COOPERATIVE RESEARCH CENTRE FOR COAL IN SUSTAINABLE DEVELOPMENT (CCSD)
PROGRAM P1.2: SUSTAINABILITY DIMENSIONS AND IMPACTS

Dear CCSD Industry Partner:

What follows is an industry discussion paper that compares alternative frameworks for sustainability policy. This is the fourth in the series of brief discussion papers specifically for industry partners. They are designed to explain the key ideas behind the approach programme P1.2 is taking to sustainable development, discuss the consequences for coal-chain industries, and provoke dialogue and feedback.

Discussion papers 1, 2 and 3, which respectively cover "Efficiency, Resilience and Adaptability, "Adaptive Sustainable Development" and "Adaptiveness Evaluation of Coal21 Report" are available (1, 2) or will be available (3) at http://www.ccsd.biz/research/project1.2.cfm. (See also http://www.newcastle.edu.au/centre/casrg/research/ccsd.html for these and for a brief overall description of the P1.2 project). More detailed and substantial technical reports that support these discussion papers will also be available through CCSD.

This 4th paper discusses the concept of Adaptive Sustainability that was introduced in Discussion Paper 2 and compares it with the more established notions of sustainability based on environmental impact reduction and natural capital enhancement.

In programme P1.2 we are well on the way towards developing a distinctive, forward-looking, strategic approach to sustainable development that we judge is both sound in itself and able to offer coal chain industries a superior framework and principles within which to prepare and evaluate their own responses to the increasing need for sustainable development.

As for previous discussion papers, the concepts and principles involved here are often recently emerged and may be novel to your thinking. It may require some reflection to see clearly how they fit your situation and how they can be applied to add value to the decisions that you must make on a daily basis. You may wish to inquire further about this. On the other hand, you may be able to provide us valuable examples of how they do fit your company or industry, and/or provide welcome improvement to our understanding and application of them. On all these counts we wish to be proactive in communicating them to you for your evaluation and feedback.

We recognise that your time is limited and valuable, so we will try to keep these discussion papers short and straightforward.

We thank you for attending and look forward to your feedback.

C.A. Hooker, project leader
T.S. Brinsmead, postdoctoral research fellow

Contact details:
C. A. Hooker: Email: Cliff.Hooker@newcastle.edu.au,
Phmail: +612 4921 5185,
T.S. Brinsmead: Email: Thomas.Brinsmead@newcastle.edu.au
Phmail: +612 4921 7247

For both people:
Fmail: +612 4921 6928,
POmail: School of Liberal Arts, McMullin LG27,
University of Newcastle, Callaghan, NSW, Australia 2308
Website: http://www.newcastle.edu.au/centre/casrg/index.html

Paper (IV)

IMPACT REDUCTION, CAPITAL MAXIMISATION, ADAPTIVE RESILIENCE SATISFICING:
3 CONCEPTS OF SUSTAINABILITY SYSTEMATICALLY FRAMED

SUSTAINABLE DEVELOPMENT: UNDERSTANDING & ISSUES FOR INDUSTRY
An occasional series of brief papers designed to explain key ideas and provoke dialogue.

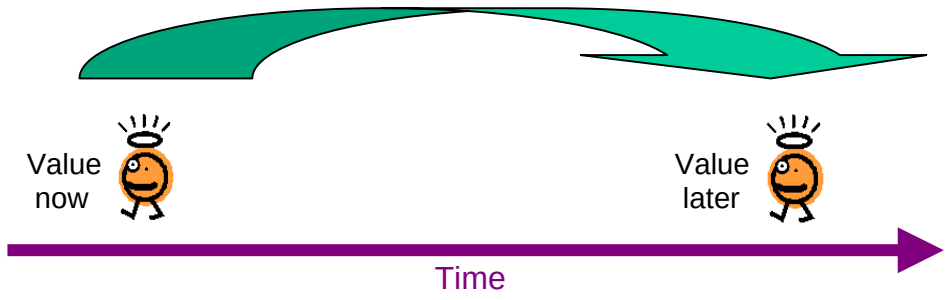
COOPERATIVE RESEARCH CENTRE FOR COAL IN SUSTAINABLE DEVELOPMENT (CCSD)

Note to the reader: the following opening section provides a brief overview of the whole.

Sustainability: the basic idea

The essential idea of sustainability is that of maintaining or enhancing some valuable feature of life into the future.

Sustainability = Maintenance of **value** into the **future**



Sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (*Our Common Future,* 1987) In this conception the key value to be kept invariant is the capacity to satisfy [human] needs.

3 concepts of sustainability compared

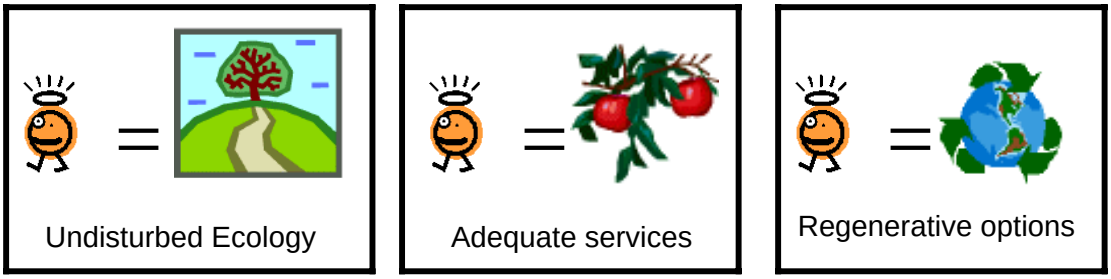
In the literature there are two dominant ideas about what sustainability is:

(1) removing our negative impacts on nature, and
(2) maximising capital, natural and human.

To these two we want to add a third concept of sustainability:

(3) maintaining and enhancing adaptive resilience, natural and human.

We can compare them as follows, where the value to be sustained is indicated in the box, and below is indicated the corresponding ideal this serves and the theoretical value ['TVal.'] in terms of which decisions are formulated.



Ideal:	Pristine nature	Quality of life	Regenerative Potential
TVal.:	Negative Impact	Total Capital	Adaptive Resilience

These positions will be (briefly) explained below. Meanwhile, note that, like satisfying needs, each of these values can remain valid because it is emptied of specific content.

We argue that this third concept is more fundamental than the others because (I) it prescribes sustaining what is essential to continued system existence, (II) is more practical than the capital notion because it avoids trying to predict the long term future and leads to better outcomes than the impact approach because it offers synergies between sustaining ecology and economy, (III) provides a more coherent ethical basis for sustainability than either because it alone has coherent positive conceptions of both stewardship and human flourishing, and (IV) is their natural successor in policy strategy because it alone incorporates fundamental uncertainty into capital's superior dynamical models and decision strategies.

To make good on these claims it is necessary to systematically compare the three approaches. To do this we have created a systematic framework of categories on which to compare them, of which only the first two categories are identified above.

We begin by exploring the nature of the more familiar impact concept of sustainability and from this develop the systematic comparative framework. We then set out the other two approaches within that framework, and summarise the arguments in favour of the resilience approach.

Sustainability as impact reduction

Introduction

The impact approach aims to reduce damaging human impacts on natural ecosystems so as to leave them in a less disturbed physical condition. (NB: impacts are physical burdens evaluated for the importance of the ecological disturbances they cause.)

In achieving its aim it is natural for this approach to focus on the reduction at source of human wastes, habitat destruction and natural resource demands (food, timber, etc.). The estimation of burdens ejected to the environment is most systematically achieved through life cycle analysis, that of natural resources through ecological footprint and like methods, while the evaluation of impacts is presently typically estimated through use of a variety of ecological quality or health indicators. These methods are all also typically used to estimate analogous impacts on human life.

Theoretical value: impact reduction
Physically realised value: ecological disturbance reduction
Measurement focus: environmental burden
Approximate measure: waste quantity, habitat destruction, resource demand
Methodological estimation tools: life cycle analysis, resource demand assessment (incl. footprints)

To illustrate this approach consider the following case.
Example problem: coal burners produce nitrogen oxide (NOx) air pollution.
Example solutions: "Scrubbing" to clean the air, e.g. using NH_3 catalyst, or oxidising with O_3 or ClO_2
Burden decreased: atmospheric NOx
Measurement focus: burden decreased = quantity of NOx to air

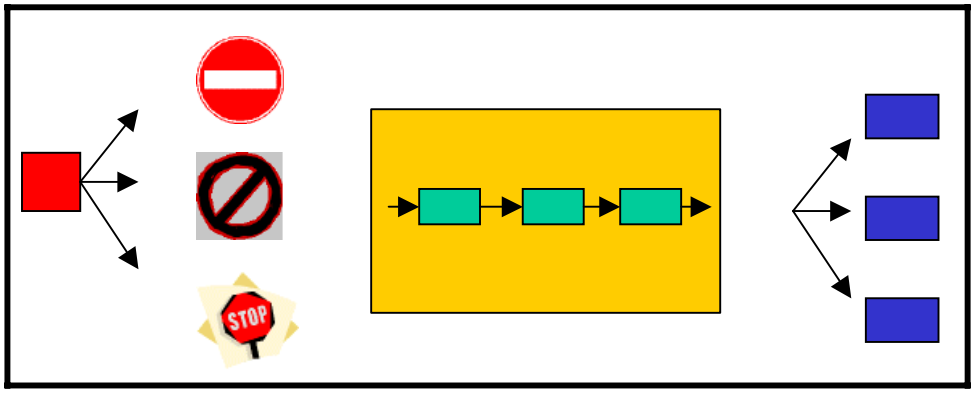
Decision making

Next we consider how sustainability decisions are made under the impact reduction approach. We need to identify the kind of options from which to choose, a set of models to use that will relate options to consequences, and a method for evaluating the consequences and deciding among options.

As we have seen, the options that present themselves concern the prevention of burdens reaching the environment: covering a waste pipe, restoring a damaged habitat, reducing a resource demand.

What needs to be modelled is the connection between such an act and the consequent beneficial environmental effect. In many, perhaps most, of the central cases considered the consequences are essentially confined to the immediate spatial environment (e.g. local land clearing or poisoning), or to a specific pathway within it (e.g. DDT concentration up the food chain). Simple uni-directional, often linear, cause-effect models then suffice to model the consequences (suppressing intervening complexities).

Pictorially, alternative prevention options (LHS) are modelled through uni-directional cause-effect relations (Centre) to give rise to correlative consequences (RHS):



These consequences are presently then evaluated using an array of quality of life or ecological health indicators and combining their individual scores in some manner, or some similar methodology. (The choice of these surrogate indicators and their rule of combining is obviously crucial. They should be chosen so as to sensitise decisions to the nature of the moral, social and economic issues and prioritising choices involved.) The option chosen is then the one whose consequence is most valuable (whose impact reduction is largest). Whence we add:

Decision method: maximise ecological impact reduction
Methodological evaluation tools: quality of life, ecological health indicators + combining rule

This basic methodology is essentially untouched by extending consideration to the interaction among various prevention actions (e.g. preventing air pollution from both steel smelting and electricity generating plants in a locality), it will simply increase the suppressed intervening complexities and restructure decisions so as to be over suites of individual prevention options.

Moral vision

Ideal. What is it of fundamental value that would be preserved under this approach? It can only be the inherent value of nature undisturbed by humans. This is what is passed on to future generations. A fully pristine nature is the ideal condition that this approach strives to attain.

Any diversion of resources from damage prevention compromises achieving this aspiration. So while the practical reality of other competing claims on scarce resources may be recognised, from *within* the position there is no place for trading off damage prevention against other considerations.

Thus we add:

Motivating ideal: fully pristine nature
Substitutional constraints: no inter-substitution between environmental impact reductions and other goods

Naturalness synergy. From the general inherent value of pristine nature is often derived a further set of more particular values, ones that are extended to provide a 'naturalness' ideal for humans as well: autonomy, inter-connectedness, respect, enoughness. In their human application these are associated, respectively, with communal self-sufficiency, inclusiveness (belonging), dignity, modesty (of demand). They are held to issue in a set of corresponding methods for achieving 'ecological' designs, for example bio-mimicry and perma-culture.

It is held that if humans come to adopt these naturalness values and realise them in their own designs then there will be a natural synergy between achieving a pristine nature and achieving a valuable human communal design - for instance that adopting modesty of human demand would both reduce ecological impacts and lead to a richer, more peaceful human community life. We will call this interrelationship the naturalness synergy for this approach.

Naturalness synergy: joint benefit of applying extendable natural attributes; assumes natural dynamics inherently valuable

In keeping with the aim of an undisturbed nature, relying on this synergy involves unqualified acceptance of the natural dynamics of systems showing these values, in pristine nature, and then in human societies emulating nature. The impact reduction approach tacitly assumes that ecosystems are the seat of many of the most inherently valuable features and tacitly insists that it and human society unfold according to its own dynamics, implicitly assuming (or perhaps normatively asserting) that thereby these ecosystem valuable features will be both exhibited and preserved.

Ethics. Within the impact approach, there is an inherent respect for life underlying the ideal of leaving nature undisturbed, but it is expressed only negatively as human non-interference. While this approach extends in an obvious way to encompass the reduction of damaging impacts on human life, this focus does not naturally provide a positive ethic of either natural or human flourishing. However, a partial positive ethic is present implicitly via the values expressed in the underlying naturalness synergy. Even so, within its terms, the position lacks a positive conception of natural stewardship beyond refraining from damage.

Similarly, the position lacks a positive conception of inter-generational equity. However, the sustainability constraint yields one such equity, confined to what is sustained – here undisturbed nature – since this is *ipso facto* maintained over time. Intra-generational equity is similarly not directly addressed, although some notion of equity is implicit in the naturalness synergy.

The approach also lacks inherent commitment to respect and sustain traditions and the past for their own sake, human (by absence) or biological – except insofar as the biological past is preserved in its natural dynamics.

Thus we add:
Natural ethic: no positive ethic of natural flourishing (only respect, expressed as non-interference)
Human ethic: no positive ethic of human flourishing (except indirectly via naturalness synergy)
Equity, inter-generational: shared undisturbed nature
Equity, intra-generational: not addressed (except indirectly via naturalness synergy)
Welfare: natural and human welfare directly but implicitly supported through impact reduction plus emulating natural values

As variously noted, often these elaborations are implicit, not explicit, in statements of the impact position. Nonetheless we make them explicit here because they contribute to a fuller, and so fairer, account of the potential of this position and will facilitate later comparison with the other positions.

Limitations

There are inherent limitations to the impact approach. We note 3 here.
(1) The absence of a positive conception of environmental stewardship leads to a dilemma. Whatever the valued ecosystems features are, they will not necessarily be preserved by undisturbed ecological dynamics. (For instance, desertification may follow on chance events, early anaerobic bacteria radically altered atmospheric chemistry, removing many life forms.) But under the no-impact approach there is no basis for constructive intervention to support these values. In the human case there is a tension between only reducing negative impacts and constructive intervention to support natural values.

(2) Often enough local uni-directional cause-effect models are clearly inappropriate. Non-linear indirect feedback can dominate and reach far beyond their local genesis. For instance, there are good reasons to believe that longer term global environmental and socio-economic dynamics will be affected by near-term human choices such as greenhouse gas emissions and are quite likely in turn to change deeply relevant environmental and economic conditions. The impact approach is too fragmented and simplistic to handle these effects.

(3) While from within the no-impact position there is no place for trading off ecological damage prevention against other considerations (e.g. supporting human welfare), these trade-offs do not vanish, they are instead effectively displaced to some external context where allocation of resources among competing claims, impact reduction being but one, is somehow decided.

Any attempt to elaborate the no-impact position so as to adequately address these limitations forces us to abandon its framework (as set out above) for a different, richer one. One major way to address limitation (3) (and (2)) gives rise to a sustainability policy based on capital, another to address limitation (1) (and (2)) gives rise to the adaptive resilience approach.

Framework

Combining all the categories used to characterise the impact reduction approach provides us with a rich picture of the position, as an approach to sustainable policy making. We will use these same categories to characterise the capital and adaptiveness approaches. This will both provide an immediate basis for comparing them and for arguing the superiority of the adaptiveness approach.

The full framework is:

Theoretical value
Physically realised value
Measurement focus
Approximate measure
Methodological estimation tools
Decision method
Methodological evaluation tools
Motivating ideal
Substitutional constraints
Naturalness synergy
Natural ethic
Human ethic
Equity, inter-generational
Equity, intra-generational
Welfare
Limitations

Sustainability as capital maximisation

Introduction

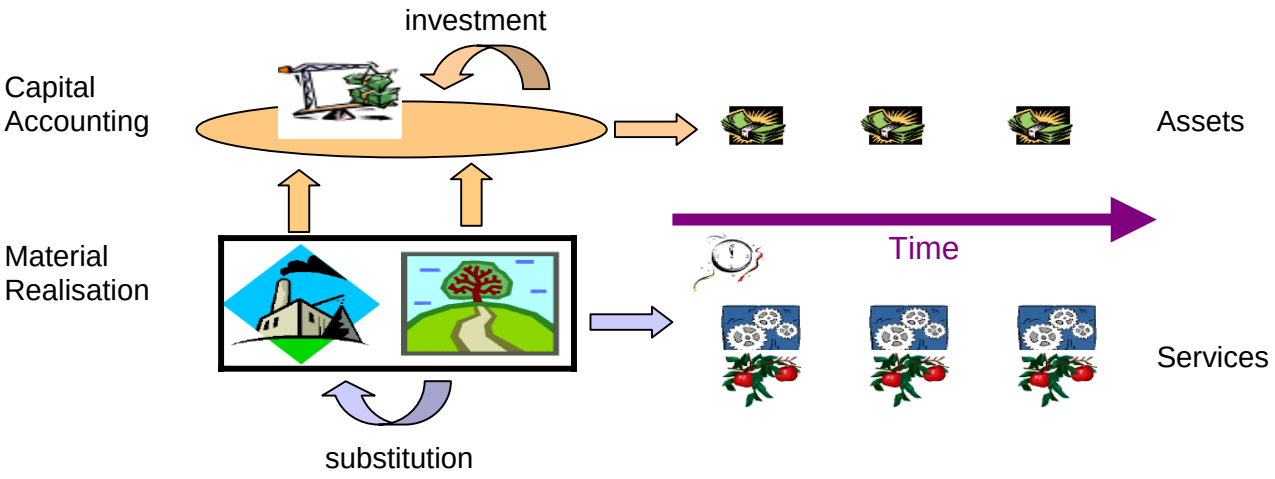
The capital approach aims to provide an optimal flow of human services over the long-term future.

In doing so it recognizes that natural ecological systems are capable of providing an ongoing flow of valuable services to humans that contribute significantly to human quality of life, for example the provision of timber, recreation, clean air and fresh water. These are services humans are willing to pay for and, at least under some conditions, will thus sustain the asset that produces them.

The human economy also produces human services. Sometimes these may be able to substitute for natural services, as witness concrete and steel for timber, gyms and movies for bush walking, de-salinated water for river water, and sometimes they may compete for scarce resources, for instance habitat for industrial land and (almost universally) investment in natural management for other investment. In all these cases they need to be traded off against one another. The capital approach adopts the position that these trade-off decisions should be made using economic cost-benefit methods that are commensurate with prices generated by the market.

The economic conception that underpins this approach is formulated in terms of the maximisation of services value over an explicitly long-term time horizon. Services are supplied by productive capital assets, so maximising services means managing capital assets to that end. Under appropriate conditions, the long-term provision of services will rationally dictate that assets, especially natural assets, be managed sustainably.

This formulation then expresses an obvious economic reading of the Brundtland sustainability requirement: manage capital so as to invest capital in the development of new productive capacity while consuming capital to meet present needed services in such a way that the capital similarly required by future generations is available to them. This approach provides a wide-ranging and flexible trade-off regime among forms of capital and between capital investment and consumption under complex economic dynamics.



The methods of economic decision making provide one way to immediately address the last 2 limitations of the impact reduction approach. For the traditional concern of economics is rational decision making under conditions where scarce resources require trade-offs among jointly unattainable goals and a highly dynamic world displaying multiple feedback requires consideration of interdependent decision sequences across long stretches of time.

The incentive to manage assets, in particular natural assets, sustainably is intended to provide the foundation for sustainable ecosystem management. Further, by focussing on ecosystem services as a source of positive value, it is possible for environmental sustainability policy to shift from the limiting negative impact reduction orientation to a more positively oriented conception of natural resource stewardship, thereby addressing the remaining limitation of the impact reduction approach.

Theoretical value: total [= natural + human] capital
Physically realised value: services provided, asset investments
Measurement focus: productive assets [natural + human], consumption
Approximate measure: investment units, sales
Methodological estimation tools: input-output models and cognate tools

To illustrate this approach consider the following case.
Example problem: coal furnace produces carbon dioxide 'greenhouse' gas
Example solution: burn wood and natural gas instead of coal
Service maintained: fuel supply
Measurement focus: service maintained = fuel supply plus investments in wood and gas production

Decision making

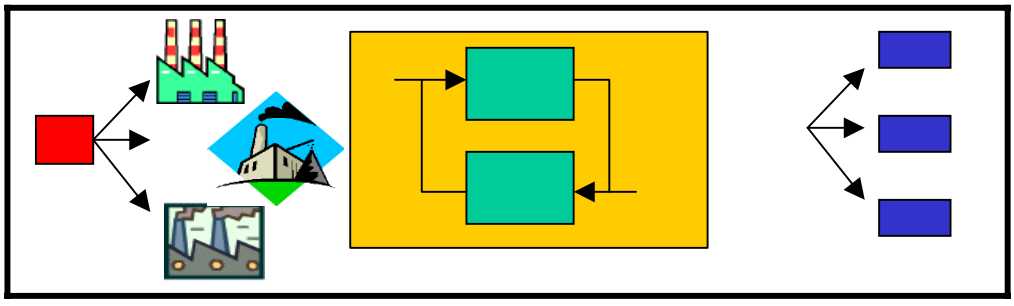
To understand how sustainability decisions are made under the capital approach we again need to identify option categories, a set of models relating options to consequences, and a method for evaluating the consequences and deciding among options.

The options that present themselves concern the usual economic consumption and investment decisions, with particular attention to natural asset management.

The models involved are the economic models required to trace through the dynamic interactions among multiple consumption and investment decisions across the economy and over time. This will in general require modelling distant and long-term non-linear interactions, often including powerful feedback effects. For instance, investment in forests is affected by building construction, electricity generation, recreation and habitat preservation demands, among others, all interacting through long-term non-linear ecosystem dynamics on the one side and equally long-term non-linear market dynamics on the other, including feedback via the effects of native insect and animal populations on species propagation and building design, fashion and taxation policy on demand for construction and furnishings timber and plantation bio-mass for electricity production, among others.

The overall economic evaluation of courses of these decisions is standardly constructed by evaluating all services in a common currency and then taking as a surrogate for the value of an asset its net present value, that is, the sum of the discounted future values of the services it provides.

Pictorially, alternative courses of consumption and investment options (LHS) are modelled through non-linear feedback relations (Centre) to give rise to correlative consequences (RHS):



Decision method: maximise total [= natural + human] capital
Methodological evaluation tools: Net present value

Moral Vision

Ideal. The fundamental value that would be preserved under this approach is the highest efficiently attainable quality of human life. What is passed on to future generations is the capacity to experience the maximally realised human life through efficient consumption. Its realisation is the ideal condition that this approach strives to attain. This quality of human life is taken to be measured by, to be realised through, the efficient consumption of services. Whence we add:

Motivating ideal: maximal efficient human quality of life across time (as realised in services)
Substitutional constraints: permit economically efficient inter-substitution of, and trade-offs between, human and natural services provisions.

Naturalness synergy. The capital position assumes the synergistic production of wealth through the 'invisible hand' of the appropriately regulated market as each individual pursues efficient acquisition of capital and services according to their own judgement, including the preservation of the natural environment as a supplier of valuable services (so long as relevant property rights are well-defined and institutionally operative).

Naturalness synergy: joint benefit of applying market attributes; assumes market dynamics (+ coordinate cost-benefit policy choices) are inherently valuable

Note that, relying on this synergy involves tacitly assuming that the properly regulated economic market is the seat of many of the most inherently valuable features (individual autonomy, responsibility, choice, etc.) and that it should unfold according to its own dynamics. This further involves implicitly assuming (or perhaps normatively asserting) that thereby the market's valuable features will be both exhibited and preserved.

Ethics. Within the capital approach there is no inherent respect for non-human life, rather nature is preserved only to the extent it is useful in supporting the quality of human life. To the extent this latter might involve a human need to have nature present, only then will nature be guaranteed preservation. However, this approach obviously encompasses the enhancement of human services and thus naturally provides a positive ethic of human flourishing, and a derivative ethic of natural stewardship, expressed in the underlying naturalness synergy. Nonetheless, within its terms, the position lacks a positive conception of natural stewardship beyond this anthropocentric perspective.

Without an exogenous normatively imposed global constraint on the preservation of capital stocks (see below) the position also lacks any inherent positive conception of inter-generational equity for natural or socio-economic features since there is no inherent inter-generational constraint of any kind in asset maximisation. Maximal quality of life across time will involve rewarding and denying generations efficiently, not necessarily equitably. Empirical facts about nature and/or ourselves may dictate conservation practices, but these are not inherent. However, insofar as anything is sustained, this is *ipso facto* maintained over time. Intra-generational equity is also entirely absent, since the market has no inherent capacity to regulate for this constraint, indeed it amplifies differences in capital and consumption of services. (To parallel the other positions we add that, in each case, there is a bare shared contemplation of overall consumption efficiency.)

The approach has no inherent commitment to respect and sustain the past, except as deriving from efficient services provision.

Thus we add:
Natural ethic: no positive ethic of natural flourishing
Human ethic: positive ethic of human flourishing directly specified as maximal consumption of services (plus indirectly elaborated as emulation of market values)
Equity, inter-generational: not inherently addressed (shared sustained consumption, if any)
Equity, intra-generational: not addressed

Welfare: human welfare only, but directly, supported through services consumption, natural welfare only indirectly supported through services value, in each case as constrained by efficient inequities

Limitations

(1) There are clear weaknesses in the sustainability ethic this position can provide and a corresponding absence of any but a pragmatic notion of environmental stewardship. These deficits can be ameliorated by adding explicit, exogenous sustainability constraints on investment + consumption trade-offs. There are two basic kinds, known respectively as weak and strong constraints: (a) sustain total capital, with traded-offs between natural and human capital otherwise unconstrained, (b) strengthening (a) by an additional ban on trading off natural for socio-economic capital, which is equivalent to requiring that natural and socio-economic capital be each separately sustained. However, these constraints remain exogenous to the capital framework, and pull the position away from the strong market-based trade-off capacity that is its chief strength.

(2) Capital maximization methods require fully predictable perfect markets. Hence the imperfect competition and incompleteness of real markets means that the basic components, prices and interest rates, are not directly observable as market prices and cannot be reliably derived or approximated from human preferences since these are both not directly observable and likely to change, with reliability reducing the more distant the future concerned. Thus using market prices as soft-constraints on strategy selection is problematic over the long time scales with which sustainability policy ought to be concerned.

(3) Entry of risk (probabilities specified) and uncertainty (probabilities unavailable) challenge the applicability of capital methods, yet intrude increasingly the more distant the future concerned. While risk probabilities can be incorporated into capital methods, at the expense of weakening the goal to maximum expected services flows, the shifting of risk preferences (e.g. from risk neutral to averse as irreversible costs mount) remains an exogenously imposed factor and knowledge of probabilities reduces sharply as distance to the future increases. However uncertainty, which increases with reducing knowledge of probabilities, poses still more fundamental problems. The goal must now be weakened to (for example) to have the same or higher pay-off as some worst-case outcome, which abandons maximisation. Since no single particular future - or even a cluster of similar futures - is selected, it no longer makes sense to aim for optimal performance since the futures on which that is achieved may not include, or even be strongly relevant to, the actual future. Over long time horizons appropriate to sustainability the effects of uncertainty easily become of such magnitude that decision analysis, within the strict limitations of a capital framework, becomes meaningless.

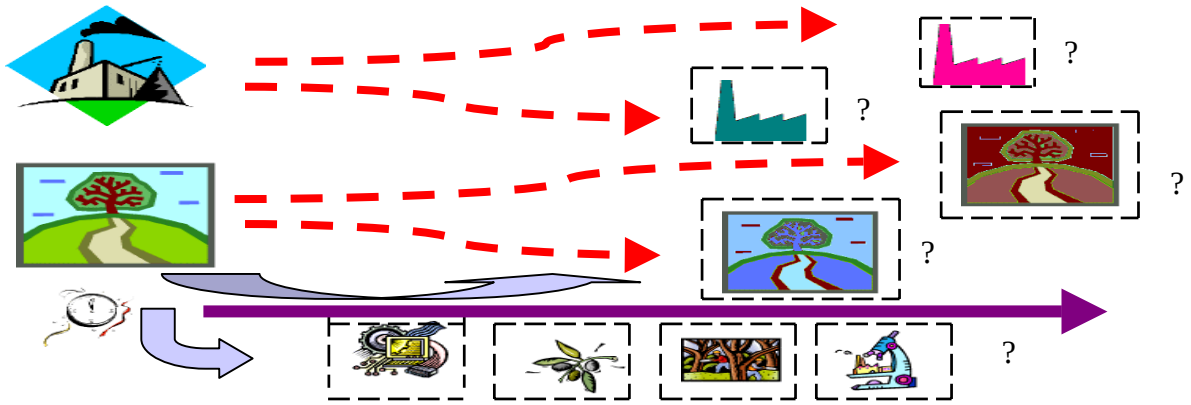
Sustainability as adaptive resilience satisficing

Introduction

The world is comprised of open, highly non-linear, irreversible, self-organising dynamical systems in a continual process of change on many levels and timescales. To finite human knowing they present manifold, often ineliminable, uncertainties, but equally they inherently have an open future replete with potentialities that is the key to both their creativity and continued survival. Valuable potentiality is the core positive value characterising such systems, and adaptive resilience its necessary and most important functional support. This applies to both individuals and their communities, according to their particular adaptive capacities.

Resilience is the capacity to maintain functioning in the face of uncontrollable changes, short or long term. In these circumstances, resilient capacity is the minimal necessary condition for any system to continue functioning while preserving its identity. For instance, an organism’s metabolism regenerates both the organism structure and capacity to regeneratively metabolise. And, as with metabolism, the regeneration must include the regeneration of the resilience capacity itself.

Thus the fundamental goal of adaptive sustainability policy is to achieve the sustaining of ecological and socio-economic system adaptive resilience, severally and jointly, and thereby sustain the valuable potentialities of, that is, rich open futures for, these systems across time.
This provides an alternative formulation of the Brundtland sustainability requirement: sustaining adaptive resilience that will meet present adaptive needs (including human need-derived demands) without compromising the capacity to meet future adaptive needs.



The direct requirement to sustain adaptive resilience immediately addresses the first limitation of the capital approach by providing for a strong, inherent conception of sustainability that also provides the proper core conception of environmental stewardship. The last two limitations of the capital approach are significantly ameliorated through the use of adaptive strategies that, by learning and building adaptive capacity, can effectively postpone commitment while reducing uncertainty.

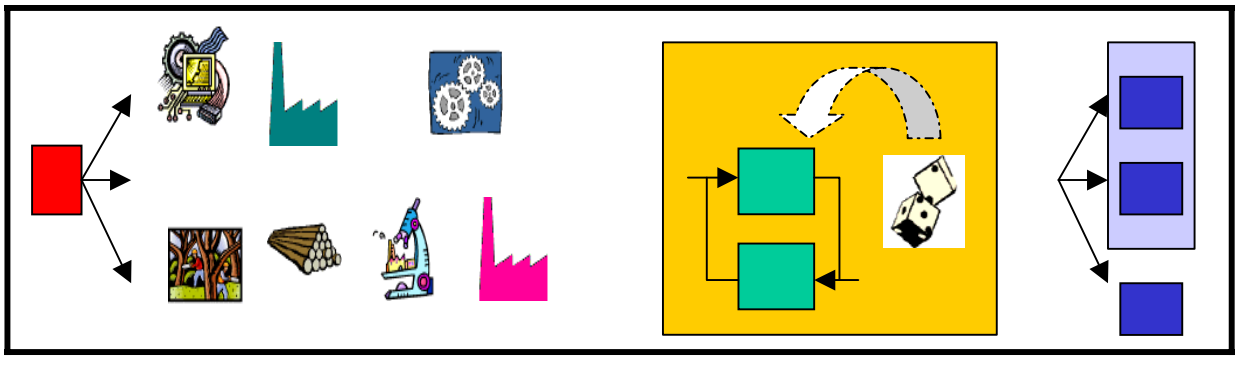
Theoretical value: adaptive resilience, ecological and economic
Physically realised value: regenerative real options, for each of ecology and economy
Measurement focus: response alternatives, e.g. compensatory functions
Approximate measure: functional redundancies (bio-diversity, trophic pathways, etc., industrial diversity, manufacturing pathways, etc.)
Methodological estimation tools: adaptiveness assessment (recently begun development, but consider partial tools like Real Options Valuation)

Example problem: choice of future adaptable electricity generation
Example solution: integrated gasification combined cycle with coal/gas/bio-mass supply
Regenerative real options maintained (increased): feed options (+ output fuel options)
Measurement focus: compensatory functions increased = feed substitution from feed redundancies, output product substitution from output redundancies

Decision making

The presence of irreducible uncertainty means that the cause-effect models are indeterminate as well as non-linear with feedback, explicitly representing unpredictability as either stochastic risk or uncertainty.

Pictorially, alternative courses of response to contingencies (LHS) are modelled through non-linear feedback relations under prevailing uncertainties (Centre) to give rise to correlative consequences (RHS), where bracketed consequences are of at least satisfactory value:



Optimisation must be abandoned since, given serious uncertainties, there is insufficient information to determine optimal strategies. Resilience instead places management emphasis on the maintenance of sufficient value across contingencies that are exogenous to system control (= satisficing over classes of possible future paths). That is, it focuses on ensuring that a satisfactory outcome results despite the occurrence of possible disturbances.

A typical long-term strategy will then be a robust adaptive strategy. It will be adaptive in the sense that particular, future strategy decisions are contingent upon future information that is revealed as unpredictability is resolved. It should be robust in the sense that it is insensitive to unpredictability that either will not or cannot be resolved sufficiently quickly. Among robust adaptive strategies the preferred strategy is one that meets a superior combination of a high satisficing performance standard across a wide range of possible futures.

Comparing alternative adaptive strategies requires developing surrogate measures for the value of a system adaptiveness profile (the set of possible trajectories in response to a specified set of perturbations). In general this will require relative evaluation among and between qualitatively distinct categories of outcome and possibility sets of outcome trajectories. It also requires comparing outcomes across time, for instance through a net present value apparatus.

Real options valuation in finance is one such evaluation method. Essentially it provides the net present value of specific future adaptiveness. In principle it could be generalised to include higher order robust adaptive strategies as the real options available under uncertainty (roughly, the net present value of acquiring the capacity to acquire future adaptiveness).

Decision method: maximise adaptive resilience, ecological and economic
Methodological evaluation tools: robust adaptive strategies, real options valuations

While adaptiveness analysis will in principle result in models that are as difficult to analyse as are capital models and strategies, it provides the richest, most adequate framework within which to formulate conditions under which the use of simpler, more limited methods may legitimately be used.

Further, the use of a satisficing criterion has the compensating merit of allowing acceptable strategies to be located without having to first possess complete dynamical models for the situation, and so avoids both demands on problem formulation that cannot be initially met and many of the computational complexities that would attend a full analysis. Additionally, possession of an adequate adaptive strategy (of any kind) thereafter permits one to remain uncertain about future perturbations (within the robust range) until they actually arrive since, whatever they are, the system will be able to adapt to satisfy them (although it may do so at still less cost if it can gain advance information about them). Finally, this period provides for further adaptive capacity building and uncertainty reduction through learning, thus reinforcing the robust adaptive strategy.

We note that this do-a-little-and-learn character of robust adaptive strategies resolves the dilemma of how to treat rationally the distant future, over which the capital approach found itself in difficulty. They avoid the need to make perfect predictions out to the infinite future by confining attention and action to sufficiently nearby bounded time horizons that a scientifically supported framework is available within which to make decisions about what to try out next (do-a-little) and what to investigate next (and-learn). Energy companies like BP, Chevron-Texaco and Shell cannot act on the basis of assured predictions about future technologies, instead they are investing in a range of technologies to gain both experience of requirements (learning) and developing a base for possible future rapid deployment (building adaptive capacity).

Moral vision

Ideal. The fundamental value that would be preserved under this approach is that of the richest attainable future potential for natural and human life. What is passed on to future generations is the capacity to exercise the widest feasible range of regenerative adaptive options, including the creation of more. Its realisation is the ideal condition that this approach strives to attain. Whence we add:

Motivating ideal: maximal open future regenerative potential for each of ecology and economy
Substitutional constraints: permit efficient substitution of regenerative options for extensive capacity, only permit inter-substitution of human and natural adaptive capacities consistent with sustainability

Naturalness synergy. The adaptiveness position assumes the synergistic generation of system flourishing through the sustaining of resilient functionality as its natural adaptiveness synergy. System flourishing is to be identified with a rich and vibrant system existence, characterised by complex differentiation, integration, and self-organisational innovation and learning, at many levels and on many timescales. For instance, there is a profound synergy between the rising resilience of human society and the rise of human scientific-technological capacities, because science-technology is simultaneously a store of knowledge and a source of manifold applied adaptive responses based upon that knowledge. In fact the synergy extends reflexively, since scientific-technological knowledge is a source of experimentation and learning that develops further knowledge and technologies. The result is an increasingly flourishing, resilient society. There is both a corresponding value to ecological resilience, and an increasing capacity for a flourishing, resilient society to intelligently support ecological resilience, both through self-shaping and benign intervention.

Naturalness synergy: joint benefit of supporting resilient attributes; assumes resilience dynamics inherently valuable

Relying on this synergy involves tacitly assuming that the richly resilient system is the seat of many of the most inherently valuable features (diversity, organised integration, innovation, etc.) and that it should unfold according to its own dynamics. This further involves implicitly assuming (or perhaps normatively asserting) that thereby the valuable resilience features will be both exhibited and preserved.

Ethics. Within the adaptive resilience approach there is an inherent respect for both non-human and human life, and of the same kind: in both cases the approach has an irreducible and necessary core positive conception of natural flourishing, that of a richly resilient system, with this functional conception further developed through the resilience naturalness synergy. This provides a positive ethic of both natural and human flourishing.

However there are limits to this commitment. A resilience ethic has no commitment to any specific state of flourishing. Whence it says, for example, nothing specific about racial or gender equity. These will count instead as welfare issues. For instance, most negative impacts on individual human health - short of pandemics, infant mortality that is devastatingly high (as it is in some poor nations) and the like - have little impact on economic or ecological adaptiveness, so under the adaptiveness conception there is little sustainability rationale for removing them. Nevertheless improving health remains a valuable welfare goal in itself, irrespective of its contribution to future adaptive capacity.

But a resilience ethic also cannot be wholly indifferent to welfare since, for example, it is unlikely that a society that is too unegalitarian can achieve either maximal adaptiveness or flourishing. In short, flourishing requires – and conversely can be used to generate – at least minimal welfare conditions, for example minimal levels of racial and gender equity. Of course, many specific welfare goals remain inherently valuable ones to pursue. But just as flourishing cannot be a sufficient good in isolation from welfare – evil regimes may sometimes show disquieting resilience – neither can welfare be a sufficient good in isolation from flourishing since it would then have to be both oppressive and ultimately self-undermining. Nonetheless, the distinction between adaptive sustainability and sustaining welfare as grounds for action is useful to the clarification of public policy: given finite resources the pursuit of each will have to be traded-off against that of the other according to circumstances. The distinction between unsustainable as degrading of options and unsustainable as otherwise intolerable is obscured under impact and capital approaches.

There is a corresponding positive conception of stewardship – toward both natural and human systems alike: it is appropriate to manage both systems to enhance their adaptive resilience. Australian aboriginal patchwork 'firestick farming' provides a good example. This applies reflexively; for instance, science creates its own study of the scientific and technological learning processes (the philosophy, economics and science of science) with the aim of both understanding and improving them. Accompanied by a fallibilism that leaves improved revision always open, science is willing to act to improve system resilience and flourishing wherever that is feasible and reasonable.

However a resilience ethic has no commitment to any specific state of flourishing. Whence it says nothing about equity (for example about racial or gender equity) beyond requiring equitable enjoyment of at least present adaptive regenerative potential. And it says nothing directly about general welfare issues at all, although synergistic resilience attributes have indirect welfare implications. Of course, many welfare goals remain valuable ones to pursue. The distinction between sustainability and welfare as grounds for action, between unsustainable as degrading options and unsustainable as otherwise intolerable, is obscured under impact and capital approaches.

Being future oriented, this approach has no inherent commitment to respect and sustain traditions and the past for their own sake. However, as with genetic diversity, the past may be preserved as part of sustaining adaptive resources. It may also be considered a part of welfare; for example it may be considered a cultural obligation.

Thus we add:
Natural ethic: positive ethic of natural flourishing as a richly resilient system + synergistic attributes
Human ethic: positive ethic of human flourishing as a richly resilient system + synergistic attributes
Equity, inter-generational: share richly resilient flourishing + synergistic attributes
Equity, intra-generational: not addressed
Welfare: not addressed (welfare is implicitly supported through synergistic attributes)

Limitations

(1) The adaptive resilience approach focuses on the functional capacities of systems, remaining agnostic about their specific states. It offers a 'functionalist' characterisation of sustainability - hence the separation of adaptive sustainability from welfare. But many fundamental values that we and other creatures seek to satisfy concern specific states, for example being free of pain and involuntary confinement. Excluding these from sustainability narrows its normative scope (but while broadening that of welfare).

(2) As an emerging concept, adaptiveness does not yet have associated modelling methods that are as well developed as for the impact or capital conceptions. In many circumstances, for instance, we do not know of demonstrably valid surrogates for adaptive resilience (for instance, biodiversity can be associated with either increased or decreased resilience).

(3) (A) Uncertainty imposes severe limits on current decision processes that are usable. For instance, real options valuation method is currently restricted to circumstances where risk (that is, probabilistic) assessments are available, precluding genuine uncertainty. It is unclear if, and if so, how, these limitations can be relaxed. (B) In many cases, the relevant adaptive resiliences will be possessed, if at all, by ecological or industrial networks of diverse individuals and it may be functionally beyond their cooperative capacities to initiate and sustain relevant adaptive strategies.