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EXPLORING SYSTEM DYNAMICS TO MANAGE TECHNOLOGIES FOR INCREASING SUSTAINABILITY

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This paper will discuss how system dynamics and computer modelling contribute to the debate of management of technologies in response to sustainability crises. The basic components and properties of socio-ecological systems were modelled in order to understand possible responses to resource scarcity or exceeding levels of pollutions in a given system. The computer programme was based on a *toy model* methodology in accordance to our commitment to simplification and focus on the relationship between ecological resources provision and human consumption and needs. The results show that computer simulation may provide interesting insights on managing the use of ecological resources when attempting to promote increased human wellbeing. The mapping of system dynamics has also proven useful to explore the nature of sustainability challenges and the appropriate responses under the expected feedback loops between the various regimes of a macro socio-ecological system such as technological and consumption regimes.

Keywords: *Sustainability; Social-Ecological Systems; Sustainability Performance*; *Systems Thinking*

Introduction

Despite recent advancements in environmental policies, use of green technologies, and public awareness; there is still doubt over whether the magnitude and velocity of improvements are sufficient to avoid a catastrophic future for humankind.

Using systems thinking as the core methodology, this paper discusses the fundamental properties of social-ecological systems to initiate a debate seeking for the unifying laws of sustainability. As known, the natural (ecological) system supplies vital 'ecosystem services' such as air, water, sunlight, pollination, amongst others. On the other hand, the socio-economic system consumes part of these resources to promote human wellbeing. The latter can be divided in various subsystems such as economic (e.g. production, trade, consumption), technological (e.g. hardware, software, humanware), and cultural (e.g. believes, values, etc) to better characterise the activities within the macro-system.

In a social-ecological system, the interactions between the macro-systems and their subsystems within them need to be analysed to determine the resilience of the whole system, i.e., the availability of resources, the implications of policies and market forces, as well as the power and limitations of technologies.

While technology plays a central role in reducing humanity's environmental impacts, significant emphasis is put on the need of controlling of human consumption. Our work provides examples of various historical and contemporary cases when technology-driven approaches were the predominant solution and others when social changes were effective for increasing resilience of social-ecological systems. Our contribution is then made by modelling the social-ecological systems considering two types of basic consumption (essential and superfluous), feedback loops between resource availability, political, market, and technology forces or interventions. These will inform the debate about the fundamental laws of sustainability of social-ecological systems linking those to the real exemplary cases described.

The discussions in this paper can be useful in helping the development of a meaningful role of Management of Technology community as it stands for the economic, environmental and political challenges we are currently facing.

Literature Review

The generalist nature of systems approaches has indeed helped us understanding and solving complex problems albeit that did not happen without resistance and controversy. Fifty years after Forrester introduced the Industrial Dynamics concept (Forrester, 1961), the effectiveness of systems approaches is still discussed. A clear message by Bertalanffy (1972) tried to create a path for General Systems Theory:

> "Modern technology and society have become so complex that the traditional branches of technology are no longer sufficient, so approaches using a holistic view or systems thinking, and of a generalist and interdisciplinary nature, become necessary" (Bertalanffy, 1972).

This section will explore the systems theories and its latest approach to measure sustainability performance of socio-ecological systems.

Systems theories

Indeed, systems approaches have been found in several branches of science as shown in Figure 1 developed by Ison (2008). Nevertheless, the scepticism about how practical systems approaches can solve complex problems and replace the traditional reductionist approaches still persists. Checkland (2000) argues in favour of systems thinking despite the fact that, in his opinion, general systems theory (GST) has failed in its application.

While the application of systems approaches is still full of controversy, their principles are much more respected and will continue to be. The main reason is because the principles of systems theories tend to reflect the reality and complexity of events, while the application, use, and success of systems tools are vulnerable to not only known factors (e.g. availability of data, certainty of causal relationships, etc) but also unknown factors (e.g. uncertainty of social behavioural changes, etc). Very few would argue against the evidence of ability and competence of self-organising systems such as biomes, social systems, and market dynamics. However, the solutions given by system theorists are far from gaining wider acceptance. The problem seems to reside more on the systems models and tools, and of course their outcomes, rather than on the principles of systems theory. This is especially true for social sciences, where human behaviour is far from being predicable for most of the time. With similar controversy due to the gap between models and reality, the recent non-linear models for climate change have still not been accepted without questions. For instance in biology, where there might be a higher certainty levels and models may reflect better the reality in some fields (e.g. cellular biology, ecosystems, neuroscience, etc), systems theorists have achieved a much respected status.

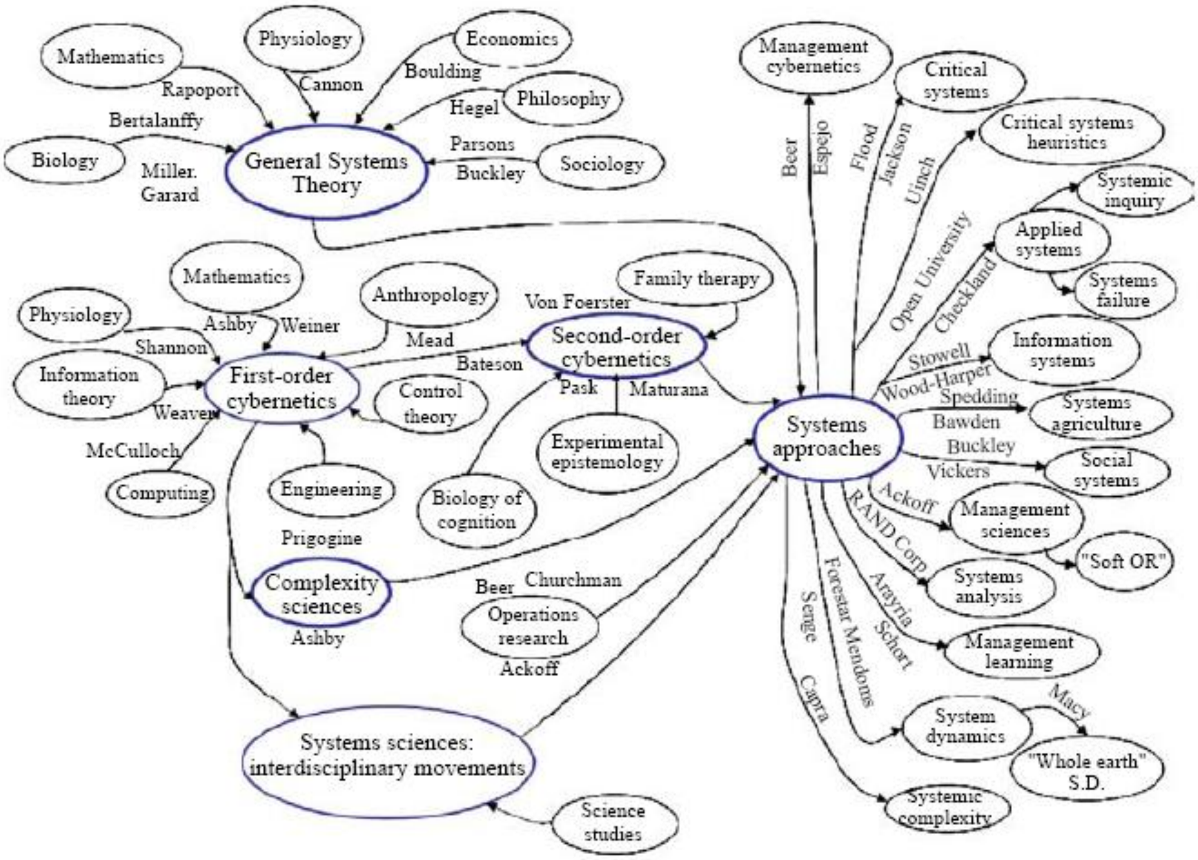

Figure 1 – Roadmap of systems approaches by Ison (2008)

For these reasons, this paper uses a systems fitness concept in order to enhance the understanding of the dynamics when a social-ecological system is pushed to its limits of fragility (e.g. scarcity of resources, destruction of social tissue, economic collapse, etc). Our work seeks to contribute to the debate of systems resilience through the lenses of management of technology.

The problem of sustainability performance measurement

The literature on sustainable development and sustainability management indicates that the first step to manage and measure sustainability performance of a given system is the identification of the system characteristics (e.g. its complex dynamics) and boundaries as well as the availability of resources within the system (Enfors, 2013). Then, the assessment of necessary interventions to promote higher levels of resilience need to be investigate through multiple lenses of governance (e.g. power, processes, etc) (Duit et al, 2010).

For years research studies (Meadows et al, 1972; Wackernagel and Rees; 1998; Meadows et al, 2004; Rockstrom et al, 2009a; Rockstrom et al, 2009b) have been showing that efficiency gains and technological progress may not sufficiently preserve the planet’s natural environment as predicted in Jevons' paradox (Jevons, 1905). If Jevons' paradox is relevant in 21st century, applying quotas will counter ineffective efficiency policies (Alcott, 2005). Thus, the importance of identifying thresholds within socio-ecological systems is vital to reduce its vulnerability (Young, 2010). Given the complexity of societal, economic and ecological systems, Meadows's studies have been influenced by Forrester's concept of system dynamics at industrial, urban, and world scales (Forrester, 1961, 1969, 1971). However, effective ways to measure sustainability performance are still under development, as we show below.

At the country level, despite the ubiquitous use of gross domestic product (GDP) and the Human Development Index (HDI) in national policies, they "are failing to capture the full wealth of a country" (UNU-IHDP and UNEP, 2012 page xi). The Inclusive Wealth Report (UNU-IHDP and UNEP, 2012) is an alternative including more realistic measures. The report measures wealth using three macro-indicators: natural capital (e.g. forests and fish stock), human capital (e.g. level of education and creativity), and produced capital (e.g. roads and factories). Going beyond GDP and HDI measures, countries and cities could have their real (inclusive) wealth better assessed. Notwithstanding the legitimate need to measure environmental wealth, green accounting will be vulnerable to the complexity around its measurement methods and criteria as well as uncertainties of nature's behavioural dynamics (Tsur and Zemel, 2006).

At the corporate level, there is difficulty in measuring sustainability performance that is truly aligned to the natural environment's sustainable development (Shrivastava, 1995a; Hart, 1995; Hart, 1997). For example, most studies focus on absolute and relative numbers of emissions, waste, and consumption of resources (Hahn et al, 2009). However, socio-economic indicators often neglect the value of products and processes to meet society's needs (Careiro et al, 2012). Social dimension is in fact considered more difficult to assess than environmental dimension (Hahn and Kühnen, 2013). In short, current corporate sustainability performance indices have little contribution in defining a clear role of companies in sustainable development. More recently, Dow Jones Sustainability Indices (DJSI, 2012) have addressed these issues (López et al, 2007) by assessing an ethical dimension. Nevertheless, those indices are not directly linked to national perspectives and contexts (Shrivastava and Kennelly, 2013) and, by ignoring time and space dimensions, their strategic value is reduced.

Unsurprisingly, therefore, most sustainability indices are not adapted to the level of individual life-styles (Caeiro et al, 2012; Sanne, 2002). Although a sustainable life-style is largely advertised as one that consumes as little as possible or as mindful consumption (Sheth et al, 2011) or rational/reasonable consumption (Kronenberg, 2007), these definitions fail to consider the importance of socio-economic factors and location-specific issues (Tukker et al, 2008).

To address these definition gaps we use a system fitness index, which is based on two aspects of sustainable development: environmental impact and essentiality (Nunes et al, 2012).

Methodology

This paper uses a toy model to address the problems of conceptualising, measuring, and analysing sustainability performance of systems.

Toy models were originally used in physics and chemistry, but only recently has their power been appreciated in biology and humanities. Successful attempts in using toy models to analyse systems that affect human society include the Tragedy of the Commons (Hardin, 1968) and Watson and Lovelock's Daisyworld (1983). The simplicity of a toy model is not in the length and scope of the developed theory, but in the simplifying assumptions by which only the most relevant variables are considered in its formulation. A good example is von Neumann and Morgenstern's Game Theory (von Neumann and Morgenstern, 1944) which can be considered as a toy model for economics without in any sense being too simple or limited. Commitment to simplicity has also been found in more recent models for analysing the effect of trade on biodiversity conservation (Polasky et al, 2004) and measuring the value and productivity of ecosystem services (Tilman et al, 2005).

The main objective of a toy model is to identify the fundamental mechanisms and relationships that would otherwise be blurred by considering too many details and thus explore the behaviour of a system and its organising principles. The design of a toy model relies on the scientific methodology to succeed. It consists of (1) identifying the relevant variables of the phenomenon and the behaviour one wants to reproduce, (2) modelling the relationship between those variables and their dynamics, (3) checking which variables or interactions can be ignored without affecting the important system characteristics. This procedure is applied iteratively until the simplest model that captures the important features of the phenomenon is obtained. Once the model is analysed, more complications can be added systematically which enables the addressing of increasingly complex effects.

The computer model was developed in C++ language. The output data was exported to Microsoft Excel to create better graphics. In addition to the model development and testing, we have researched real cases from contemporary media news to illustrate the fundamental principles of our model. These cases are presented in the discussion section.

Furthermore, our computer model includes a model simulation in which the *health/fitness* of the system is calculated based on a non-linear algorithm, which measures the essentiality level and resource availability in a given system. Figure 4 will show the behaviour of systems fitness, essentiality, and resource surplus.

Modelling of Socio-Ecological Systems

Figure 2 shows the modelling of activities in a socio-ecological system considering the ecological, socio-economic, technological, and consumption regimes. Figure 3 illustrates the application of the modelling for a socio-ecological system and its regimes for sustainable personal mobility.

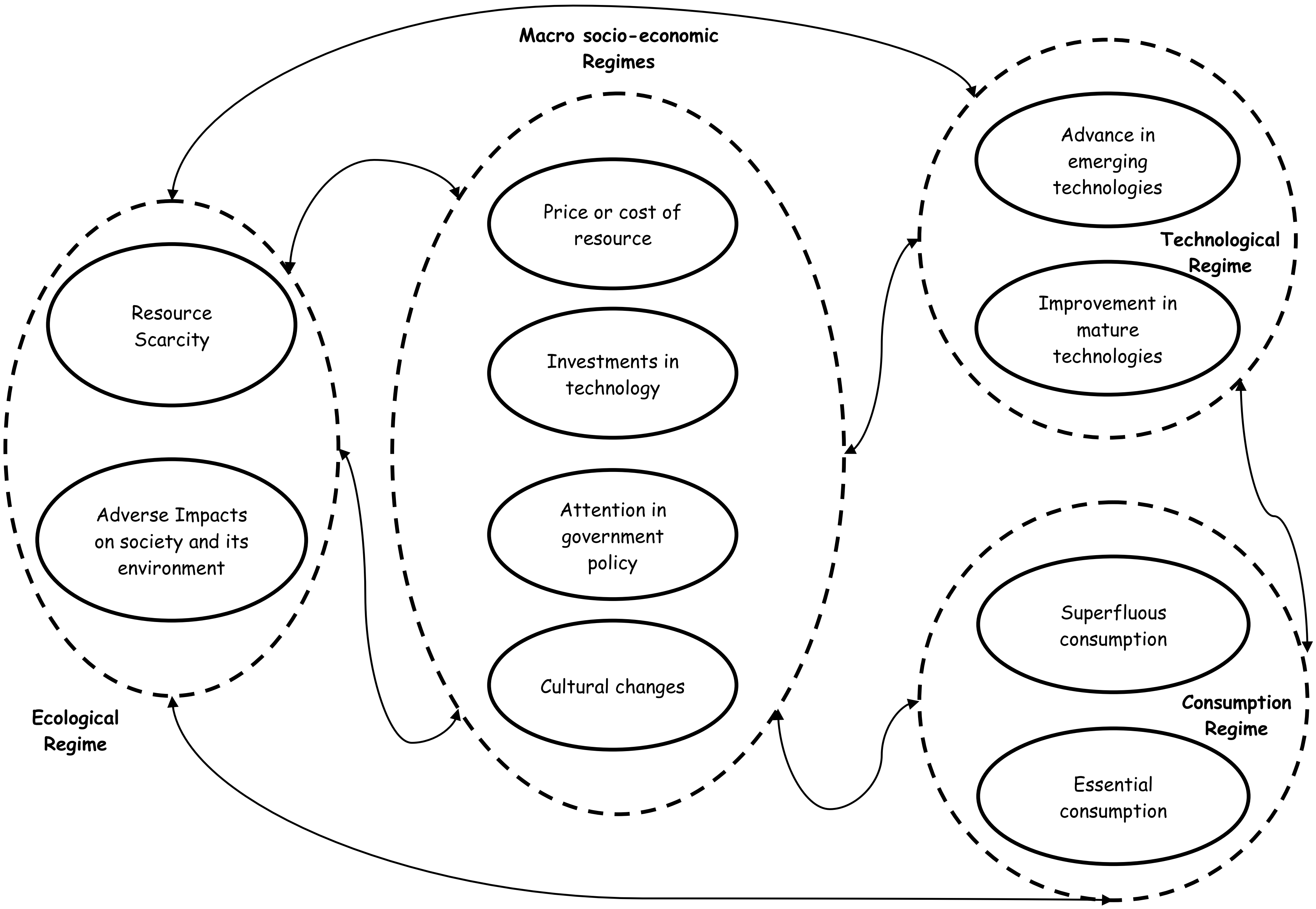

Figure 2 – Socio-Ecologial systems and its regimes

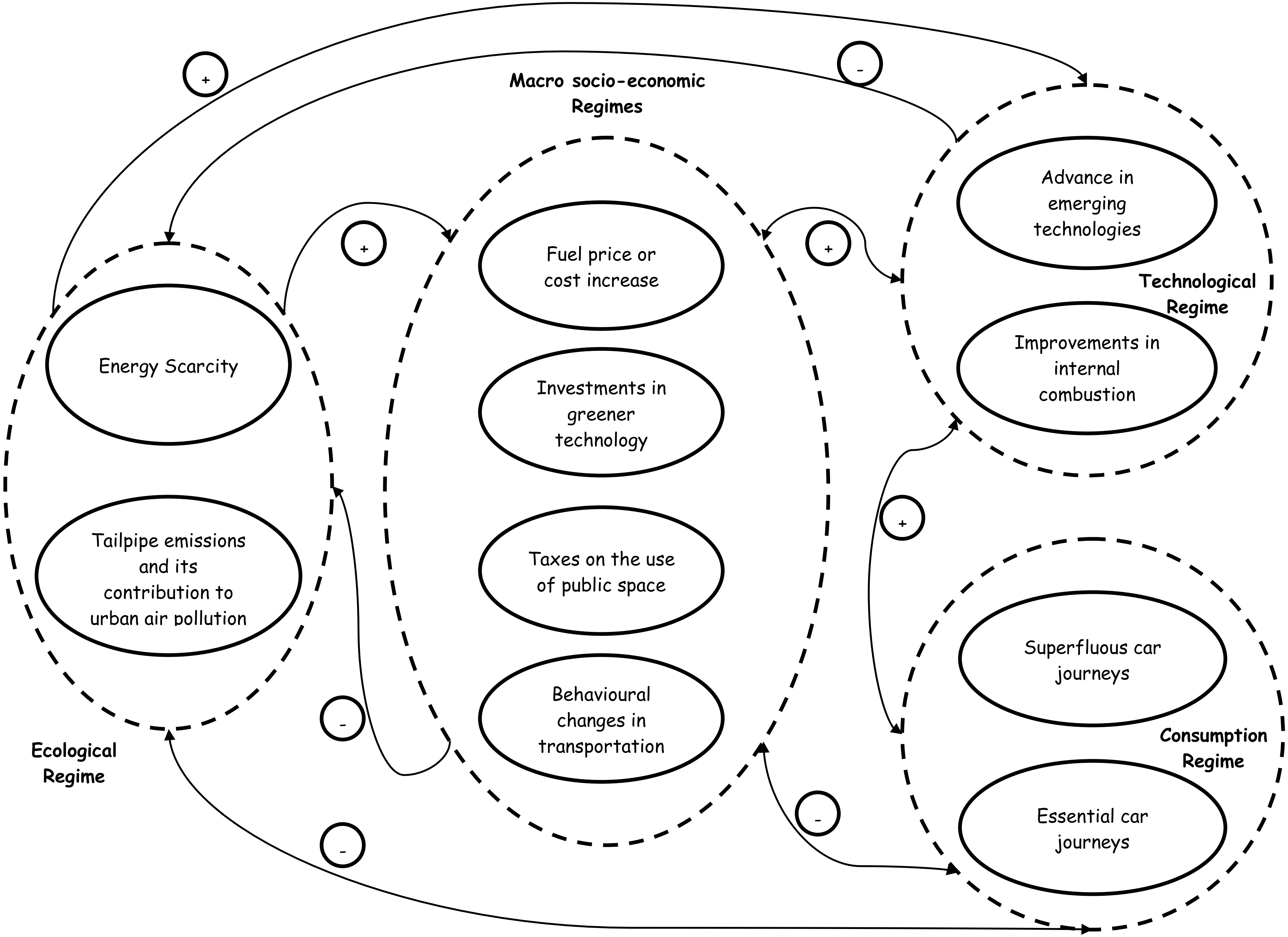

Figure 3 – Simplified socio-Ecologial systems and its regimes for personal mobility

Figure 2 combines the principles of systems dynamics and toy models. Ecological resilience is considered per type of resource whose thresholds are proposed to avoid its scarcity and deterioration. In Figure 3, the illustration shows on how the predominant form of energy (oil and other fossil fuels) may become scarce for a given region or pollution levels become unacceptable. The macro socio-economic regimes include interventions from market forces, technology application, government policy, and cultural changes. These are represented in Figure 3 for the case of personal mobility as price of fuel, investment in greener (or cleaner) technologies, government taxes such as congestion and parking charges in urban areas, and finally, behavioural changes with regard to personal mobility (e.g. use of public transportation, car sharing, etc).

Two further subsystems (regimes) are included in the model (Figure 2). Firstly, the technological regime makes explicit the advance in emerging technologies and the improvement in mature technologies. These two progress simultaneously as the so-called 'sailing boat effect'. Secondly, the consumption regime divides superfluous and essential consumption to clarify the differences between basic needs and aspirations of individuals in a society. In Figure 3, investment in greener technologies will be split in improvement of internal combustion engines (mature technology) and advancement of hybrid and electric vehicles (emerging technology), for instance. On the consumption regime, car journeys are divided in essential and unnecessary journeys

Findings & Lessons from Model Development, Test, and Application

Our pilot tests with the computer model show that socio-ecological systems first experiences an excessive waste led by overconsumption of superfluous products when resources are abundant. This is usually followed by an intervention (e.g. government policy, cultural change, market forces, technological progress, etc) which reduces the impact or consumption of these products, bringing the system back to a healthier state. Subsequently, as the ratio between impact (from consumption) and resources increases, a new intervention is needed to maintain the surplus in the system (e.g. increased efficiency, the use of a new technology or improvement of mature technologies). The system forces reductions in both superfluous and essential consumption baskets. Finally, without this control and self-organisation based on both essentiality and impact, a socio-ecological system becomes unstable and approaches collapse. The evolution of a socio-ecological system is presented in Figure 4.

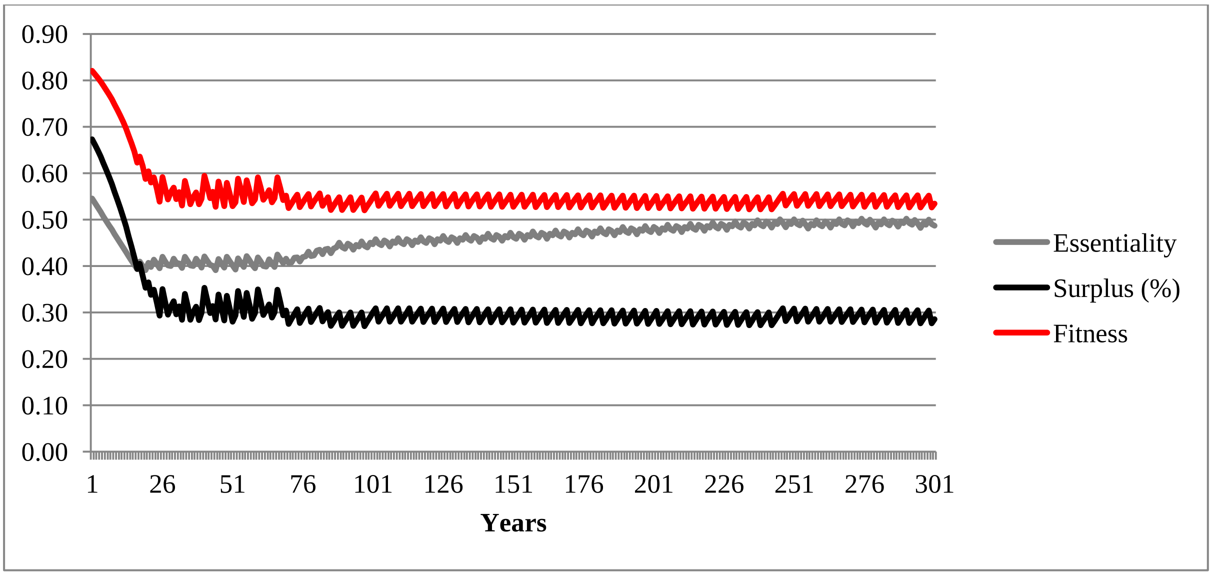

Figure 4 – Scores of essentiality, surplus, and fitness from computer modelling

There are many lessons for sustainability management from modelling of socio-ecological systems.

First, as expected the combined essentiality-environmental impact intervention is the best policy to keep the system healthy. The model was tested with different settings, and the intervention based on environmental impact can also keep the system healthy if there are lower growth rates for the baskets, albeit with a lower fitness score than a combined policy. In a laissez-faire policy, the socio-ecological system enters in collapse in year 28 and its fitness score remains zero as surplus continues to grow towards higher negative values (where importing becomes necessary). In an essentiality-based policy (controlling only consumption baskets of superfluous products only), the survival is increased only to year 43 due to the collapse of local resources.

Example-Based Discussion

This paper uses a toy model to address the problems of conceptualising, measuring, and analysing sustainability performance of a socio-ecological system. As a result, we are able to identify and monitor the relationship between its subsystems (regimes) in order to explore, understand, and influence the interventions in the system, including the management of technologies.

This section provides distinct responses to sustainability challenges from four contemporary exemplary cases. These examples were found in our desk research and they serve to illustrate the potential of our model for policy making and its link to the reality of socio-ecological systems. First example (Box 1) shows how the increase of fuel prices impact on consumers' car purchases. Drivers tend to choose more fuel efficient cars when fuel prices are perceived too high. It is a 'natural' market mechanism that provokes a consumer behavioural change which prolongs the availability of resource protecting the essential and part of the superfluous consumption in the system.

Box 1. Market forces acting against the increase of fuel prices

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SMART SPENDING

Yet Again, High Gas Prices Boost Sales of Small, Fuel-Efficient Cars

By Brad Tuttle @bradrtuttle | Aug. 27, 2012 | 2 Comments

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August 2012 is shaping up as another strong month for car sales, with the total number of new vehicles sold up nearly 19% compared to the same time last year. But some categories of vehicles are experiencing hotter sales than others, and it's not much of a mystery why.

According to a new report from Kelley Blue Book, "Gas prices have increased by $0.30 per gallon since early July, and as a result, Kelley Blue Book has seen an increased interest in fuel-sipping small cars both in terms of KBB.com shopper activity and retail sales volume." The subcompact category is seeing the biggest year-over-year increase in sales. Dealerships are on pace in August 2012 to sell 57,300 subcompact cars, a 42% increase from last August's total. Compacts have also been hot, with 182,050 vehicles expected to be sold by month's end, a 31% year-over-year rise.

The other car category boasting a year-over-year sales increase in excess of 30% is the compact crossover. The Honda CR-V, Ford Escape, and other of these smaller, more fuel-efficient offspring of bulky SUVs of the past have soared to popularity in recent years, and remain especially hot while gas prices rise. Sales of compact crossovers are up 38% in August, compared to

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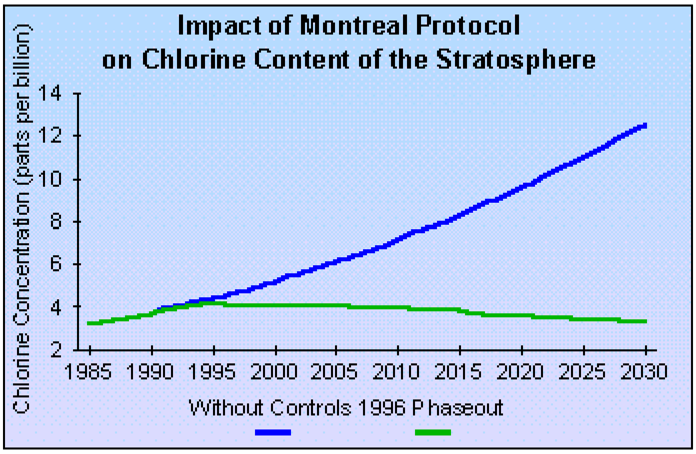
Source: http://business.time.com/2012/08/27/yet-again-high-gas-prices-boost-sales-of-small-fuel-efficient-cars/

The second example (Box 2) presents a combined response from government and industry on the deterioration of ozone layer due to overuse of CFC. This was predominantly a technology-driven solution triggered by government policy. Thus, the final outcome or change in the socio-ecological system is given from the technological regime. Almost no behavioural change is needed to make it work and allow consumers to continue using refrigerators and alike at home.

Box 2. The response via investment in technology and government policy to ozone layer depletion



Source(1): http://www.epa.gov/Ozone/science/indicat/

Ban on Production and Imports of Ozone-Depleting Refrigerants

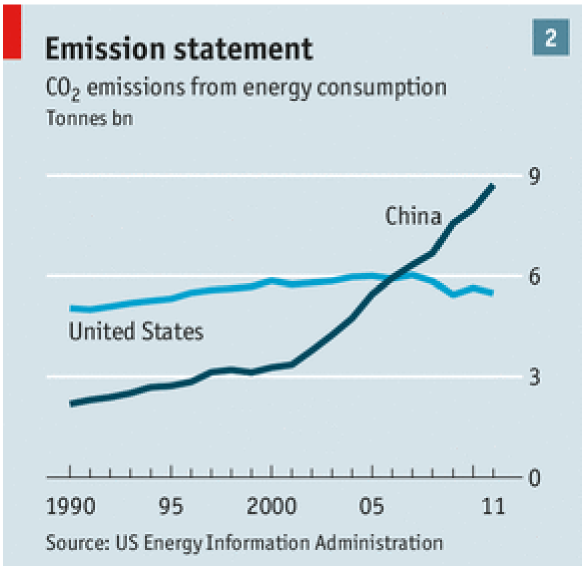
"In 1987 the Montreal Protocol, established requirements that began the worldwide phaseout of ozone-depleting CFCs (chlorofluorocarbons). These requirements were later modified, leading to the phaseout in 1996 of CFC production in all developed nations. In 1992 the Montreal Protocol was amended to establish a schedule for the phaseout of HCFCs (hydrochlorofluorocarbons). HCFCs are less damaging to the ozone layer than CFCs, but still contain ozone-destroying chlorine".

Source (2): http://www.epa.gov/ozone/title6/phaseout/22phaseout.html

The third example (Box 3) shows that under sever ecological distress government may act to prevent collapse of national socio-ecological systems. This is a particularly important solution when behavioural change is difficult, and market and technology forces are unable to appropriately respond to ecological crises.

Box 3. Government response to energy scarcity and environmental pollution

Rapid growth is exacting a heavy environmental price



Source(1): http://www.economist.com/news/briefing/21583245-china-worlds-worst-polluter-largest-investor-green-energy-its-rise-will-have

“The environmental fallout from China's burgeoning demand for natural resources is another source of concern. Processing iron ore, timber or oil requires electricity, and 80% of China's electricity comes from coal. But the sulphur that spews from the smokestacks of coal-fired power stations causes acid rain and the soot generates smog. In many Chinese cities, a thick shroud of pollution literally blots out the sun much of the time. Acid rain, meanwhile, reduces agricultural yields and eats away at buildings and infrastructure. The OECD cites a finding that air pollution alone reduces the country's output by between 3% and 7% a year, mainly because of respiratory ailments that keep workers at home (…) To discourage energy- and import-intensive metals-processing, the government raised export duties on iron, steel and related alloys to 25% in December. It also abolished all duty on imports of copper, in the hope that higher imports of finished metal might displace some domestic smelting. And on two previous occasions it has reduced the level of tax rebates that exporters of energy-intensive goods can claim, in some cases down to zero” (The Economist, March 2008)

Source (2): http://www.economist.com/node/10795813

Fourth example (Box 4) demonstrates a behaviour-based approach which is useful mainly when changes in the technology are not perceived necessary or feasible.

Box 4. Behaviour change to reduce energy consumption
 Source: http://www.bbc.co.uk/news/world-asia-17917183 “A month earlier than last year, Japan has launched its annual "Cool Biz" campaign to save electricity during summer. The initiative allows civil servants to work tie-free and with their sleeves rolled up. In June, Japan is set to go even further with "Super Cool Biz", allowing flip flops and Hawaiian shirts in the public service”. (BBC News Asia, 1 May 2012)

Conclusions

This paper presents the modelling of socio-ecological systems to explore the system dynamics of managing technologies to increase sustainability in countries, regions, firms, and even for individuals. This was possible by developing the concept of system fitness based on the essentiality balance and relative surplus in a system. These two latter variables were derived, respectively, from the measurements of essentiality and environmental impact. By considering essentiality as a sustainability variable, contextual perceptions of consumption can be accommodated alongside environmental impact when assessing sustainability performance. By reflecting on product essentiality, societies could move towards higher levels of sustainability. The assessment of the economic and social value of goods and services when using resources to meet the population needs and aspirations is fundamental to the development of sustainable development strategies. Thus, the local context (Shrivastava and Kennelly, 2013) is respected considering both the availability of resources to produce/consume goods and services as well as the differences in perceptions of essentiality of these products (Tilman et al, 2005; Tukker et al, 2008; Sanne, 2002; Caiero et al, 2012; Sheth et al, 2011). As noted by Boyko et al 2012), the use of appropriate indicators is key to foster long-term survival of regions.

The computer model has advanced the learning in the field of systems dynamics and sustainability management as advocated in several previous studies (Fisher et al, 2013; Enfors, 2013; Young, 201; Duit et al, 2010; Kelly, 1998; Saysel et al, 2002). The learning developed by using the model can assist governments when developing their technology strategy, national industrial policies (Whiteman, et al, 2013), climate change policy (Leach, 2009), and consumption taxation as well as informing companies when they formulate their sustainability strategy and evaluate their product portfolio during the innovation process (Seebode et al, 2012; Hall and Vredenburg, 2003; Shrivastava, 1995b).

The first version of the computer model and system dynamics (Fig.2) have limitations to be addressed. First, we have considered that the system has the economic power to recover from consumption crisis whenever resources are available. In reality, consumption growth is not easy to spur even with abundant resources. Similarly, we assume that decisions can be implemented effectively and quickly, while in reality a delay would be likely. Other refinements to the toy model could include natural dynamics of systems such as substitutability between products in the different baskets, reuse of resources or by-products, resource storage over time, exchange of resources between interdependent systems (e.g. China and Africa as discussed by (Mol, 2011), amongst other dynamics in the complex industrial ecosystem (Chertow and Ehrenfeld, 2012).

References

Alcott, B. (2005). Jevons' paradox. Ecological economics, 54(1), 9-21.

Bertalanffy, L.V. (1972), The History and status of general systems theory, The Academy of Management Journal, Vol. 15, No 4, pp. 407-426.

Boyko, C. T., Gaterell, M. R., Barber, A. R., Brown, J., Bryson, J. R., Butler, D., Caputo, S., Caserio, M., Coles, R., Cooper, R., Davies, G., Farmani, R., Hale, J., Hales, A. C., Hewitt, C. N., Hunt, D.V.L., Jankovic, L., Jefferson, I., Leach, J.M., Lombardi, D.R., MacKenzie, A.R., Memon, F. A., Pugh, T. A.M., Sadler, J.P., Weingaertner, C., Whyatt, J.D., & Rogers, C. D. (2012). Benchmarking sustainability in cities: The role of indicators and future scenarios. Global Environmental Change, 22(1), 245-254.

Caeiro, S., Ramos, T. B., & Huisingh, D. (2012). Procedures and criteria to develop and evaluate household sustainable consumption indicators. Journal of Cleaner Production, 27, 72-91.

Checkland, P (2000) Soft Systems Methodology: A Thirty Year Retrospective. Systems Research and Behavioral Science. 17, pp 11-58

Chertow, M., & Ehrenfeld, J. (2012). Organizing Self- Organizing Systems. Journal of Industrial Ecology, 16(1), 13-27.

DJSI – Dow Jones Sustainability Index (2012) < http://www.sustainability-indices.com/> accessed on 6th January 2014

Duit, A., Galaz, V., Eckerberg, K., & Ebbesson, J. (2010). Governance, complexity, and resilience. Global environmental change, 20(3), 363-368.

Enfors, E. (2012). Social–ecological traps and transformations in dryland agro-ecosystems: Using water system innovations to change the trajectory of development. Global Environmental Change.

Fisher, J. A., Patenaude, G., Meir, P., Nightingale, A. J., Rounsevell, M. D., Williams, M., & Woodhouse, I. H. (2013). Strengthening conceptual foundations: Analysing frameworks for ecosystem services and poverty alleviation research. Global Environmental Change, 23, 1098-1111.

Forrester, J. W. (1961). Industrial dynamics. 1961. Pegasus Communications, Waltham, MA.

Forrester, J. W. (1969). Urban Dynamics, Pegasus Communications. Inc., Waltham.

Forrester, J. W. (1971). World Dynamics, Wright. LN, Cambridge

Hahn, R., & Kühnen, M. (2013). Determinants of sustainability reporting: A review of results, trends, theory, and opportunities in an expanding field of research. Journal of Cleaner Production, 59, 5-21.

Hahn, T., Figge, F., & Barkemeyer, R. (2008). Sustainable Value in Automobile Manufacturing: An Analysis of the Sustainability Performance of Automobile Manufacturers Worldwide. Sustainable Value - Downloaded at SustainableValue.com

Hall, J., & Vredenburg, H. (2003). The Challenges of Innovating for Sustainable Development. MIT Sloan management review, 45(1), 61-68.

Hardin, G. (1968) The Tragedy of the Commons, Science. 162 (3859), pp 1234- 1248

Hart, S (1997). Beyond Greening: Strategies for a Sustainable World. Harvard Business Review. Jan/Feb97, 75 (1), pp 66-76.

Hart, S. (1995), “A Natural-Resource-Based View of the Firm”. The Academy of Management Review. Vol 20, N 4, pp. 986-1014.

Ison, Blackmore, Collins and Furniss (2007) “Systemic environmental decision making: designing learning systems”, Kybernetes, Vol. 36 No. 9/10, pp. 1340-1361

Jevons, W. S. (1906). The coal question: an inquiry concerning the progress of the nation, and the probable exhaustion of our coal-mines. 3rd edition, Augustus M Kelley, New York, USA.

Kelly, K. L. (1998). A systems approach to identifying decisive information for sustainable development. European Journal of Operational Research, 109(2), 452-464.

Kronenberg, J. (2007). Making consumption "reasonable". Journal of Cleaner Production, 15(6), 557-566.

Leach, A. J. (2009). The welfare implications of climate change policy. Journal of Environmental Economics and Management, 57(2), 151-165.

López, M. V., Garcia, A., & Rodriguez, L. (2007). Sustainable development and corporate performance: A study based on the Dow Jones sustainability index. Journal of Business Ethics, 75(3), 285-300.

Meadows, D. H., Meadows, D., Randers, J. and Behrens III, W.W. The Limit s to Growth: A Report to The Club of Rome's project on the predicament of mankind. New York, Universe Books.

Meadows, D. H., Randers, J., & Meadows, D. (2004). Limits to Growth: Limits to Growth. Chelsea Green.

Mol, A. P. (2011). China's ascent and Africa's environment. Global Environmental Change, 21(3), 785-794.

Neumann, J. V., & Morgenstern, O. (1944). Theory of games and economic behavior. Princeton University Press, Princeton.

Nunes, B.; Shaw, D.; Bennett, D.; Theodorakopoulos, N. (2012) Philosophy, theory, and practice of green operations management. Proceedings of Iamot Conference, Taiwan, 2012.

Polasky, S., Costello, C., & McAusland, C. (2004). On trade, land-use, and biodiversity. Journal of Environmental Economics and Management, 48(2), 911-925.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., ... & Foley, J. (2009b). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society, 14(2), 32

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., ... & Foley, J. A. (2009a). A safe operating space for humanity. Nature,461(7263), 472-475.

Sanne, C. (2002). Willing consumers—or locked-in? Policies for a sustainable consumption. Ecological Economics, 42(1), 273-287.

Saysel, A. K., Barlas, Y., & Yenigün, O. (2002). Environmental sustainability in an agricultural development project: a system dynamics approach. Journal of Environmental Management, 64(3), 247-260.

Seebode, D., Jeanrenaud, S., & Bessant, J. (2012). Managing innovation for sustainability. R&D Management, 42(3), 195-206.

Seebode, D., Jeanrenaud, S., & Bessant, J. (2012). Managing innovation for sustainability. R&D Management, 42(3), 195-206.

Sheth, J. N., Sethia, N. K., & Srinivas, S. (2011). Mindful consumption: a customer-centric approach to sustainability. Journal of the Academy of Marketing Science, 39(1), 21-39.

Shrivastava, P. (1995a). The role of corporations in achieving ecological sustainability. Academy of Management Review, 936-960

Shrivastava, P. (1995b). Environmental Technologies and Competitive Advantage. Strategic Management Journal, 16, 183-200.

Shrivastava, P., & Kennelly, J. J. (2013). Sustainability and Place-Based Enterprise. Organization & Environment, 26(1), 83-101.

Tilman, D., Polasky, S., & Lehman, C. (2005). Diversity, productivity and temporal stability in the economies of humans and nature. Journal of Environmental Economics and Management, 49(3), 405-426.

Tsur, Y., & Zemel, A. (2006). Welfare measurement under threats of environmental catastrophes. Journal of Environmental Economics and Management, 52(1), 421-429.

Tukker, A., Emmert, S., Charter, M., Vezzoli, C., Sto, E., Munch Andersen, M., Geerken, T., Tischner, U., and Lahlou, S. (2008). Fostering change to sustainable consumption and production: an evidence based view. Journal of cleaner production, 16(11), 1218-1225.

UNU-IHDP and UNEP, (2012) Inclusive Wealth Report 2012. Measuring progress toward sustainability. Cambridge: Cambridge University Press.

Wackernagel, M., & Rees, W. (1998). Our ecological footprint: reducing human impact on the earth (Vol. 9). New Society Publishers

Watson, A. J., & Lovelock, J. E. (1983). Biological homeostasis of the global environment: the parable of Daisyworld. Tellus B, 35(4), 284-289.

Whiteman, G., Walker, B., & Perego, P. (2013). Planetary Boundaries: Ecological Foundations for Corporate Sustainability. Journal of management studies, 50(2), 307-336.

Young, O. R. (2010). Institutional dynamics: resilience, vulnerability and adaptation in environmental and resource regimes. Global Environmental Change, 20(3), 378-385.