-efficiency, especially in energy and water savings and toxic disposal. Also, the new improved designs of data centers that employ a mix of technologies (including server virtualization, sensors and next-generation air- and equipment-cooling processes) and services that aid utilization of far less non-renewable resources, offer the promise of eco-equity. Finally, the massive computing power of cloud centers facilitates innovation of sustainable products delivering opportunities for eco-effectiveness.

Keywords: cloud computing, information systems innovations, sustainability, eco-goals

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In a world that is increasingly conscious of environmental issues, (particularly in IS as it pertains to the energy demands of computing platforms), there is, and will increasingly be, attention to green issues in new IS innovations. Watson et al, 2010 proposes three broad sustainability goals for Information Systems which are classified as Eco-Goals:

1. *Eco-efficiency*: competitively priced goods and services that also reduce ecological impacts and resource use;
2. *Eco-equity*: fair distribution of resources within and between generations; and
3. *Eco-effectiveness*: goods and services designed from the beginning to be sustainable, which often requires transformational thinking about those goods or services.

We believe that these goals, in addition to the organizational goals already entailed, provide a more complete set of factors for the diffusion phenomenon. In light of this we propose an addition to the classic diffusion of innovation factors of a sixth factor: *Relative Sustainability* (see Figure 1), which is determined by the the eco-goals . Like the *Relative Advantage* construct*, Relative Sustainability* compares the new innovation to the technology in existence in the organization. The new construct is conceptualized as illustrated in the Figure2

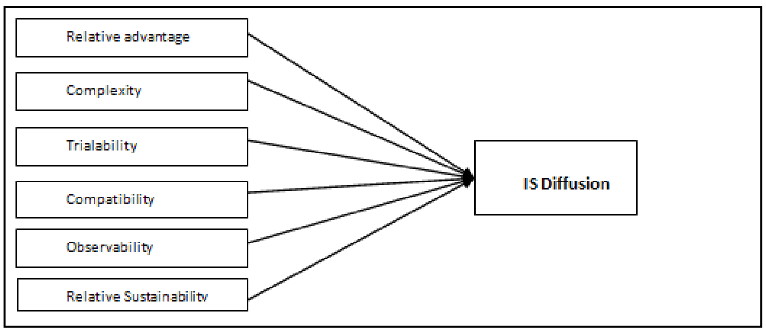


Figure 1: Diffusion Model with Sustainability

We consider the case of the diffusion of cloud computing as an innovation. In particular we look at the establishment of data centers for the facilitation of private and public clouds, specifically focused on how these centers performs as regards to the three measures of sustainability: eco-efficiency, eco-equity, and eco-effectiveness. On the basis of our analysis, Cloud computing, described as “the biggest shift in computing in two decades” [2], offers a transformational change in how the centers are designed from the start, and in the innovations in sustainable products that they facilitate; thus there is an opportunity for eco-effectiveness. The cloud concept delivers eco-efficiency both in how computing services are delivered and paid for, and via the replacement of distributed data centers with fewer, centralized data centers that keep their costs in check. They are also constantly being designed and/or improved with a mix of technologies (including server virtualization, sensors and next-generation air- and equipment-cooling processes) and services in data centers that utilize far less non-renewable resources and promise eco-equity. Our conceptualization implies that *eco-equity* is impacted by both *eco-efficiency* and eco-

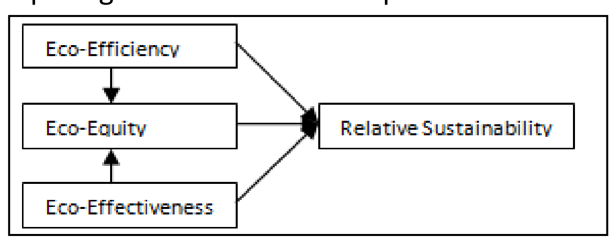


Figure 2: Sustainability as an Eco-Goals Factor

effectiveness, and itself, along with the others determine *Relative Sustainability* (see Figure 2). The rest of our paper proceeds as follows: our next section provides illustrations of cloud computing as a sustainable set of technologies. In that section we present four cases of sustainability in the clouds, consider the measurement issue and present our conclusion about sustainability and the cloud. We conclude concerning our opinion: inclusion of sustainability as a construct in the Diffusion of Innovation Theory.

Case Study: Relative Sustainability and Cloud Computing Data Centers

In this section we look at four cases of design/innovation in cloud data centers highlighting the economical and ecological benefits of each. The cases are below (with examples in Table 1):

Case 1: Migration of IT services to data centers:

Migration can be said to be primarily driven by eco-efficiency, described in Watson et al as "essentially an economic pressure, as organizations will seek this goal in their quest for greater profits" [1, Page 28]. Such a migration involves virtualizing and abstracting back-end IT applications and infrastructures to a common service layer that the entire organization can use[3] In doing so, although costs are incurred, the resulting consolidation leads to both economic and ecological (contributing to the triple bottom line).

Case 2: Improved Data Centre Design

Some centers were not designed from the start to be sustainable cloud facilities. However, as new technologies become more efficient, these centers were refined to be eco-efficient. A presentation of the "Top 12 Green-IT Users" by Robert L. Mitchell in Computerworld magazine on February 15, 2008 [4] highlighted extraordinary improvements by data center owners.

Case 3: **Innovations in Data Center Design**

Innovations (not improvements) in design counter the criticisms [5], [6] of data centers' high energy consumption. These innovations include such as the use of heat output to create energy to cool buildings, incorporation off sensors to drive greater efficiency in energy use, and others.

Case 4: Innovations using Cloud Computing Power

Along with the much touted economic benefits of the clouds, environmental savings clearly exist. The greatest potential for environment sustainability, however, lies in the benefits of smarter designs enabled by to the massive computing power available in the clouds that "far outweigh the efficiencies associated with consolidating servers"[2].

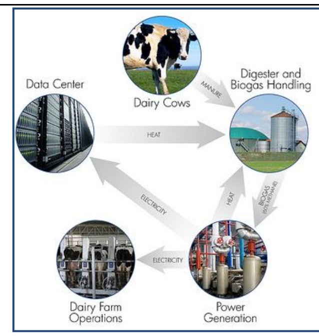
Cases	Cloud Feature: Improvement/Innovation
Case1	**Server Virtualization:** Consolidation of #servers needed to deliver same computing power
Case2	**Data Centre Improvement: Highmark Inc.**: cold air is pushed under raised floor in the center to cool server racks, which are equipped with monitors to regulate fans, based on the generated heat. Also, rain runoff from roof cools equipment.
Case3	 **Center Design: HP Cow Farm**: HP researchers presented a new data center designed on a farm of 10,000 dairy cows at the ASME International Conference on Energy Sustainability in Phoenix, Ariz. The farm could fulfill the power requirements of a 1-megawatt (MW) data center (equivalent of a medium-sized data center) with power left over to support other needs on the farm [7]. According to HP, "our goal here is to see if we can take the data center completely off the grid", Chandrakant Patel, HP Fellow and director of HP's Sustainable IT Ecosystem [8].
Case4	**Innovating renewable energy: Harvard Solar Cell Project:** Researchers from IBM and **Harvard** teamed up to create the World Community Grid (WCG) project. This project will comprise over 413,000 members in 200 countries, each donating idle compute cycles to a massive cloud-based computer of >1,000,000 cores. The effort will look for organic materials capable of producing low-cost, easy-to-manufacture solar cells which, according to WGC's stated goals, could help reduce man's contributions to global warming by reducing the amount of fossil fuels burnt[9].

Table 1: Green Data Centers: Improvements and Innovations demonstrating Eco-Goal Attainment

A Note on Quantifying Eco-Goals for Data Centers

Taxes, implemented by cities, provinces, and countries will represent a geographic context factor in calculating the savings from energy use (table 2 gives examples). Tax rates vary across and within cities, provinces and countries, based on fuel type and who is using the fuel, with different exemptions in each locale implying that assessing eco-efficiency will be locale specific.

Other issues are the costs of what Sharma et al, 2008 refer to as the three main sub-systems of a data center, “Cooling, Power and Compute”. Already extensive research is ongoing in coming up with actual measures that will enable precise calculations of these. The concept, [10], has been extensively researched and was later validated using a large test bed created at HP Research and Development center in Bangalore [11].

As these regulations are instituted, and research on “optimizing sustainability metrics and total cost of operations” [11] in the data center matures, it will become necessary to demonstrate quantitatively that innovations in data center designs clearly exhibit greater efficiency and more effectiveness than what the technologies being replaced.

Country	Year	Description
Finland	1990	Tax = €18.05 per ton of CO2 (€66.2 per ton of carbon)
Costa Rica	1997	3.5 percent carbon tax on fossil fuels
Germany	1999, updated in 2003	Ecological tax of 2,05 € Cent per kWh.on energy, and mineral oil for heat and electricity production is 25 € per 1000 kg.
Boulder, Colorado, USA	2007	carbon emissions tax from electricity of approximately $7 per ton of carbon; in 2009 the rates were increased by sector: residential = $0.0049/kWh; commercial = $0.0009/kWh; industrial = $0.0003/kWh
Quebec, Canada	2007	carbon tax on “hydrocarbons” (petroleum, natural gas and coal)
Switzerland	2008	carbon tax on all fossil fuels, such as coal, oil and natural gas, unless they are used for energy; tax = US $11.41 per metric ton of carbon

Table 2: Country, Year and Description of Regulations in Place for Taxation of Natural Resource Inputs and Emissions

Beneath the Clouds: A Greener Earth?

Cloud computing centers use fewer resources to operate, reduce IT costs and centralize information, all essential elements in analyzing the highly-distributed, complex nature of greenhouse gas (GHG) data to run an efficient and accurate carbon emissions reporting system [12]. Based on the four cases we presented, with respect to the sustainability factor measured in terms of the eco-goals, we conclude the following:

1. *Eco-efficiency: the consolidation of IT services and all the implicit benefits illustrate efficiency with eco-goal attainment.*
2. *Eco-effectiveness*: This becomes increasingly evident as more regulations are enforced and the business benefits of sustainable practices are felt.
3. *Eco-equity*: We have seen that necessarily, attaining eco-effectiveness and eco-efficiency in clouds will lead to attainment of eco-equity. However one caveat: if the consumption of services in data centers increases to the point where all the benefits are overrun by the sheer volume of demand **but** no major breakthroughs in innovation of major renewable

energy sources are forthcoming, then the eco-equity could potentially be wiped out and sustainability efforts lost to the next generation, [13], [14].

Conclusion: Diffusion with Sustainability

One desire we have in proposing relative sustainability as a diffusion factor is for there to be greater attention paid to this topic in IS (both in industry and in academia). Already we see Jim Stikeleather, Chief Technology Officer at Dell Perot Systems, quoted as saying "change doesn't happen unless there is an economic value. And that's why cloud computing will make such a huge impact on outsourced services". But there is other evidence of the recognition of IS sustainability. The 6 top reasons cited for cloud adoption had the first listed as the potential to reduce " buyers' up-front costs and decreases their total cost of ownership … especially attractive coming on the heels of an economic recession …", and the last, to "support globalization efforts without having to deal with associated infrastructure issues", [15].

In this paper we looked at sustainability as an IT innovation diffusion factor, giving consideration to the case of the diffusion of cloud computing, in particular the establishment of data centers for private and public clouds. Cloud computing is selected for three reasons. First, it represents a transformational change in how the centers are designed from the start. Along with the massive computing power of these centers, facilitate innovation of sustainable products there are opportunities for eco-effectiveness). Second, the replacement of distributed data centers with fewer, centralized data centers appears to deliver eco-efficiency (especially in energy and water savings). Third, the new improved designs of data centers that employ a mix of technologies (including server virtualization, sensors and next-generation air- and equipment-cooling processes) and services that aid utilization of far less non-renewable resources, offer the promise of eco-equity.

Proof of the concept of sustainability as an important innovation diffusion factor will require empirical test, and cloud computing provides an excellent context in which to study this effect. Other IS innovations would also be well served by investigation with the enhanced theory. We believe that, as environmental regulations become stricter, the sustainability concept is critical to increasing the explanatory power of diffusion of innovation theory.

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