SURROGATE MEASURES FOR URBAN BIODIVERSITY, AND HUMAN HEALTH AND WELL-BEING

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ABSTRACT: Within a sustainable urbanization context there is a need for an overarching theory addressing the concepts of biodiversity and public health benefits holistically. The authors report on their innovative approach, which aims to develop a grounded theory addressing the links between urban biodiversity, and public health and well-being. The approach involves the use of surrogate measures for urban biodiversity and health: urban habitat structural diversity and peoples' activities respectively. Other socio-economic, environmental and cultural aspects of local communities can also be useful surrogates. Based on an interdisciplinary literature review, this paper outlines the justification for the choice of approach and surrogates. The use of simple surrogates makes the study of complex interrelationships more manageable, offers better opportunities for inter-disciplinary understanding and can readily yield primary data for grounded theory development. This paper will be of interest to urban ecologists, urban planners, public health practitioners and urban sustainability researchers.

Keywords – physical activity, public health, surrogate measures, urban nature conservation, urban sustainability

1. INTRODUCTION

The contribution of urban green space to the social, economic and environmental aspects of sustainable urbanization have been well documented in research reports and advocated in urban policy. Research reports from urban nature conservation such as those of Lee and Evans, (2003); Taylor and Coalter, (2001); National Urban Forestry Unit, (1998); Barker, (1997) and Stephen *et al*, (1995) have variously outlined social, economic and environmental contributions of urban green space. Urban sustainable development policy also realise the potential multifunctional contributions of urban green space, including health and well-being, Commission of the European Communities, (2004); ODPM, (2003) Department of Environment Transport and the Regions, (2000).

A number of conceptual models and explanatory theories have been suggested for the contributions of various aspects of the environment to health and well-being. The "arch of health" (WHO, 1998) is a public health model illustrating the environmental, cultural, socio-economic, working and living conditions, community, lifestyle and hereditary factors of public health. The "arch of health" is a good conceptualization model. However, it does not explain specifically the role of biodiversity in public health. Another conceptual, but not explanatory, framework for the contributions of nature to quality of life is suggested by English Nature (2002). This framework is called "revealing the value of nature". The social functions of nature are seen as stemming form peoples' appreciation and knowledge of nature, from the utility of products and ecosystems services, and from a variety of motivations or values for nature

conservation. References to contributions of nature (including biodiversity) to healthy living surroundings, personal development and medicine are illustrated on the framework. However, the framework "revealing the value of nature" does not explicitly cover the health and well-being functions of urban biodiversity (English Nature, 2002). Hence, the "arch of health" and the framework "revealing the value of nature" do not provide an explanatory basis specifically regarding the role of biodiversity in contributing to public health and well-being.

"Stress recovery" theory (Ulrich, *et al* 1991, 1983 and 1979) suggests that the restorative potential of nature stems from its capacity to provide a sense of refuge from environmental stress and pressures of life, thus helping recovery from stress. "Stress recovery theory emphasizes" the immediate affective responses to scenes of nature as the main source of its restorative potential. "Attention restoration" theory (Kaplan, 1995; Kaplan and Kaplan 1989) agrees on the refuge role provided by nature. However "attention restoration" theory emphasizes the long term cognitive benefits of contact with nature as the main source of its restorative potential. "Stress recovery" and "attention restoration", are the two main theories attempting to explain the restorative mechanisms of human contact with nature. These two theories link the restorative potential of nature with preferred scenes, but not to biodiversity. Furthermore, these two theories refer mainly to the psychological restorative potential of nature. Thus, "stress recovery" and "attention restoration" provide initial explanations (albeit different) for the psychological restorative potential of nature, but do not explicitly address the role of biodiversity in this.

Freeman (1984) suggested a "model of environmental effects on mental and physical health". This model stipulates that physical, social and cultural factors through intervening variables impact on the nervous system and this is manifested through other intervening variables into mental or physical illness. This model does provide an explanatory framework for the role of environmental variables in health but, again, it does not refer to biodiversity specifically. Henwood (2002) in her review of the role of environmental and countryside agencies in promoting benefits to health used McVey's "psychosocial stress and health model". According to this model a poor environment can lead to chronic anxiety, chronic stress, and high blood pressure with consequent health implications. This model is valuable in linking the psychological well-being with physical health. Nonetheless, the "psychosocial stress and health model" addresses environmental factors to health in general and not biodiversity specifically. So, public health models also recognise the general role of environmental parameters in public health but do not specifically address the role of biodiversity in contributing to public health and well-being.

More recently the hypotheses of "biophilia" and "biophobia" have been suggested to account for peoples' affiliation, or aversion to certain aspects of nature. According to the "biophilia" hypothesis humans have an innate need to be in contact with nature. This innate need may have evolutionary origins: humans are affiliated to aspects of nature that provided them with evolutionary advantages. This explains why people feel affiliated to certain aspects of nature (Wilson, 1993). Also, probably based on an evolutionary origin, the "biophobia" hypothesis explains aversion to certain aspects of nature in terms of association with danger and threat during some time in the human evolutionary history (Ulrich, 1993). The "biophilia" and "biophobia" hypotheses attempt to explain in

evolutionary terms affiliation or aversion to certain elements of biodiversity. However, the link between affiliation or aversion and health, and well-being is not made explicit.

This review of the theories and conceptual models addressing contributions of various aspects of nature to various aspects of health and well-being revealed that the theories are fragmented, some could be seen as contradictory, and they are not integrated. None of the theories that were reviewed was specifically developed within a sustainable urbanization, public health and biodiversity context. Consequently, there is no overarching theory addressing the role of urban biodiversity to public health and well-being.

The aim of this paper is to present a justification for the approach and choice of simple surrogate measures for studying complex concepts such as urban biodiversity and public health and well-being. This approach has been followed by a PhD project aiming to develop a theory of biodiversity contributions to public health and well-being within a sustainable urbanization context.

2. RESEARCH APPROACH

Generally, an inductive approach to research is followed for generating theory and the hypothetic-deductive approach is taken when a theory has been formulated and needs verification. The aim of this PhD is to formulate a theory; so a primarily inductive approach is taken. The research approach is composed of seven broad stages (left hand side of Figure 1) each one of which is operationalised through a number of sub-stages (right hand side of Figure 1). Appropriate surrogates for the complex concepts of urban biodiversity, public health and well-being are established first. Then, data is collected on these surrogates and patterns in the data are used to construct a theory explaining the contributions of urban biodiversity to public health and well-being.

Ontologically most research in humans-nature relationship tends to be based on the assumption that psychological responses to environments are predictable. Environmental parameters and psychological functioning are seen as independent but to larger or lesser extend related variables. Generally, a cause effect relationship is assumed with systematic associations between variables (Uzzel, 1991). Epistemologically most research follows reductionist quantitative techniques measuring amounts of environmental variables and relating them with amounts of psychological or health outcomes. Reductionsist approaches are working for simple systems but break down for complex and complicated systems (Waldrop, 1992; Gleick, 1987; Lincoln and Guba, 1985). Applying reductionists approaches in complex systems can only produce reductionist fragmented theories. This domination of the positivist paradigm is why existing theories do not address the humans-nature relationship holistically.

Biodiversity has many levels of measurement and many dynamic dimensions. Public health and well-being are also multiple level and complicated concepts incorporating dynamic states. An alternative to the positivist paradigm is offered by the naturalist paradigm (Lincoln and Guba, 1985) and an alternative to reductionism is dynamic systems theory. Dynamic systems theory is based on the idea that complex systems give rise to simple behaviour. That is, complex systems organise themselves into emergent patterns (Waldrop, 1992; Gleick, 1987). Studying these emergent patterns simplifies the study of complex systems, revealing simple underlying principles (Donaldson, 2004).

Accordingly, an approach based on appropriate simple surrogates could reveal patterns for the more complex concepts of biodiversity, health and well-being.

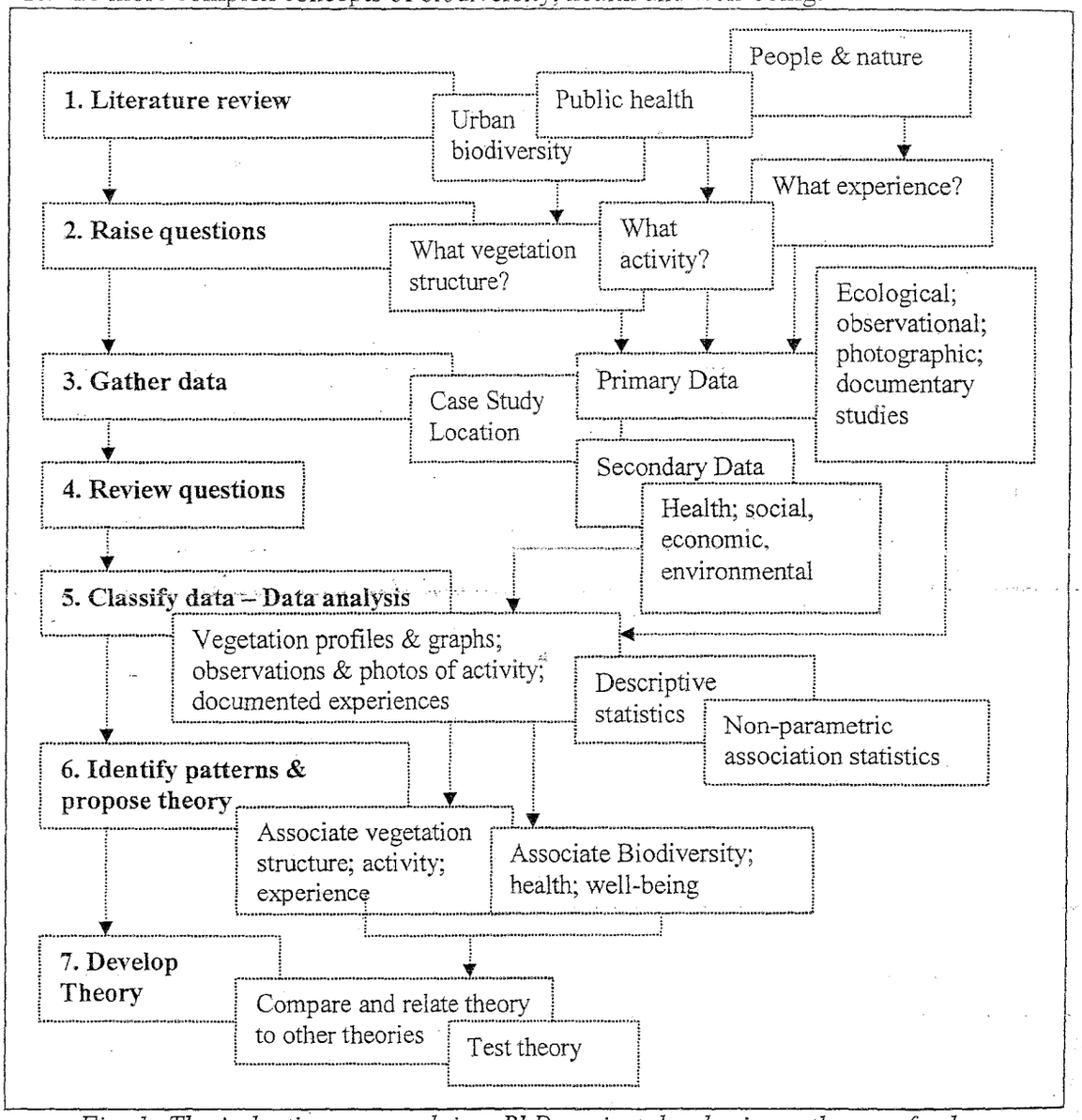

Fig. 1: The inductive approach in a PhD project developing a theory of urban biodiversity's contributions to public health and well-being (see text for explanation).

Grounded theory was defined by Glaser and Strauss, (1967, p 1) as "the discovery of theory from data - systematically obtained and analysed". The authors, in their initial formulation of grounded theory, placed an emphasis on systematic constant comparative analysis and this became known as the Glaser approach. However, Strauss developed an alternative approach (Strauss and Corbin, 1998). The Strauss approach uses various analytical techniques and is more methodologically flexible than Glaser's constant comparative analysis. Another approach to grounded theory is based on identifying patterns of explanations based on patterns of empirical data (Reason, 1981). The

inductive approach to the development of grounded theory in this research is underlined by naturalist axioms, ontology and epistemology but also draws ideas from Reason (1981). The naturalist approach to grounded theory is characterised by the development of qualitative and quantitative summaries of primary and secondary data, review of hypotheses, and categorical structuring of patterns between themes and relationships, which, consequently leads to the development of grounded theory (see Figure 1, stages 3-7). This approach allows the use of a variety of qualitative and quantitative methods producing respective data. This is appropriate since biodiversity and public health have both qualitative and quantitative aspects. The naturalist approach to grounded theory also enables interdisciplinary data collection and analysis, thus facilitating integration. Finally, the naturalist approach permits flexibility to research design, so that it can be tailored to specific situations, while also retains rigour.

A paradigm shift from positivism to integration in ecology has been expressed through new ecology. In humans-nature relationship this shift is seen in the transactional approach. According to the transactional approach humans-nature are seen as holistic entities (i.e. confluences of inseparable factors). The dynamic interplay between nature and humans makes the outcome of the interaction unpredictable. However patterns may form across events allowing for principles to be developed (Rohde and Kendle, 1994). These patterns or principles could be used to build a theory of the contribution of urban biodiversity to public health and well-being. To establish appropriate surrogates for the complex concepts of urban biodiversity, human health, and well-being a multidisciplinary literature review was undertaken, which is reported below (see Figure 1, stages 1 and 2).

3. SURROGATES FOR BIODIVERSITY

Habitat diversity was chosen as the level of measurement for urban biodiversity, because it is at this level where people interact with nature most. Complex habitats with vertical and horizontal structural diversity offer more niche opportunities than homogenous habitats, increased micro-habitat creation and increased opportunities for species (Krebs, 2001; Jeffries, 1997). Consequently, the more stratification and the greater spatial arrangement of urban habitat vegetation the more likely it will support a greater urban biodiversity. Table 1 summarizes some of the studies that have linked biodiversity with habitat structural diversity.

Often ecological studies make explicit comments on the importance of habitat characteristics for the diversity of specific populations or communities. Studying bird diversity in relation to land use cover in Scotland French and Picozzi (2002) found that at landscape scale species diversity should be related to landscape characteristics. Again studying bird populations Fernandez-Juricic and Jokimaki, (2001) found that fragmentation of urban green spaces affects birds and that park size and the range of habitats within urban parks are important factors on bird biodiversity. Hence, range and structural characteristics of habitats within urban areas is important for bird diversity.

Table 1: Studies referring to the use of surrogates for biodiversity
(for full reference see the references list)

Study	Biodiversity aspect	In relation to	Findings
French and Picozzi (2002)	Bird populations	Land use cover	species diversity should be related to landscape characteristics
Fernandez-Juricic and Jokimaki, (2001)	Bird populations	Fragmentation; habitat size; range of habitats	Park size and the range of habitats within urban parks are important factors on bird biodiversity
Young and Jarvis (2001)	Habitat biodiversity	Habitat structural diversity	structural diversity of habitats is linked with biodiversity in most, although not all cases
Hercock, (1997)	Surrogate for biodiversity	Vegetation structure	vegetation structure of habitats can give a surrogate measure for biodiversity
Whitford *et al*, (2001)	Ecological performance (incl. biodiversityy)	Ground surface percent covers	Percentage of green areas and particularly trees had the greatest influence on ecological performance

Other researchers take the habitats approach to urban ecology. Young and Jarvis (2001) evaluated habitats in terms of their internal diversity. They found that structural diversity of habitats is linked with biodiversity in most, although not all cases. They concluded that structural diversity of urban habitats can be a powerful tool for assessment of biodiversity. Hercock, (1997) presented a concept of, and a methodology for studying vegetation structure of woodland remnants around Perth, as surrogate for biodiversity. He found that vegetation structure of habitats can give a surrogate or an indication measure for biodiversity. Furthermore, he argued that this method helps bridge understanding difficulties between disciplines. Whitford *et al*, (2001) measured ecological performance (including run off, temperature, carbon storage, and biodiversity) of cities based on a method that simply records different surface percent covers. Percentage of green areas and particularly trees had the greatest influence on ecological performance. Therefore, initial studies support the idea that biodiversity is related to habitat characteristics and structure, and that the later can be used as an indicator (or surrogate) for the former. Also, habitat diversity studies offer opportunity for better understanding between disciplines.

Since it has been established that urban habitats diversity and specifically vegetation structure can be a useful surrogate of biodiversity a methodology was created to collected primary data for this surrogate measure. A case study location (Birchwood, Warrington) was chosen and an ecological study measuring the land cover of different land uses and vegetation structures was organized (see Figure 1, stages 2-5). Vegetation profiles, land cover graphs and species lists are produced as surrogates for urban biodiversity. These data can be treated with appropriate descriptive statistics and correlated with the data from the surrogates for health and well-being with non-parametric association statistics to reveal any associations, or patterns.

4. SURROGATES FOR PUBLIC HEALTH AND WELL-BEING

Traditionally, public health tended to emphasize the environmental determinants of health. Godlee and Walker (1992) reviewed the health implications of the major environmental issues of the 1990s. Stanners and Bourdeau (1995) in the Dobris assessment provide a review of the urban environment and conditions for human health at EU level. Such approaches (see table 2) pay more attention to the quality of the physical elements (air, water, land, radiation) of the environment and less so on the biological elements. The approach of the World Health Organization to public health is one of creating and improving those physical and social environments and community resources supporting health; the approach is based in appropriate policy, governance and participation (WHO, 1998).

Table 2: Studies referring to environmental and socio-economic factors as surrogates for public health and well-being (for full reference see the references list)

Study	**Environmental and socio-economic determinants of health**
Godlee and Walker (1992)	Population; climate change; ozone layer depletion; waste; air pollution; transport; noise; water quality; radiation
Stanners and Bourdeau (1995)	Air pollution; water pollution; radiation; housing; workplaces; accidents
WHO, (1998).	Agriculture and food; education; living and working conditions; unemployment; water and sanitation; health care services; housing; social; and personal characteristics
Wilkinson and Marmot, (1998)	Stress, childhood, social exclusion, employment, social support, lifestyle and transport
Davey-Smith *et al,* (1997)	Age, occupation, social class, and lifestyle

So, public health recognizes a significant affect of the physical environment on health but has tended to ignore the biotic elements.

The socio-economic determinants of health have also been studied (see table 2). Wilkinson and Marmot (1998), for instance, provide a review of evidence of the public health implications of socio-economic background, social exclusion, lifestyles and stress. Davey-Smith *et al,* (1997) reported how an individual's socio-economic position can affect risk for morbidity. They found that there are different health risks for different socio-economic positions; manual workers are in more risks from cancers, non manual workers are in more risk from cardiovascular disease. Thus, not only the physical environment but also the socioeconomic and cultural environments are important factors of public health.

Since both background environmental quality data and socio-economic conditions of a community have been linked to public health, they should be appropriate surrogates for it. Data on the socio-economic, demographic and environmental determinants of public health are readily available. These include population density, gender, deprivation, employment, socio-economic composition, education housing and access to services. Environmental quality data is also available from local authorities and the Environment

Agency. Such secondary (surrogate) measures have often been used in public health studies and advocated by the Healthy Cities Approach (WHO, 1998). Furthermore, direct health statistics from Primary Care Trust can also be used as initial indicators of public health. Therefore, secondary, readily available data on the socio-economic and environmental parameter of a community should be good surrogates of the public health and well-being of that community.

One link commonly recognised between green space and physical health is the opportunities for physical activity that it provides (Takano, *et al*, 2002; Handy, *et al*, 2002; Payne, *et al,* 1998). A number of reviews of evidence have been published for the health and psychological health implications of physical activity (see table 3). Bouchard, *et al* (1990) summarizing the evidence for the health benefits of physical activity concluded that when taken regularly it can significantly reduce the risk of major chronic diseases such as cardiovascular disease, some cancers, diabetes, musculoskeletal disease and mental disorders. The evidence for the health benefits of physical activity is not equally strong for all the different diseases. However, there is a general consensus that physical activity has significant preventative benefits. Some evidence for the curative benefits of physical activity also exists but is generally weaker. Similar reviews of the health and psychological benefits of physical activity are provide by Department of Health, (2004); Fox, (2003) and Sallis and Owen, (1999). Furthermore, physical activity in public parks specifically has been linked to health outcomes (Killingsworth, *et al*, 2003; Takano, *et al*, 2002; Handy, *et al*, 2002; Payne, *et al,* 1998). The more physical activity that is taken the more health risks is reduced over the long term (DoE, 2004). Consequently, physical activity can be a significant determinant of public health. This is why physical activity patterns were chosen as a surrogate measure for physical health.

Table 3: Studies reviewing the evidence for health and well-being benefits of psychical activity (for full reference see the references list)

Study	**Physical activity and health**
Bouchard, *et al* (1990)	Circulatory system; mental health; respiratory system; diabetes; obesity; back pain; cancers; immune system
Department of Health, (2004)	Cardiovascular disease; type 2 diabetes; musculoskeletal disorders; colon and breast cancers ; obesity; mental well-being
Fox, (2003)	Coronary heart disease and stroke; obesity; diabetes 2; cancer; musculoskeletal health; mental well-being
Sallis and Owen, (1999)	Longevity; cardiovascular; obesity; diabetes; cancers; osteoporosis; elderly functioning; low back pain; immune system; depression; anxiety

The main concerns, debates and source of pride and attachment of local communities for their green space can be glimpsed through local documentary records. The local debates as recorded in local records should reflect peoples' experience of their local green spaces. Vuorisalo, *et al* (2001) used newspaper records to assess urban ecology and human attitudes to it. They found that local records can be a rich source of ecological information and peoples' attitude to it. Accordingly, specifically targeted records should be a good source for accessing people's experience of their local environment. Local Authority Park Rangers records, local groups' meetings archives, local newspapers and newsletters are all potential sources for more in depth data on local experiences.

Analyzing such experiences should reveal community perceptions of well-being and concern from their local green space. Local experiences of green space were chosen as surrogate for well-being because they reflect peoples' values, perceptions, affiliations and concerns associated with their local green space. It is anticipated that the more positive experiences that are recorded the more the community well-being should be and vice versa.

Since it has been established that socioeconomic and environmental determinants, physical activity and local experiences can be useful initial surrogates for public health and well-being a methodology was organized to collected primary and secondary data for these surrogates. Secondary data on socio-economic, demographic and environmental parameters of the case study location were simply collected from the relevant organizations. To collected primary data on the physical activity patterns an observational and photographic study was organized. To collect data on local experiences local archives were reviewed (see Figure 1, stages 2-5). Records of observations, photographic records of physical activity, and recordings of local experiences are produced. Photographs and local records are analyzed with content analysis. These data are summarized with appropriate statistics and associated with the surrogates for biodiversity with non-parametric correlation statistics to reveal any patterns.

Once data for vegetation structure, physical activity and local experiences has been collected, summarized and correlated any emerging patterns between these surrogates measures should also reveal underlying patterns between urban biodiversity and human health and well-being (see Figure1, stages 6 and 7). Such patterns could be drawn together to reveal a grounded theory on the contributions of urban biodiversity to human health and well-being.

5. CONCLUSSION

The benefits and contributions of urban green space to the social, environmental and economic aspects of urban sustainable development have been variously described. Reductionism in humans/nature relationship has produced a number of fragmented theories. Thus, existing theories only address parts of the humans-nature relationship and do not, specifically and holistically, address the contributions of urban biodiversity to human health and well-being. There is a need for an overarching theory, addressing the concepts of biodiversity and public health benefits holistically. To develop such a theory this research project has followed the naturalist paradigm and approach to grounded theory. To avoid reductionism on the complicated systems of urban biodiversity and public health and well-being this PhD developed an approach based on ideas from dynamic systems theory and the use of surrogate measures for complex concepts.

It has been shown that urban habitat structural diversity and especially vegetation structure is a good surrogate for urban biodiversity. Similarly, physical activity patterns and local experiences can be a strong surrogate for public health and well-being. Therefore, any patterns between vegetation structure, physical activity and experiences should reveal patterns between urban biodiversity, health and well-being respectively, thus making the study of complex systems much more manageable. The use of simple surrogates offers better opportunities for inter-disciplinary understanding and can readily yield primary data for grounded theory development.

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