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Optimizing Flow Network Design With A Green IS Framework: An Exploration Of The Bikeshare Domain

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It is being increasingly acknowledged, in both the IS and sustainability literature that the greatest opportunity for "green" information systems is in the reduction of energy consumption and associated green house gases through the optimal design of supply and demand networks. This paper reports the findings of a multiple case study investigation into how a comparatively new green IS framework - energy informatics – might be used to enhance the design of bikeshare schemes. The central concept of bikeshare is to provide an affordable alternative to motorized transportation and in so doing reduce congestion, noise, and pollution. The findings from the research validate an extended version of the framework and add to the current body of knowledge on the capacity of information systems to support environmental sustainability. Future research will be required to understand the degree to which the framework can inform the design of supply and demand networks in other domains.

Keywords: Green IS, Sustainability, Supply and Demand Networks, Energy Informatics, Bikeshare

1 Introduction

1.1 Background

A recurring theme in the sustainability literature is our continued reliance on the burning of fossil fuels for energy production. The consequence of this has been a significant increase in atmospheric carbon dioxide, (CO_2) which in turn has resulted in a range of problems including air pollution, ocean acidification and a loss of biodiversity (Jacobson, 2008). A broad consensus exists amongst scientists and social commentators alike that reducing our levels of CO_2 will be pivotal in addressing these problems. The need to fundamentally change the way we manage our resources has never been greater. The response from businesses and corporations in particular, given their importance within our societies is increasingly seen as key to the success of the sustainability agenda. Due to the close attention of the media, lobbyists, and an increasingly eco-conscious public, all areas of corporate activity have now come under scrutiny and businesses are expected to be far more proactive, and indeed creative, in how they meet their sustainability obligations.

1.2 The Role of Green Information Systems in the Sustainability Agenda

The information systems community has responded to this changing climate by exploring the potential of technology to work in conjunction with people, processes and business practices to deliver holistic solutions that can make entire systems more sustainable. This approach has become known generically as green IS or green information systems and it incorporates not only the principles of green information technology, which focuses largely on data centre and hardware efficiency, but also on the capacity of a range of digital tools, and information itself, to enable organisations and communities to become more sustainable. It recognises that sustainability is a multi-faceted concept involving economic, environmental and social contexts. While an information technology (IT) transmits, processes, or stores information, an information system (IS) is an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or social goals. The focus of this research is, therefore, on “green IS” rather than “green IT” because green IS gives us the potential to (i) measure and process vast amounts of data, (ii) transform physical processes into virtual ones and (iii) improve the efficiency of physical processes. Though very much in its infancy, the literature notes a role for green IS in a range of areas including traffic management systems, virtual presence technologies, and in supporting informed decision making in the provision and use of services. An increasingly important role for green IS is highlighted in the management of supply and demand networks. Supporting both service provision and service usage through intelligent systems design is an opportunity to fundamentally transform business processes while delivering on the economic, social and environmental imperatives of sustainability. Energy informatics (Watson et al, 2010) is an IS framework which specifically addresses this area. The framework proposes an integrated approach to the design and implementation of systems which support energy efficiency while adopting specific architecture and design elements. The core concept behind the energy informatics (EI) approach is that *energy + information* should results in the consumption of less energy. As such, the framework concerns itself with improving the efficiency of energy demand and supply systems. The framework aims to incorporate disciplines such as management science, design science and policy formation in conjunction with high granular data about the provision and use of energy to develop systems that can improve outcomes for the environment. The framework is illustrated below.

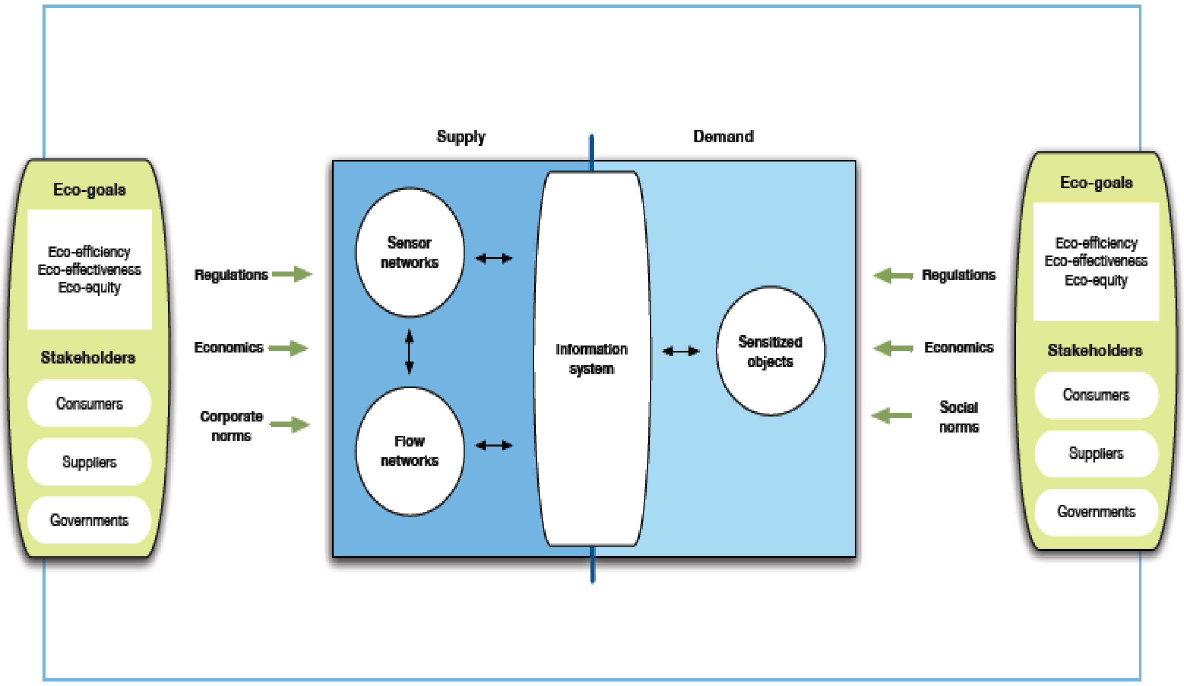

Figure 1. Energy Informatics Framework (Watson et al, 2010)

The framework is based on the assumptions that:

- Consumers are more likely to change their behaviour if they are supplied with the appropriate information on how they use energy (Wood, Newborough, 2002).
- Suppliers can more effectively manage service delivery if supplied with the appropriate usage information from the consumer (Watson et al, 2009)

A flow network is a set of interconnected transport elements that enables the movement of continuous matter such as oil, electricity, water etc or discrete objects such as cars, bikes, packages or people (Watson et al, 2010). A sensor network, as defined by the energy informatics framework, is a set of connected, distributed devices whose purpose is to report on the status of some physical object or environmental condition i.e. air pollution or machine health (Milenkovic et al, 2006). Effective sensor networks are reliant on fine grained information. A sensitized object is a physical item which is owned by the energy consumer and has the ability to gather and report data about its use. Domestic appliances for example can be sensitized with smart plugs which report on power usage and support smart metering (Jahn, 2010). Of central importance to the framework is the capacity of sensitized objects to give the consumer the information they need to use the object intelligently and with the environment in mind. The role of the information system is to integrate all the other elements of the framework to provide a complete design. The technical elements of the framework are augmented by integrating social and organisational contexts, eco-goals and the primary stakeholders in the supply and demand network paradigm i.e. service suppliers and service users.

Eco-goals are well documented in the sustainability literature. Unsurprisingly, cost saving remains high on the list of expected returns from green IS investment. Corporations are largely motivated to pursue eco-efficiency by the prospect of cost reduction and it typically involves the “efficient” use of resources in order to reduce negative impacts on the environment (Dedrick, 2010). Eco-equity relates to the principle that all peoples and generations should have equal rights to environmental resources (Gray, Bebbington, 2000). Developing these norms and ensuring that energy sustainability is seen as an imperative will require the active support of opinion leaders and governments (Watson et al 2010). Eco-effectiveness is concerned with “doing the right things” as opposed to “doing things right”. Political leaders in Denmark for instance have levied a 180% tax on petrol engined cars while zeroemission vehicles are exempt, and the New York Times (29 July, 2011) notes that countries such as France, Germany, Britain, Portugal and Spain all heavily subsidize the purchase of electric vehicles (EVs). Similar approaches are in evidence in both the US and Asia (Ahman, 2004).

In addition Watson proposes four key design elements. These are ubiquity, uniqueness, unison and universality and their usefulness in the design of information systems is well established within the IS literature (Outram, 2010, Tzeng, 2008, Sammer, 2011, Galanxhi-Janaqi, 2004, Placido et al, 2011). Ubiquity is *access "to information unconstrained by time and space"* (Junglas, Watson, 2006). Providing ubiquitous access to information about a service enables users to access information from wherever they may be located and to explore their options to increase the usefulness of that service. Unison, sometimes referred to as consistency, proposes that the procedure of accessing information varies as little as possible. This might mean that users could access information from multiple services or locations while needing only to learn a single procedure. Universality relates to the drive to reduce compatibility issues or *friction* between information systems in order to achieve seamless data exchange. XML (extensible markup language), web services, and application programming interfaces (APIs) have become the de facto means of achieving this interoperability (Rainer and Cegielski, 2011, pp184). Uniqueness is described in the literature as "*knowing precisely the characteristics and location of a person or entity*" (Junglas, Watson, 2006). With information, it can be used to find the best match between the user's needs and the physical resources available. Many bikesharing schemes for example uniquely identify both bikes and users, which means that users can view the availability of bikes and parking spaces on a station by station basis while system administrators can use usage patterns to inform fleet management and other operational functions (Buttner et al, 2012)

Research suggests, (Watson, 2009, Outram et al 2010, Midgely 2009, Chowdhury, 2007), that the more successful systems have supported their physical infrastructure with information systems which implement these elements. They "*minimise the limitations of the physical system and enable and support users to adopt behaviours that help rather than hinder the environment"* (Outram et al, 2010). Given its relative maturity, the energy informatics framework was chosen as the most appropriate instrument to investigate how information systems could support design within the bikesharing domain. From an EI perspective, bikeshare schemes can be seen to represent conventional supply and demand networks which attempt to manage the "flow" of bikes in order to maximise the number of trips.The basic premise of bikeshare schemes is that bikes are made available at key locations throughout the city and are then used to support what are, for the most part, relatively short trips. Schemes typically use independent docking stations capable of automatically checking-out and returning bikes. Users are required to subscribe to the schemes initially and can then access the bikes through a variety of technologies which include smart cards, fobs, direct access codes, or SMS (Buttner et al, 2011). System information, such as the availability of free bikes and stands, or the riders' usage statistics, is typically made available through web based applications, or at interfaces incorporated into the station kiosks. Kiosks can usually support registration and payment options. The recent adoption of mobile phone applications by many schemes has also improved access and usability (Buttner et al, 2011).

2 Methodology

The research comprised a multiple case study investigation of three globally distributed bikeshare schemes. Yin (2009, p53), notes that while a single case study might be effective in investigating a critical or unique case, a multiple case study approach is usually preferable as it provides a more comprehensive means of investigating the phenomena, adds additional validity to the findings and may allow the findings to be generalised. The study was deductive in nature in that it compared a set of theoretical constructs from the EI framework with those observed in the operational environments. The study was supported using pattern match logic. The technique compares an empirically based pattern with a predicted one (Trochim, 1989). If the patterns coincide then both internal and external validity is strengthened. The process compares "non-equivalent independent variables" i.e. the various (non-equivalent) constructs derived from a theoretical framework, with “non-equivalent dependent variables” i.e. those constructs observed in the case study environment. Finding a predicted overall pattern of outcomes across multiple cases supports replication, which is the core of the pattern matching logic approach. Essentially the process became a mapping exercise to determine firstly the degree to which the bikeshare environment could be understood from an EI or supply and demand perspective and secondly the extent to which the framework could support system design. Having evaluated the relevant bikesharing literature, three cases were selected for inclusion in this study. This number was chosen as being likely to either support the theoretical perspectives which informed the study or to allow rival explanations emerge. The schemes operate in a variety of cultural and political environments and each represents a different approach to systems design. Accordingly the technique used in the selection process was information-oriented rather than random. The schemes chosen were Dublinbikes (Ireland), WeBikes (United States) and the Copenhagen Wheel (Denmark). Field work involved three methods of data collection: online survey, documentary evidence and semi-structured interviews.

Due to geographical and time constraints, the online survey was conducted with Dublinbikes users only i.e. the survey population was local to the researcher. The survey was a useful tool in ascertaining how cyclists currently use and experience the informational and digital resources available to them when using the system. It also sought to explore how cyclists felt about a range of innovations currently being deployed in other schemes globally. The survey used a non-random convenience sampling technique i.e. it included only users of the scheme and those individuals willing to participate.

In total, seven semi-structured interviews were conducted in support of the study. In addition to bike share schemes, representatives from the Dublin Cycling Campaign - a cycling lobby group - and the office of the Lord Mayor of Dublin participated in the interview process interview. Due to the globally distributed nature of these schemes, the interviews were conducted using Skype. With the permission of the interviewees, interviews were audio recorded in order to support accurate transcription and subsequent analysis.

Documentary evidence varied from case to case depending on availability. It included company and government reports, academic articles, organisational websites, patent documentation, newspaper and website articles and videos.

3 Findings

3.1 Introduction

The findings relate not only to the constructs defined by the EI framework but also to the additional goal of eco-collaboration, which emerged during the research as an important factor in system design and performance. Eco-collaboration is described as the goal of ensuring that green IS initiatives are collaborative efforts involving partners, other companies, and customers (Brooks, et al 2010). The concept incorporates everything from intra-organisational business process innovation to the use of user generated content (UGC) in aiding eco-friendly product development.

3.2 Case One: Dublinbikes

Dublinbikes is a public private partnership (PPP) involving Dublin City Council and French advertising firm JC Decaux. State support emerged as key to providing the scheme with stability and long term financial support. The Scheme is typical of 3rd generation station-based schemes seen globally. The flow network in Dublinbikes, as in all bikeshare schemes, is comprised of the commuters themselves. While flow networks often attempt to limit flow, as can be seen for example in energy grids or water supply systems, the priority for bikeshare schemes is to optimise flow i.e. maximise the number of trips taken

Radio Frequency Identification (RFID) tags, which represent the scheme's sensor network, are fitted to each bike, and feed information to the docking stands, i.e. sensitized objects. Data collected is then processed by a central information system and used to enable system updates which are then made available to cyclists via kiosk interfaces or through the web application. The information also supports management and operational activities such as bike distribution, fleet management and infrastructure planning. RFID however does not support active tracking and so has limited capacity to mitigate the impacts of vandalism and theft.

Multiple access channels – the station kiosks and web application - support relatively high levels of ubiquity. JC Decaux also provides a mobile app but its poor quality was noted by interview participants. Uniqueness is evidenced by the systems ability to identify both rider (subscription) and bike (RFID). Unison is seen in the provision of a common system view supported by an integrated database while universality is supported by payment options using multiple debit and credit card platforms. Dublinbikes however does not currently import or export data and so does not avail of a range of external data streams which have the potential to enhance usability i.e. weather forecast data or information on other transmit modes. It also means that collaborations with 3rd parties are not currently a feature of the scheme. Allowing data to be exported to social media sites for example could improve the profile of the scheme and encourage increased membership.

While the concept of bikeshare is inherently consistent with the goal of eco-effectiveness, different system designs can different degrees of impact on the environment. Given the high levels of infrastructure that needs to be installed and maintained, Dublinbikes represents a significant disruption to the natural environment. Additionally and in terms of eco-efficiency, costs are considerable. Capital costs per bike run at between €3500 and €4000, with operational costs running at €1500 per annum. Eco-equity, in practice the degree to which the political and regulatory environments have acted to support the scheme, can be seen in the role government has played in supporting the scheme. In addition to creating the alliance with JC Decaux, local government has been responsible for cycle training in Dublin schools, removing Heavy Goods Vehicles (HGVs) from the city centre and introducing the 30kph speed limit. However eco-collaboration, the degree to which initiatives are partnering with other entities to enhance usability and system effectiveness, is almost non-existent. In addition to developing links with social media, such collaboration might also include effective integration with public transportation through enhanced information exchange and common payment mechanisms.

3.2.1 Findings from the Customer Survey.

A brief summary of results from the survey are as follows:

- The majority of trips are supported by system information i.e. cyclists check for free bike and/or dock availability when planning to use the system.
- Respondents were positive about the quality of the schemes' information access channels which support high levels of unison and ubiquity.
- The majority of trips link directly with buses or trains and respondents are positively disposed to improving the relationship between Dublinbikes and public transportation through enhanced information integration and common payment processes.
- Users see the inclusion of a broad range of additional information streams as having the potential to add value to the scheme and enhancing usability. In particular, transit and weather forecast data were highly rated.

- Users indicated strong support for the stationless design model which was perceived as enabling greater flexibility. Such schemes are enabled by a combination of technical and informational design elements.

3.3 Case Two: WeBikes

WeBikes is a stationless design currently being deployed in the bikeshare domain. The scheme is targeted primarily towards smaller environments such as business parks and collegiate communities. WeBikes, a relatively new company, provides software and consultancy services and essentially wholesales the scheme to local operators. Again, it replaces the traditional kiosk and docking station model but with its own unique implementation of mobile and web technologies which they describe as "*right tech, not low tech*". The sensitized object in the WeBikes design is represented by the riders themselves. The system is heavily reliant for its operation on the information generated by users. Users find available bikes by visiting a custom web portal which shows the availability and location of the fleet. Once a bike has been identified, the user texts the bikes' ID number to the system which then automatically responds with the combination of a U-lock fitted to the bike. Once the user has completed their trip they text the location and ID number of the bike to the central server which updates the web portal accordingly. Although WeBikes communication platform is SMS based, it is the riders again that fulfil the role of sensor network. All information is generated by users and then relayed to the system using text messages. In addition to fleet location, the data generated also supports operations such as maintenance and fleet distribution. As with RFID, this visibility is limited however, plus the quality of information updating the system at any one time is dependent entirely on the integrity and/or competence of the users generating it.

WeBikes users can only access information from the web portal resulting in limited information ubiquity. A mobile application is not currently available but the scheme reports that one is under development; however the stationless nature of the scheme supports ubiquitous availability on a physical level. Given that the capacity to import and export data are not currently design components of WeBikes, the level of universality in the system can be characterised as relatively low. The scheme however does acknowledge the improved degree of usability that these elements would provide and say they are committed to incorporating this functionality as part of a longer term agenda. As with the previous schemes, unison is supported by an integrated database, however the lack of consistency in how users represent the location of bikes is identified by WeBikes as a significant issue. This issue similarly impacts uniqueness.

In terms of efficiency and effectiveness, WeBikes' design is considerably less impactful on the environment, and costs runs at approximately a quarter of its station-based equivalent. The relatively low cost of the scheme means that it also has the potential to be deployed in a wider range of settings. Regarding equity, WeBikes reports that bikesharing in the US is currently at a cross roads with federal and local government undecided about how bikesharing should be categorised with the result that schemes do not enjoy the same level of financial and regulatory support as their European counterparts. In fact the lack of funding has been the catalyst for the innovative, less expensive design. WeBikes noted that if bikesharing were to be successful in North America then the regulatory authorities would need to view schemes as legitimate public transportation modes and fund them accordingly. Regarding collaboration, the level of system inter-operability will need to be significantly enhanced to enable links with the broader community.

3.4 Case Three: The Copenhagen Wheel

The Copenhagen wheel is a research project developed in 2009 by the Massachusetts Institute of Technology's SENSEable City lab for the Kobenhavns Kommune - the Copenhagen Municipality. It is an approach to turning an ordinary bike into an electric hybrid bike, quickly and with relative ease. The rear wheel hub, using a Kinetic Energy Recovery System (KERS), captures the dissipated energy from pedalling and braking using torque sensors and stores it until needed by the rider. The hub also contains real-time sensing technology which can transmit information about the environment, personal fitness and location to an integrated smartphone and also via the cell phone network to the web. Though the Copenhagen Wheel is not being developed exclusively for bikeshare, MIT anticipate that, once developed, one of its primary applications will be in the bikeshare domain. The sensitized object in this design is represented by the hub. The sensors it contains can detect CO_2, NOx (nitrogen oxide), temperature, noise (dB) and humidity. In addition to environmental sensing, the suite also monitors the riders speed, relative inclination (through the use of a gyroscope) distance travelled and so on. The system uses global positioning system (GPS) to provide its sensor network which supports active tracking. Route information, plus the data generated locally by the sensor suite, is then relayed to the central server using the cellular network. This allows riders to review the data in their own time using the systems' web based interface. Data developed over extended time periods can also be used to support predictive and demand modelling. In addition, the real-time visibility of the fleet significantly reduces the impact of theft and vandalism.

The information system in the Copenhagen Wheel is an open, XML compliant platform and designed with high levels of inter-operability and universality in mind. The scheme provides social media functionality within its site to support user interaction and has also developed links to Facebook and Google+. Riders see any badges or awards they or their friends have received from the system for achieving personal targets in relation to calories burned or CO_2 offset etc. MIT describe these initiatives as "*technology persuasion techniques*" and report that they have proven especially popular with riders to date. In addition, the scheme notes the importance of incorporating external data sets which they feel have the potential to enhance usability and performance. An app to incorporate real-time weather forecast data into the existing information suite is currently being deployed for example.

Unison, as with Dublinbikes, is supported by a common system view. Uniqueness is enabled in the Copenhagen Wheel by having visibility of riders and bikes not only at the beginning and end of every trip but throughout the entirety of the usage period. Ubiquity is perhaps the schemes' defining characteristic. Multiple streams of real-time data are available to riders at all times via the smartphone interface which mirrors the trend towards the use of dashboard telemetry in motorised transportation in informing driver behaviour. To avoid cognitive overload the rider can choose to view as much or as little data as they feel appropriate.

It's still unclear at the moment whether the Copenhagen Wheel will deploy as a station-based or stationless system. The preference would be the latter but some technical challenges will need to be overcome to make this a reality. The outcome will obviously have direct implications for both efficiency and effectiveness. The findings regarding equity largely support those from the other schemes, namely that the political and regulatory environment plays a large part in the success or failure of bikeshare schemes and that the environment in the US is significantly different from that in Europe. In terms of collaboration, the Copenhagen Wheel places a high value on reciprocal relationships, both internal and external. The scheme encourages riders, through the use of incentives, to add value to the data collected through feedback and route annotation. It is also focused on creating partnerships with both local government and independent 3rd parties to exploit the value of the data it collects i.e. to drive improved cycling infrastructure, enhance integration with other transport modes and so on.

3.5 Cross Case Analysis

Although the technologies found across the studies differed from case to case, all three schemes were seen to map effectively onto Watson's supply and demand network architecture. At the heart of each scheme is an information system which integrates and manages information from the systems other elements i.e. sensitized object, sensor network, and flow network. The choice of technologies supporting these elements was shown to have a direct bearing on performance and design. The role of riders and the use of user generated content (UGC) in two of the schemes can also be seen to represent additional forms of the sensitized object and sensor network. In the case of the Copenhagen Wheel it is used in conjunction with sensing technologies to provide valuable secondary data i.e. route annotations, comments and feedback etc. In the case of WeBikes it is responsible for primary data also. The role of the central information system is pivotal, not only to the collection, integration and dissemination of user and provider data but also in supporting collaborations, both internal and external. The level of platform inter-operability emerged as the key determinant of the degree to which systems are likely to integrate with their environments.

The four design elements emerged as important factors in supporting both system management and usability, and evidence from all three cases suggests that these elements are dependent on a number of factors including technical architecture, the information system platform, and business process design. The primary difference that emerged was in the area of universality. Both Dublinbikes and WeBikes supported relatively low levels of inter-operability. Eco-goals were also shown to have a bearing on performance and design. Both eco - efficiency and eco-effectiveness emerged as catalysts for the development of the stationless models. The research suggests for example that the kinds of information and design innovations seen in WeBikes - which receives no state funding - are driven in large part by the need find both cost effective and highly sustainable solutions. Eco-collaboration, not currently a feature of the framework, was seen to impact numerous design elements such as the level of platform inter-operability, the degree of reciprocity in the system and the use of UGC and social media.

4 Conclusions

4.1 Addressing the Research Question

The EI framework, expanded to incorporate the goal of eco-collaboration, provided a comprehensive understanding of all of the determinants of system performance and emerged as having the capacity to improve the capability of existing schemes and inform the design of schemes of the future. Figure 2 illustrates this new framework. The more effective schemes had exploited the potential of technology and design to enhance information quality and improve information integration between providers and their stakeholders.

The core framework elements i.e. sensitized object, sensor network, flow network and information system, when augmented by key design elements and eco-goals provided a clear road map for the design of schemes which can leverage the potential of information to improve performance. Though the framework may not prescribe specific technologies it does provide an architectural plan which can be used to understand the potential of information and identify those elements likely to exploit it fully.

The research demonstrated for example that the sensitized object in a scheme such as the Copenhagen Wheel, which makes a variety of fine-grained, real-time data sets available to both rider and operator, is far more likely to add value than that found in Dublinbikes, which is limited to recognising whether or not a bike is being used. Likewise, the choice of sensor network emerged as an important design characteristic. RFID for example is limited to detecting bike availability while GPS can support the real-time location of bikes, mitigate the impacts of theft and vandalism and provide an accurate record of routes taken. This in turn allows operators to make informed planning decisions and provides users with a comprehensive array of usage statistics which have the potential to support informed decision making. The information systems platform, at the heart of Watson’s framework, emerged with equal importance in the research. Open, XML compliant systems characterised schemes like the Copenhagen Wheel which prioritized collaborative relationships with their environments. It is platforms designed for these attributes that will support, for example, improved partnerships with public transportation or car-to-go initiatives, as well as being best placed to integrate useful external data sets as they become available.

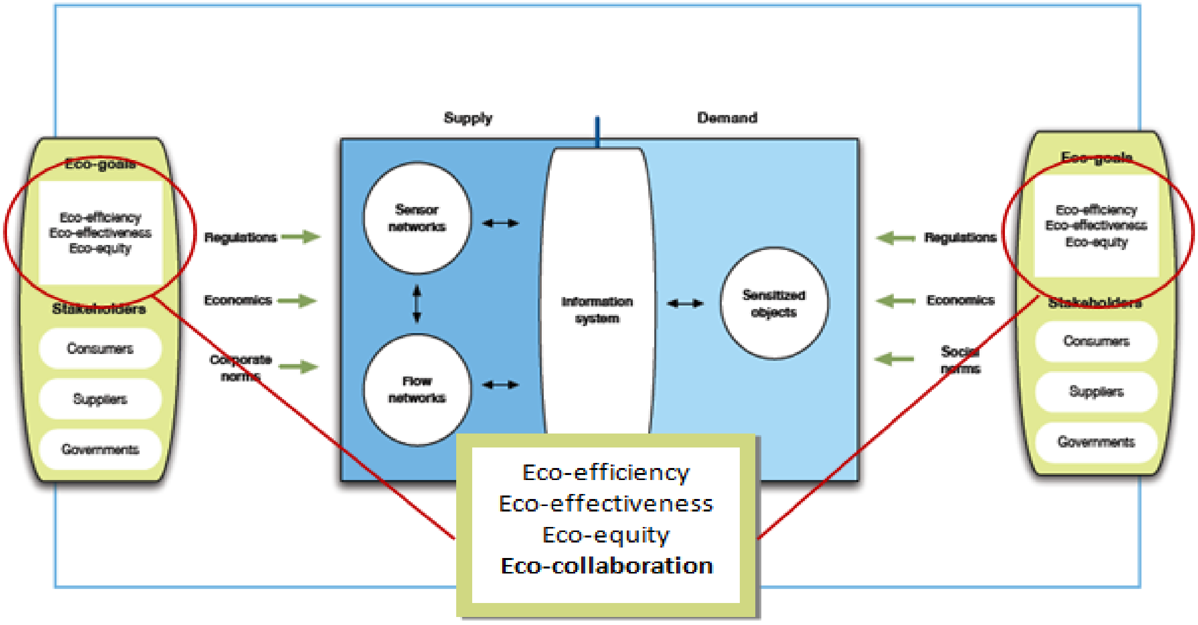

Figure 2. The expanded energy informatics framework

The importance of Watson’s U-constructs, ubiquity, unison, uniqueness and universality, emerged as a recurring theme in the case study environments and their role in creating synergy between the scheme’s physical and informational components emerged as key to enhancing system usability and efficiency. This was an important validation of the framework.

Energy informatics is a “green” framework, driven to support environmental sustainability through system optimisation. The research demonstrated that eco-goals can be major contributors to design and performance. Findings noted for examples that eco-efficiency and eco-effectiveness need not be mutually exclusive. On the contrary, the findings suggest that stationless designs, which impacted least on their environment and supported the greatest levels of usability and customisation, were also the most cost effective. Eco-equity, in practice the degree to which governments are willing to acknowledge and fund schemes as legitimate transport modes, was also seen to directly impact design. The move towards a stationless model is driven at least in part by the need to manage expenditure by creatively exploiting the full potential of technology and information.

A key learning from the research was the importance to system performance and design of eco-collaborations. It is these partnerships which define the extent to which the schemes integrate with their environments. They drive platform openness, business process design and a range of initiatives such as the use of UGC and social media. Significantly, using social media to communicate information on how a rider’s peers are behaving may be especially effective in modifying behaviour based on early findings from the Copenhagen Wheel. Watsons’ framework, in its current form, focuses primarily on the value of the information generated internally and exchanged between the two primary stakeholders i.e. service supplier and service user. Significantly, the use of

Given that schemes operate in a variety of environments and benefit from different levels of financial and regulatory support, there may not be a single optimal design solution. WeBikes for instance is operating in an appreciably different market space to Dublinbikes and with far less resources. Schemes which function well in smaller settings may not be effective when scaled to operate, say, in metropolitan areas. From an EI perspective, the important point is that the framework can be used to enable incremental improvements. In summary, improved design is achieve by:

- Allowing operators to understand schemes from the perspective of supply and demand networks.

- Providing a frame of reference by which the value of their existing information and technical infrastructure can be understood and evaluated.
- Recommending a set of informational attributes, design elements and eco-goals which can be used to improve performance and sustainability.

4.2 Limitations of the Research

Due to the restrictions of time and resources, the study explored the potential of green IS to impact the design of supply and demand networks through an investigation confined to the bikesharing environment. Supply and demand networks can be found in a wide variety of settings, however the findings from the research can only be taken to apply to the environment investigated. In addition, the findings should be viewed in light of the following:

- The survey used a non-random convenience sampling technique. As such the findings cannot be generalised to the entire population and may not be reflective of the target population – Dublinbikes
- It is the assumption of the research that responses to the survey and interviews represent the honest and informed opinions of the respondents.
- While the study was designed to optimise the validity of the findings through multiple replications, it should be noted that schemes may exist which do not support the findings of this study.

4.3 Future Research Opportunities

Useful further research would be to explore the potential of the framework to support the design of networks across other domains. In addition to the transportation environment, opportunities exist for example in areas such as the delivery of utilities like electricity, water, or gas. These environments are comparable to bikesharing in many key respects. The potential of information to support both service provision and service use in a similar manner is high and the industries are influenced by regulatory and environmental factors that also resonate with bikesharing i.e. political stakeholders, corporate motivations and so on. From a sustainability perspective of course the ultimate aim of these networks is to reduce rather than optimise flow but there seems to be ample grounds to warrant further research.

There may also be potential in exploring the value of informational tools in increasing the efficiency of areas such as open data platforms, telephony or internet service provision, which again contain the core elements of supply and demand networks i.e. service providers, service users, and a flow of content to be regulated.

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