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Change resistance as the crux of the environmental sustainability problem

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Abstract

Why, despite over 30 years of prodigious effort, has the human system failed to solve the environmental sustainability problem? Decomposing the problem into two sequential subproblems, (1) how to overcome *change resistance* and (2) how to achieve *proper coupling*, opens up a fresh line of attack. A simulation model shows that in problems of this type the social forces favoring resistance will adapt to the forces favoring change. If change resistance is high this adaptation response either prevents proper coupling from ever being achieved or delays it for a long time. From this we conclude that systemic change resistance is the crux of the problem and must be solved first. An example of how this might be done is presented.

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> There are a thousand hacking at the branches of evil to one who is striking at the root.
>
> Henry David Thoreau, *Walden*, 1854

Introduction

This paper seeks to help solve the global environmental sustainability problem by approaching it from a novel and possibly more effective perspective. Instead of beginning with the usual "What are the proper practices needed to live sustainably? How can we get them adopted?" we ask a radically different question: "*Why, despite over 30 years of prodigious effort, has the human system failed to solve the environmental sustainability problem?*"

The science of environmental sustainability is undergoing a profound paradigm shift (Kuhn, 1996) in its problem-solving process. Due to inability to solve its central problems, the field finds itself struggling to replace its defective old paradigm (its old process) with a new one that works. Laments like "modern environmentalism is no longer capable of dealing with the world's most serious ecological crisis" (Shellenberger and Nordhaus, 2004) abound. In the spirit of Kuhn's "revolutionary science," this paper identifies the old paradigm, explains why it's flawed, and presents a seed candidate for the new paradigm.

Kuhn felt that "…scientists will be reluctant to embrace [a new paradigm] unless convinced that two all-important conditions are being met. First, the new candidate must seem to resolve some outstanding and generally recognized problem that can be

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met in no other way. Second, the new paradigm must promise to preserve a relatively large part of the concrete problem solving activity that has accrued to science through its predecessors" (p. 169). Third, the new paradigm must solve more important problems than the old one. The candidate has been thoughtfully constructed to meet these criteria.

We begin by identifying the old paradigm.

The old paradigm: proper coupling as *the* problem to solve

To answer our driving question we must introduce a new term, proper coupling, so that we can more correctly understand system behavior. **Proper coupling** occurs when the behavior of one system affects the behavior of other systems in a desirable manner, using the appropriate feedback loops, so the systems work together in harmony in accordance with design objectives. For example, if you never got hungry you would starve to death. You would be improperly coupled to the world around you. In the environmental sustainability problem the human system has become improperly coupled to the greater system it lives within: the environment.

The universal consensus among environmentalists is that how to achieve proper coupling is *the* problem to solve. The early literature of global environmental sustainability framed the debate this way.

In 1972 *The Limits to Growth* brought the environmental sustainability problem to the world's attention, and defined the problem as how "to establish a condition of ecological and economic stability that is sustainable far into the future" (Meadows *et al.*, 1972). In other words, how can we properly couple the ecological and economic systems, by finding and implementing the right policies to keep environmental impact at a sustainable level? Works like *The Limits to Growth* and its predecessors, notably Rachel Carson's *Silent Spring* in 1962 and Jay Forrester's *World Dynamics* in 1971, firmly established the normal science of environmental sustainability as one that saw what can be called "proper coupling" as *the* problem to solve.

Subsequent analyses and dialog strengthened this perspective into the dominant paradigm. In 1987 the United Nations' Brundtland Report stated that "*Our Common Future* serves notice that the time has come for a marriage of economy and ecology…" (World Commission, 1987, back cover). In 1997 the nascent field of ecological economics argued that "three policies to achieve sustainability" are "a broad natural capital depletion tax, application of the precautionary polluter pays principle, and a system of ecological tariffs" (Costanza *et al.*, 1997, pp. 206–207). These are all proper coupling mechanisms. They attempt to internalize externalized costs, which itself is a proper coupling perspective.

Turning to the common-pool resource literature, in 1968 Garrett Hardin's *The Tragedy of the Commons* launched a fiery, long-running debate on how to manage common-pool resources. His thesis that "freedom in a commons brings ruin to all" caused sustainability scholars to see their driving question as: What rules are necessary to effectively manage common resources? Hardin discussed potential management solutions including privatization, polluter pays, and regulation. These too are proper coupling mechanisms.

In 1990 Elinor Ostrom published *Governing the Commons: The Evolution of Institutions for Collective Action*. This influential work presented eight design principles for

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community-based resource management. For Ostrom a design principle is "an essential element or condition that helps to account for the success of these institutions in sustaining the [common-pool resources] and gaining the compliance of generation after generation…" Rule compliance is a proper coupling point of view.

In 2002 the U.S. National Research Council published *The Drama of the Commons*, a 500-page exhaustive study of commons research. It too takes a proper coupling perspective. How strongly the field adheres to the old paradigm may be seen in this sentence from chapter 1, page 25 (italics added):

> It requires considerable ingenuity to design *institutions* that cope effectively with the attributes of a particular resource given the larger macro-political institutions, culture, and economic environment in which that resource is embedded.

In commons literature "institutions" means "the rules that people develop to specify the do's and don'ts related to a particular situation" (p. 21) Substituting "proper coupling mechanisms" for the first occurrence of "institutions" in the sentence causes no change in its meaning. Even a high-level synthesis of "a universal set of factors that are critical to successful governance of common-pool resources," based on three studies including the work of Ostrom, fails to break out of the old paradigm of proper coupling as *the* problem to solve (pp. 53–54).

Finally, in 2007 the fourth Intergovernmental Panel on Climate Change (IPCC) report stated that: "A wide variety of policies and instruments are available to governments to create the incentives for mitigation action. They include integrating climate policies in wider development policies, regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, and research, development and demonstration" (IPCC, 2007, p. 18). Once again, these are all proper coupling mechanisms.

Because proper coupling is seen as *the* problem to solve, finding and implementing the right coupling policies has become the *raison d'être* of the sustainability movement. But if we examine the problem from another perspective and decompose it differently, it's possible to see a potentially much more productive approach, one driven by a new paradigm.

The new paradigm: change resistance as *the real* problem to solve

Years ago the author was discussing a perplexing problem with a bright young engineer/manager from the U.K. He suggested that if you've looked at a problem from all angles and are still stumped, then you probably have a missing abstraction. Find it and the difficulties will melt away.

The voices of Lewin, Senge, Sterman and many more tell us that change resistance is that missing abstraction.

Change resistance is the tendency for a system to continue its current behavior, despite the application of force to change that behavior. Also known as policy resistance (Sterman, 2000, pp. 5–12), the origin of the concept is described by Dent and Goldberg (1999, italics added):

> The notion of resistance to change is credited to Kurt Lewin. His conceptualization of the phrase, however, is very different from today's usage [which treats resistance

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> to change as a psychological concept, where resistance or support of change comes from values, habits, mental models, and so on residing within the individual]. For Lewin, resistance to change could occur, but that resistance could be anywhere in the system. As Kotter (1995) found, it is possible for the resistance to be sited within the individual, but it is *much more likely to be found elsewhere in the system*.
>
> Systems of social roles, with their associated patterns of attitudes, expectations, and behavior norms, share with biological systems the characteristic of *homeostasis*—i.e., tendencies to resist change, to restore the previous state after a disturbance.
>
> Lewin had been working on this idea, that *the status quo represented an equilibrium between the barriers to change and the forces favoring change*, since 1928 as part of his field theory. He believed that some difference in these forces—weakening of the barriers or strengthening of the driving forces—was required to produce the unfreezing that began a change.

Today's "status quo" is, alas, an unsustainable world. When problem solvers attempt to solve the sustainability problem, their strengthening of "the forces favoring change" causes the system to maintain homeostasis by automatically increasing the "barriers to change." This is a natural and expected adaptive response that must be expected and taken into account.

We hypothesize that one way to do this is to decompose difficult social problems into two sequential subproblems: (1) *how to overcome change resistance* and then (2) *how to achieve proper coupling*. This is the timeless strategy of divide and conquer. By cleaving one big problem into two, the problem becomes an order of magnitude easier to solve, because we can approach the two subproblems differently and much more appropriately. We are no longer unknowingly attempting to solve two very different problems simultaneously.

There's a simple reason this decomposition works so well: change resistance is usually what makes social problems difficult. In fact, regardless of whether change resistance is high or low, it is impossible to solve the proper coupling part of a social problem without first solving the change resistance part. This is nothing new, however. As the old joke goes, "How many psychologists does it take to change a light bulb? Just one. But first the light bulb has to want to change."

In difficult social problems the system spends a long time trying to overcome change resistance. Once that occurs proper coupling is achieved relatively quickly by introduction of new norms/laws and related mechanisms, and is refined still further over time. This pattern has occurred in countless historic social problems whose solution benefits the common good, like universal suffrage, slavery, racial discrimination, the dangers of smoking tobacco, the rule of colonies by other countries, the recurring war in Europe problem (solved by creating the European Union, which properly coupled member nations together to reduce pressures for future wars), and the non-benevolent ruler problem (solved by invention of democracy, which properly coupled the people and their rulers via the voter feedback loop). True to form, the pattern is occurring again in the sustainability problem.

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Here's what the third edition of *Limits to Growth* had to say about change resistance. The term was never used, because it was a missing abstraction (Meadows *et al.*, 2004, p. 24):

> [The second edition of *Limits to Growth*] was published in 1992, the year of the global summit on environment and development in Rio de Janeiro. The advent of the summit seemed to prove that global society had decided to deal seriously with the important environmental problems. But we now know that humanity failed to achieve the goals of Rio. The Rio plus 10 conference in Johannesburg in 2002 produced even less; it was almost paralyzed by a variety of ideological and economic disputes, [due to] the efforts of those pursuing their narrow national, corporate, or individual self-interests.
>
> . . . humanity has largely squandered the past 30 years . . .

What is the underlying cause of such massive change resistance? Whatever it is, it must be incredibly strong to cause such a powerful effect.

In business, change resistance has long been known as resistance to change, organizational momentum, or inertia. Peter Senge describes the structural cause (Senge, 1990, p. 88, italics added):

> In general, balancing loops are more difficult to see than reinforcing loops because it often looks like nothing is happening. There's no dramatic growth of sales and marketing expenditures, or nuclear arms, or lily pads. Instead, the balancing process maintains the status quo, even when all participants want change. The feeling, as Lewis Carroll's Queen of Hearts put it, of needing 'all the running you can do to keep in the same place' is a clue that a balancing loop may exist nearby.
>
> Leaders who attempt organizational change often find themselves unwittingly caught in balancing processes. To the leaders, it looks as though their efforts are clashing with sudden resistance that seems to come from nowhere. In fact, as my friend found when he tried to reduce burnout, the resistance is a response by the system, trying to maintain an *implicit system goal*. Until this goal is recognized, the change effort is *doomed to failure*.

This applies to the sustainability problem. Until the "implicit system goal" causing systemic change resistance is found and resolved, change efforts to solve the proper coupling part of the sustainability problem are, as Senge argues, "doomed to failure."

In this paper **systemic** means originating from the system in such a manner as to affect the behavior of most or all social agents of certain types, as opposed to originating from individual agents.

Classic Activism

Under the old paradigm, problem solvers see proper coupling as *the* problem to solve, so that's what they're doing. Their work follows a pattern that can be called Classic Activism, as diagrammed in Figure 1. While overcoming individual change resistance

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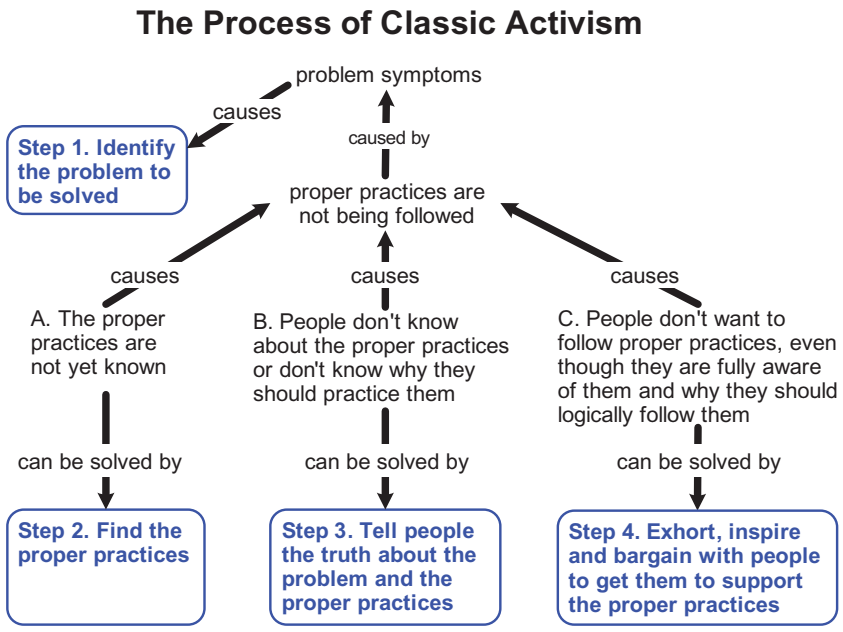

Fig. 1. The process of Classic Activism

is included, overcoming systemic change resistance is not, which explains why the process frequently fails.

Classic Activism has been used for centuries by citizen groups to solve common good problems that democratic governments are not addressing. If it succeeds then governments assume solution responsibility.

The process begins with discovery of the problem symptoms, which triggers step 1: identify the problem to be solved. This consists of understanding the symptoms enough to identify what they are, when they will occur, and what their immediate causes are, such as loss of habitat contributes to species extinction.

The symptoms are caused by the proper practices are not being followed. For example, the symptoms of environmental degradation are caused by too many people not following the proper practices that would make their behavior sustainable. Proper practices are not being followed has three possible causes:

- **Cause A, solved by step 2.** If the problem is new, problem solvers must start with the first cause: A. The proper practices are not yet known. This can be solved by step 2: find the proper practices. For example, renewable energy sources can be developed, tested, and proven to be effective.
- **Cause B, solved by step 3.** Once the proper practices are found, classic activists move on to the second cause, which is: B. People don't know about the proper practices or don't know why they should follow them. This is to be expected if the problem or proper practices are new. This can sometimes be solved by step 3: tell people the truth about the problem and the proper practices. The truth can be spread by lobbying,

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articles, environmental magazines, interviews, conferences, pilot projects, scientific reports, and so on. For extremely easy problems, solutions 2 and 3 are enough.

- **Cause C, solved by step 4.** But usually there is a third cause: C. People don't want to follow the proper practices, even though they are fully aware of them and why they should logically follow them. This is individual change resistance, though due to the missing abstraction it is seldom called that. The standard strategy to overcome it is step 4: exhort, inspire and bargain with people to get them to support the proper practices. This is attempted with eloquent writing, passionate speeches, pleadings with decision makers, bargaining with concerned parties, demonstrations, marches, confrontational stunts to shock the public into coming to its senses, and so on.

To my knowledge, all what-to-do environmental literature falls into this process. *Silent Spring* was a superb mixture of steps 3 and 4, with a little bit of 2. *Natural Capitalism*, a book about how corporations can take the lead and create the "next industrial revolution" by switching to more environmentally sustainable technology, uses mostly 2 and 3. Al Gore's *Earth in the Balance* is mostly 3. Environmental and nature magazines, such as *Sierra*, *National Wildlife*, and *Audubon*, are 3 and 4. Step 3 is also known as education on the facts or "appeal to logic," while step 4 is the "appeal to emotion," which attempts to magnify the truth with rhetoric and bargaining. The 2006 *Stern Review on the Economics of Climate Change* performed step 1 from an economic point of view and presented evidence that "the benefits of strong, early action considerably outweigh the costs," which is step 3. The actions reviewed were all proper practices. As discussed earlier, the common-pool resource literature sees its mission as finding the right proper coupling practices, which is step 2.

Environmental organizations also rely on steps 2, 3, or 4 to achieve their goals. Lawsuits to comply with existing environmental regulations would seem to fall outside of 2, 3, or 4. However, this is enforcement of the legal truth by telling judges about the truth of the facts involved. It is thus a form of 3. Lobbying is a mixture of 3 and 4. Scientific research into alternative energy, sustainable agriculture, recycling, ways to reduce population, and so forth is 2. Extremist actions such as sit-ins and blocking nuclear test sites are forms of 4. So are demonstrations, marches, and publicity stunts. Polls, such as how strongly people support a clean environment, are a form of 3. They are "the truth" why decision makers should enforce proper practices. Corporate social responsibility campaigns, since they play on psychological elements, are step 4.

Even the innovative sustainability solutions pioneered in developing countries, such as ecotourism, microfinance, acceleration of the demographic transition, direct marketing cooperatives for green products, and community-based common-pool resource management, are a collection of better proper practices. Perfecting them is step 2. Education and assistance are step 3. Pleading and bargaining with developed nations, NGOs, and international agencies to support them and with developing countries to adopt them are step 4.

The Limits to Growth employed the general pattern of Classic Activism. The World3 model focused mostly on step 1: identify the problem. The 1972 first edition said little about the solution. But due to lack of solution progress, the second and third editions did. The 1992 second edition presented "a simple set of general guidelines for restructuring the world system toward sustainability," such as "improve the signals . . . speed up response times . . . minimize the use of nonrenewable resources" (pp. 213–214). These

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are proper coupling practices, so the book was advocating step 2 and performing step 3. The authors acknowledged the presence of change resistance: "Systems strongly resist changes in their information flows, especially in their rules and goals" (p. 223). But when addressing how to deal with resistance, the authors turned to the old paradigm of Classic Activism: "In our search for ways to encourage the peaceful restructuring of a system that naturally resists its own transformation, we have tried many tools" (p. 223). The tools were "visioning, networking, truth-telling, learning, and loving" (p. 224). These are techniques used to implement Classic Activism steps 3 and 4. The 2004 third edition repeated these suggestions.

More recent modeling efforts continue to follow the four steps of Classic Activism. The Millennium Institute's Threshold 21 sustainability model focuses on how a nation can better manage proper coupling. The IPCC assessment reports seek "the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation" (IPCC, 2009). But this understanding, which is heavily model based, starts with the symptoms and stops at the same intermediate causes of the World3 model: the IPAT factors.[1] Like the three editions of *Limits to Growth*, the four IPCC assessment reports have progressively tiptoed into Classic Activism steps 3 and 4. The fourth report took a leap in section 4: adaptation and mitigation options. This contained an extensive listing of existing proper practices and projections by sector on their effectiveness, which is step 3. Section 5, the long-term perspective, used "five reasons for concern" to emphasize that "Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios assessed." While expressed in the dry language of scientists, this is nevertheless the exhortation of step 4.

We have shown that sustainability writers, organizations, innovative developing country solutions, and models all employ Classic Activism to achieve their objectives. None that we are aware of deviate from the four steps. Let's model these steps so we can determine why, while Classic Activism works on some problems, it has so far failed to solve the global environmental sustainability problem.

The three-loop dynamic hypothesis

We begin with a generic high-level model. The three main forces at play are represented by the three feedback loops in Figure 2.

Intermediate causes is the problem to solve. When symptoms of those causes begin to arrive or a few forward-looking thinkers spot those causes and figure out the consequences, unsolved problem symptoms starts to grow. This activates the **Problem Commitment** loop. This causes force committed to favor change to start growing, which activates the **Forces Favoring Change** loop. If the model contained only the loops below the dotted line, growth of the middle loop would eventually increase adopted proper practices enough to reduce the intermediate causes to an acceptable level, which would solve the problem.

But the human system is not that simple. A third loop sits atop the other two, silently lurking, just waiting to be activated. That occurs when known proper practices start growing. This increases anticipated loss for some agents, causing the **Forces Resisting Change** loop to spring into action. *If loop amplification is strong enough*, change

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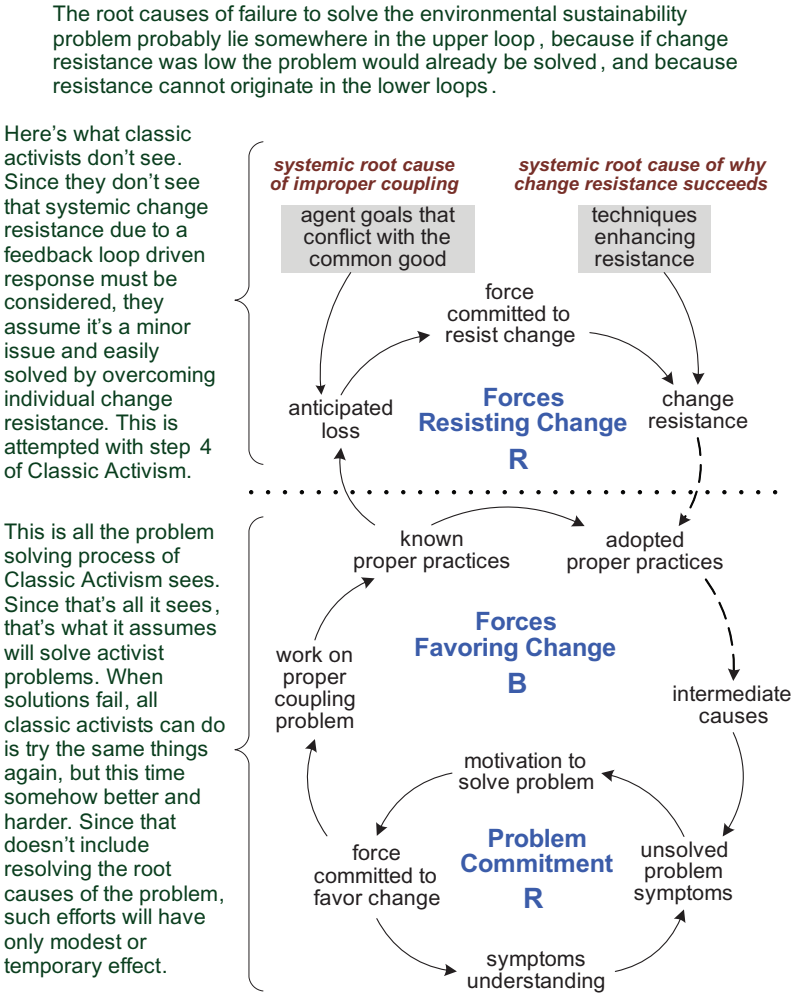

Fig. 2. Causal loop diagram of the process of Classic Activism. Solid arrow is a direct relationship; dashed arrow is an inverse relationship

resistance will be high enough to overwhelm efforts to get the known proper practices adopted. The result is solution failure.

Our analysis has discovered two possible *systemic* root causes of why the upper loop exhibits such high gain. These are instances of the two high-level root cause classes shown. The root cause of why techniques enhancing resistance succeed must be resolved first, since this resistance also applies to changing agent goals that conflict with the common good.

Given the consequences of not proactively solving the environmental sustainability problem, problem solvers need to push on points with the highest leverage possible. Systemic root causes like these allow that.

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Table 1. Places to intervene in a system (in increasing order of effectiveness)

12.	Constants, parameters, numbers (such as subsidies, taxes, standards)
11.	The size of buffers and other stabilizing stocks, relative to their flows
10.	The structure of material stocks and flows (such as transport network, population age structures)
9.	The length of delays, relative to the rate of system changes
8.	The strength of negative feedback loops, relative to the effect they are trying to correct against
7.	The gain around driving positive feedback loops
6.	The structure of information flow (who does and does not have access to what kinds of information)
5.	The rules of the system (such as incentives, punishment, constraints)
4.	The power to add, change, evolve, or self-organize system structure
3.	The goal of the system
2.	The mindset or paradigm that the system—its goals, structure, rules, delays, parameters—arises out of
1.	The power to transcend paradigms

Reproduced from *Leverage Points: Places to Intervene in a System*, by Donella Meadows, 1999. Available: sustainer.org/pubs/Leverage_Points.pdf.
Of interest is the last page, where Donella writes: "The higher the leverage point, the more the system will resist changing it…"

Resolving dominant agent goals that conflict with the common good changes "The goal of the system." This scores a 3 on Donella Meadow's scale of leverage in Table 1. By contrast, popular solutions like taxes, regulations, and alternative energy subsidies push on leverage point type 12, which has the lowest leverage of them all. Even recent dynamic solutions like cap and trade only push on type 8, though that has aspects of type 5.

The other root cause class, techniques enhancing resistance, scores only a 7. But as we explain later, one of these techniques is the root cause of the success of the universal paradigm presently driving the human system over the cliff of unsustainability. Resolving the root causes changes that paradigm to a sustainable one. Since paradigms score a 2, so does resolving their root causes. This follows the principle that leverage comes from what other places in the system a place to intervene controls, rather than just the point of intervention itself.

The core of the dynamic hypothesis lies in the tension between the upper and middle loops. This directly models Kurt Lewin's "…idea, that the status quo represented an equilibrium between the barriers to change and the forces favoring change…" To preserve the status quo the upper loop strives to block adoption of proper practices, while the middle loop promotes adoption. The winning loop determines whether the problem is solved or not.

Next we turn to system dynamics to understand the dynamic behavior of this structure.

The simulation model

Figure 3 is a generic model showing how Classic Activism is used to solve problems whose solution would benefit the common good. *It's a qualitative model since measurement of*

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Note: The model image contains an error.
"causes" should be "intermediate causes".

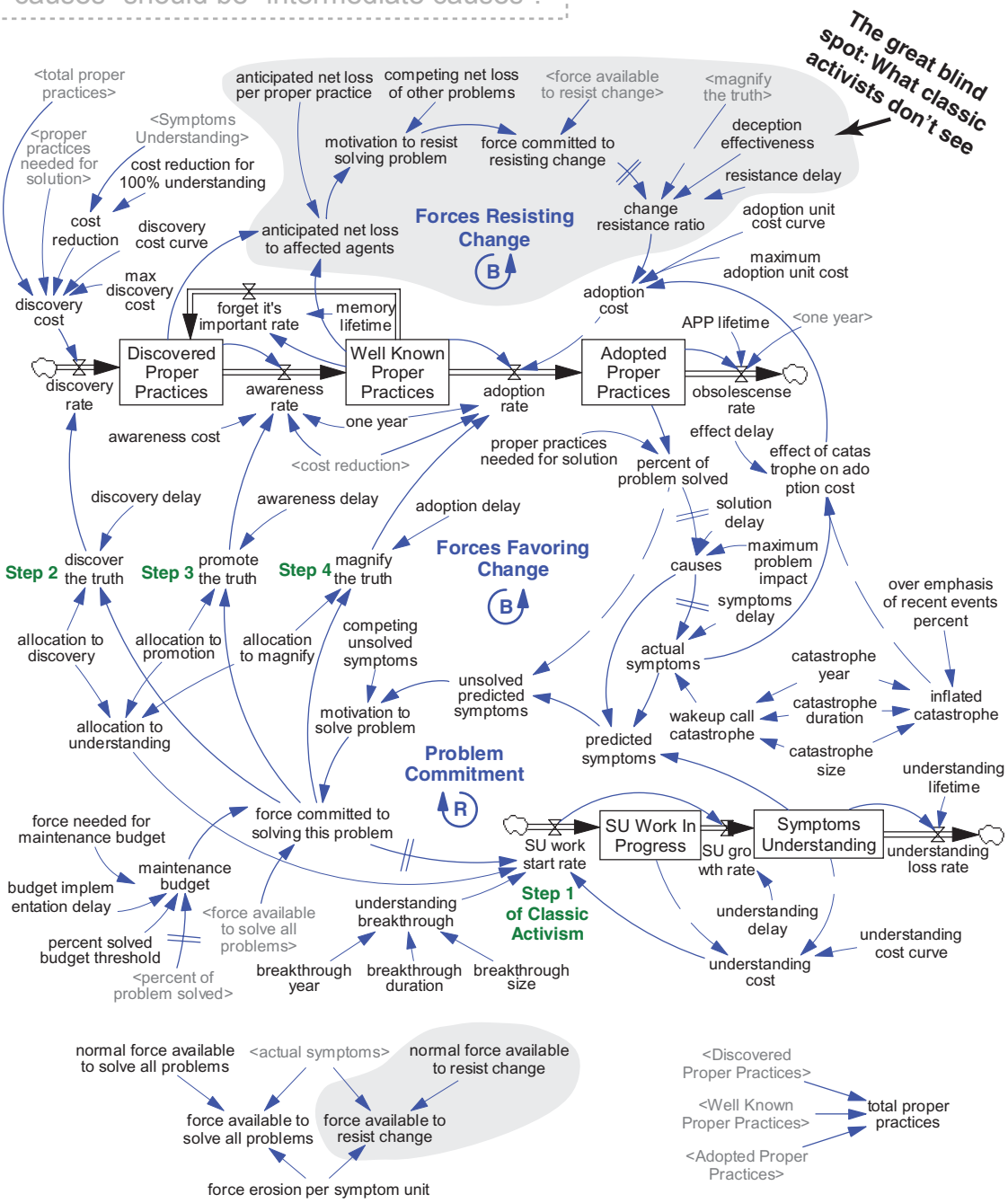

Fig. 3. The process of Classic Activism, with emphasis on why it fails when change resistance is high. Solid arrow is a direct relationship; dashed arrow is an inverse relationship; dotted arrow is a constant or lookup table

so many soft factors has never been done. The model is designed to explore the dynamic hypothesis in the simplest manner possible so the model may be understood by a wide audience. Thus it fits on one page. The model is not meant to be the definitive analysis of how problem solvers work or where the root causes of resistance are. Rather it is a first step in a new direction of exploration, one pointing to where we might start digging to find those causes.

Model validity depends primarily on the soundness of the concepts of proper coupling, change resistance, and Classic Activism, plus arrangement of the three main loops. The rest is detail that could be modeled many ways. See the end of this paper for model equations.

The purpose of the model is to find the systemic root causes of solution failure in the observed pattern of Classic Activism by modeling the critical things social agents have been doing. *Why* they are doing them is a large and separate topic, except for root causes and the motivation to solve problem and motivation to resist solving problem nodes, and is not addressed in this paper.

This paper uses "common good" in the utilitarian sense of "the greatest good for the greatest number." Thus the **common good** is the mixture of industrial production, social factors, environmental health and other elements that optimizes *quality of life* for all living people and their descendents. The general goal of the common good should not be confused with **common-pool goods**, which are shared goods whose wise management benefits the common good.

To understand the model let's begin with the right side of the **Forces Favoring Change** loop. Maximum problem impact is 100 quality of life (QOL) units/year. If the problem is not solved then the system will lose that amount of common good. 100 is the arbitrary amount all other variables in the model are *relative* to.

In a qualitative model constants like this are estimated. What's important are not their actual values but their values relative to each other. When the model is run, insights come from the relative differences in the simulation runs, rather than exact numerical outcomes.

A simulation run begins with all stocks empty. Because Adopted Proper Practices start at zero, so does percent of problem solved. This causes intermediate causes to start at 100 percent of maximum problem impact. Later intermediate causes falls as percent of problem solved rises. When the problem is 100 percent solved intermediate causes equals zero.

After a symptoms delay of 200 years the actual symptoms appear. But if we wait until then to solve the sustainability problem it will be too late, due to overshoot and collapse. The model handles this with the Symptoms Understanding stock. This varies from zero to 100 percent and represents how well society understands what the symptoms are, when they are likely to occur, and what their intermediate causes are. This is the type of work the IPCC and many environmental scientists are engaged in, as well as what early efforts like *The Limits to Growth* focused on. Symptom understanding is the equivalent of problem identification, the first step of Classic Activism.

As Symptoms Understanding rises from zero to 100 percent, predicted symptoms changes from actual symptoms to intermediate causes. Thus as our understanding starts to grow, predicted symptoms rise faster than actual symptoms. This prediction of what hasn't happened yet represents the foresight required to proactively solve problems with large symptom delays.

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Unsolved predicted symptoms grow just as quickly as predicted symptoms at first, since percent of problem solved starts at zero. Later, as percent of problem solved rises toward 100 percent, unsolved predicted symptoms falls toward zero.

The **Problem Commitment** loop starts growing when unsolved predicted symptoms begin to rise above zero. The model theorizes that in a democracy (and to some extent socialist and theocratic societies), when people and organizations notice problems their government is not addressing a *pool of potential public-interest activists* react by becoming motivated to work on solving the new problem instead of competing problems (and opportunities, which is merely another problem type), either of their own or society. They compare how bad that problem is to the other problems they and their society faces. This reaction, which is the very heart of activism, is modeled by motivation to solve problem = unsolved predicted symptoms / (unsolved predicted symptoms + competing unsolved symptoms).

From a stimulus response standpoint, unsolved predicted symptoms is the stimulus and motivation to solve problem is the response. Competing unsolved symptoms are competing stimuli. While each agent works on one or a small number of problems, the model represents the aggregate behavior of all activists. This allows the use of a macro-oriented equation.

This formulation is consistent with social-psychological theories of individual behavior change. Jackson (2005, pp. 21–61) reviews 22 such theories as they apply to motivating sustainable consumption. Ranging from rational choice to means-end-chain to value-belief-norm theory, the theories share a common pattern: favorable preconditions plus problem stimulus leads to behavior change as the response. Here the favorable preconditions are the "pool of potential public-interest activists" referred to earlier. While this propensity can be measured with scales such as the New Ecological Paradigm (Dunlap *et al.*, 2000) and the threshold required for commitment could be modeled, this level of detail is not needed for model purposes.

Competing unsolved symptoms is 500 QOL units/year, which is five times the size of maximum problem impact. If unsolved symptoms are all of that then motivation is 17 percent: (100 / (100 + 500) = 17 percent). Larger problems cause higher motivations. For example, if a comet will hit the earth in ten years, society might conclude maximum problem impact was a catastrophic 10,000. At first all of that would be unsolved, giving an ultra-high motivation of 95 percent (10,000 / (10,000 + 500) = 95 percent). This is realistic. Of course, in an extreme case like a comet more people would suddenly join the pool of activists. This simplified model omits that behavior.

Once activists are motivated they act in proportion to that motivation and their ability to take action. This social reaction is captured in force committed to solving the problem = (force available to solve all problems × motivation to solve problem) + maintenance budget. The budget is normally zero and is explained later.

Next comes the first step of Classic Activism. The force committed to solving this problem is allocated to the four steps. Allocation to understanding contains the portion going to step one. That and understanding cost determine the system understanding work start rate. After a delay for work in progress to be completed, the Symptoms Understanding stock increases. This in turn increases predicted symptoms, which increases unsolved predicted symptoms and we're back where we started. The **Problem Commitment** reinforcing loop grows until the problem is solved, excessive diminishing returns are encountered in understanding cost, or the problem

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is not solved and collapse occurs, which erodes the force available to solve all problems.

The **Problem Commitment** loop does one main thing and does it well: it reinforces growth in the force committed to solving this problem, which creates the social pressure needed to drive the four steps of Classic Activism.

Out of the force committed node emerge the three branches of the **Forces Favoring Change** loop, one for each of the remaining steps of Classic Activism. As force committed to solving this problem grows, so do these branches. Where the force goes is determined by the allocation constants. In run one 5 percent goes to step 2, 10 percent to step 3, 30 percent to step 3, with the remainder of 55 percent to step 1. 5 percent to step 2 may seem low, but it's industry and government who mostly fund technological R&D, not activists. For simplicity, allocation is restricted to 5 percent increments and is fixed during a run, rather than dynamic or stepped.

The three stocks containing proper practices form an aging chain. While step 3 causes some adoption, most require step 4, especially when resistance is high. For simplicity the model shows only step 4 as causing adoption.

When the change resistance ratio is zero, adoption cost is 5 percent of maximum adoption unit cost. The 5 percent is the normal amount of individual change resistance. It approximates the relatively low amount of individual change resistance arising out of instinctual responses and long-formed habits, versus the high amount of systemic resistance originating in the upper loop due to the two systemic root cause types shown in Figure 2. *The model thus theorizes that when change resistance is high, the vast majority of it is systemic.*

As steps 2, 3 and 4 of Classic Activism are performed, the proper practices needed to solve the problem move closer to where they must be to do that: the Adopted Proper Practices stock. When they get there activists take a quick break, dance a little jig and celebrate, because this causes percent of problem solved to go up, which causes unsolved predicted symptoms to go *down*.

That is does go down is what makes the **Forces Favoring Change** loop a *balancing loop*. As more and more of a problem is solved, motivation to solve problem decreases. This could easily cause the problem to never be fully solved, except for the way activism works. Once the forces of activism solve enough of a major problem, governments usually take over and solve the rest by passing new laws and implementing/enforcing them, which usually requires a much larger budget. The model handles this with the percent solved budget threshold constant, which is 40 percent. Once percent of problem solved rises to 40 percent a system phase change occurs. The maintenance budget is turned on and changes from zero to the force needed for maintenance budget, which is $6000/year. Comparing this to the normal force available to solve all problems of $10,000/year, you can see why this is a welcome outcome for activists. Otherwise they can solve no more than a handful of problems.

Looking at the upper left of the model, the cost reduction node captures the increasing returns from knowing more about symptom cause and effect. This node reduces the cost of the first three rates in the aging chain. For example, the more we know about the immediate causes and trends of freshwater scarcity, the easier it is to develop plans to reduce consumption and manage reservoirs/sources, the more data there is to promote the truth about the plans, and the more proof there is they should be adopted.

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Finally, notice the small subsystem at the bottom left. Actual symptoms can erode the forces available to solve problems or resist change. Erosion is an important consideration: "The difference between the overshoot and oscillation, and overshoot and collapse, is the presence of *erosion loops* in a system. These are positive feedback loops of the worst kind. Normally they are dormant, but when a system gets bad, they make it worse by carrying a system downward at an ever-increasing pace" (Meadows *et al.*, 2004, p. 164, italics are in the original).

Public-interest activists tend to be a minority. They have limited resources for solving problems. This state is captured in normal force available to solve all problems, which is $10,000/year. If no erosion of problem-solving ability has occurred yet, this equals force available to solve all problems. But as actual symptoms increase, the force decreases. For simplicity a linear relationship between symptoms and erosion is used.

Pitted against agents favoring change are those resisting change. The normal force available to resist change is $50,000/year, which is five times as much. In the real world this might represent activist NGOs struggling against large corporate interests, who have much larger budgets. These are so large that five times as much is conservative. The advantage of the opposition is much more.

The force available to solve all problems and force available to resist change nodes approximate the way those with lower discretionary spending power (activists) suffer more at first when economic or environmental problems occur. For example, in simulation run 3 (Figure 6) each side loses about $5,000/year of force to erosion. But because the normal force is $10,000 for activists and $50,000 for those resisting change, activists suffer 50 percent erosion, while those resisting change suffer only 10 percent erosion.

This completes description of the lower two loops.

How Classic Activism *should* work

What we've described so far is the way classic activists think and work. Running the model gives the behavior in run 1 (Figure 4). This shows how the process *should* work on all problems.

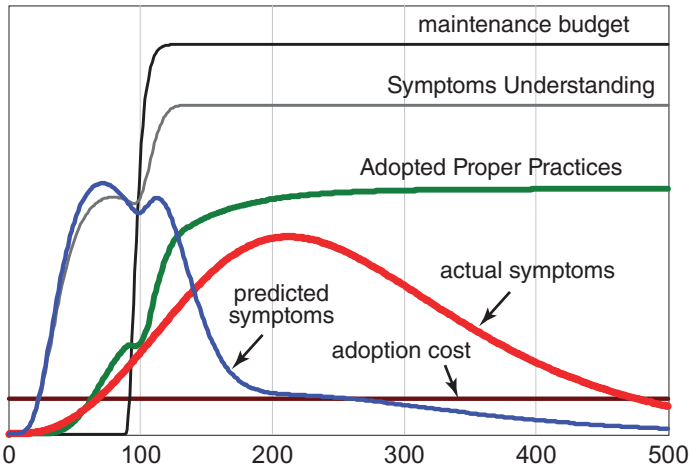

Fig. 4. Run 1: what should happen, given the process

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Table 2. Simulation run settings

Model settings	Simulation runs						
	1	2	3	4	5	6	7
Allocation to magnify	30%	50%	50%	50%	50%	50%	50%
Deception effectiveness	0	10%	15%	15%	15%	40%	40%
Catastrophe start year	NA	NA	NA	70	65	NA	NA
Catastrophe size	0	0	0	10	10	0	0
Normal force step change year 200	No	No	No	No	No	No	Yes
Problem solved?	Yes	Yes	No	Yes	No	No	Yes

Due to the symptoms delay of 200 years the actual symptoms arrive gradually. But the rapid growth of Symptoms Understanding causes predicted symptoms to rise rapidly at first. This motivates activists to solve the problem. After the delays of the proper practices aging chain, Adopted Proper Practices starts to rise. This reduces the intermediate causes of the problem, which results in a slight drop in predicted symptoms, which is a prediction that the actual symptoms won't be that bad after all. After about 90 years the Adopted Proper Practices rise to 40 percent of what's needed to solve the problem. This triggers the government's maintenance budget to start. Since this has only a ten-year delay, this almost immediately shoots from zero to high enough to solve the problem. The result is a new homeostasis that uses a maintenance budget to hold the Adopted Proper Practices high enough to bring the actual symptoms down to zero eventually.

Table 2 shows the settings used in run 1 and later runs. These may be used to download the model and duplicate all seven runs.

The Forces Resisting Change loop

Run 1 illustrates the general pattern common good problems go through as they are solved by the traditional process of Classic Activism. But it's not working in this case. Civilization is nowhere close to solving the *complete*[2] global environmental sustainability problem. *Why is this?*

To find the answer problem solvers must expand their paradigm to include the **Forces Resisting Change** loop. This loop models the adaptive response so common in complex social systems, as well as the way the strongest forces resisting change tend to be systemic in nature, rather than located in individuals.

For example, Beder (2002, p. 16) describes the response of U.S. corporations to the rising success of activism in the 1960s. Note how it took them only seven years to adapt:

> In various business meetings, corporate executives lamented their decline in influence. "The truth is that we've been clobbered," the CEO of General Motors told chiefs from other corporations. The Chairman of the Board of General Foods asked "How come we can't get together and make our voices heard?"—which is of course what they did. Throughout the 1970s, US corporations became politically active,

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> getting together to support a conservative anti-regulatory agenda and financing a vast public relations effort aimed at regaining public trust in corporate responsibility and freedom from government regulation.
>
> According to David Vogel in his book *Fluctuating Fortunes: The Political Power of Business in America*, "It took business about seven years to rediscover how to win in Washington." Once they realized how the political scene had changed, corporations began to adopt the strategies that public-interest activists had used so effectively against them—grassroots organizing and coalition building, telephone and letter writing campaigns, using the media, research reports and testifying at hearings, "to maximize political influence." To these strategies corporations added huge financial resources and professional advice.

The Discovered Proper Practices and Well-Known Proper Practices stocks contain the proper practices social agents must follow once the practices are adopted. It's obvious to some social agents that these practices will cause them to suffer a net loss, as captured in the anticipated net loss per practice. This times the number of discovered and well-known practices equals the anticipated net loss to affected agents. As soon as those agents recognize this potential loss they do the same thing activists did: they compare the size of that problem to the competing net loss of other problems and calculate their motivation to resist solving problem in a manner identical to the way motivation to solve problem was calculated. This in turn is used to arrive at the force committed to resisting change, in the same way force committed to solving the problem was calculated.

Change resistance is the ratio of forces resisting change to those favoring change. Thus it would appear that change resistance ratio equals force committed to resisting change divided by the force of magnify the truth.

This leads to unrealistic model behavior, however. The normal force available to resist change is $50,000/year, while the normal force available to solve all problems is only $10,000/year. Since activists are allocating only 30 percent to magnify the truth, that equals only $3000/year. This gives a ratio of 50,000/3000 = 17. This is such an overwhelming advantage it should smother proper practice adoption efforts, via counter efforts like pseudo think tanks, political donations, and lobbying. But activists are not losing to those resisting change by such a lopsided margin. So what have we missed?

In a common good problem, altruistic activists stand on the side of the truth of what will benefit the common good, while selfish special interests resisting change cannot. Special interests must instead depend on deception (defined below) to influence voters, politicians, and other decision makers. The model captures this by change resistance ratio = (force committed to resisting change × deception effectiveness) / magnify the truth.

Compared to the truth, deception is much less reliable, which causes deception effectiveness to be well under 100 percent. If effectiveness was 10 percent then the change resistance ratio would be 1.7 instead of 17. This is fairly realistic.

All models are a simplification of reality. This one doesn't capture the way some so-called activists pursue their own selfish interests, dressed up as ones that purportedly improve the common good. Likewise, the model omits the many honest and altruistic people who, even though they work for those resisting change, are pushing from

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within to cause their employers to behave less selfishly and more honestly. But these are exceptions. Overall, one side employs the truth about the need for proper practices while the other side utilizes bold lies, half-truths, spin, sophism, reality as they see it, and all sorts of twaddle. We need to capture in a single term all of the forces working against the truth.

Here **deception** means the act of convincing others to believe what is not true or only half-true, though in most cases this is not done out of malice but as a rationalized, subconscious expediency to achieve the goals of those resisting change. There are those who honestly believe a different "truth" is correct. "Deception" should therefore not be interpreted as a pejorative term, but as a neutral one describing observed behavior that must be modeled.

Deception is a technique for enhancing resistance. Without it those resisting change would have to rely on the truth. However, earlier we defined the common good as that which optimizes quality of life for all, and implied there exists a class of problems whose solution would clearly benefit the common good, though when these problems are young this is less clear due to low certainty about symptom cause and effect. *Therefore opposition to solving common good problems with high certainty (a component of high* Symptoms Understanding*) cannot be based on the truth, because solving these problems is desirable to society as a whole.*

Therefore selfish special interests must depend on deception. This is used to attack the argument that a particular solution would increase the common good, to argue a solution won't work or will cost more than expected or will take too long or is unfair, to attack the premise that the problem exists in the first place, to argue that solving the problem would create other problems that are worse, to argue that uncertainty is so high that no action is necessary now, to argue there are higher priority problems, and so on. The ubiquity of fear, uncertainty, and doubt (FUD) campaigns against stricter environmental legislation is one result.

For simplicity other techniques for enhancing opposition, such as political donations, bribery, and force, are omitted. We feel mass deception is the most important technique, since deception appears to play the largest role in influencing political decision making.[3] Thus deception alone is an imperfect but adequate choice for use in this concept model. Adding more factors would change only one of the sample solutions and none of our main conclusions.

Unless deception effectiveness is absurdly low (less than about 3 percent) change resistance is high enough to dramatically slow down the adoption rate. This is accomplished by increasing the adoption cost to such a high level that activist's resources are exhausted. They simply can't afford to match what the **Forces Resisting Change** can throw against them. The result may be seen in run 2 (Figure 5), where a deception effectiveness of 10 percent is used. (0 percent was used in run 1 to turn the resistance loop off.)

The activists have adapted too, by changing allocation to magnify from 30 percent to 50 percent. This is their optimum allocation strategy in run 2. But it's not enough to prevent it taking 125 years (versus the 90 years of run 1) to cause the maintenance budget to be triggered, because change resistance is now inflating adoption cost. The jump in that curve creates a mountain activists can barely climb over.

Worse yet, run 2 does not reflect what's happening in the real world. Although the world began awakening to the catastrophic consequences of unsustainable growth in

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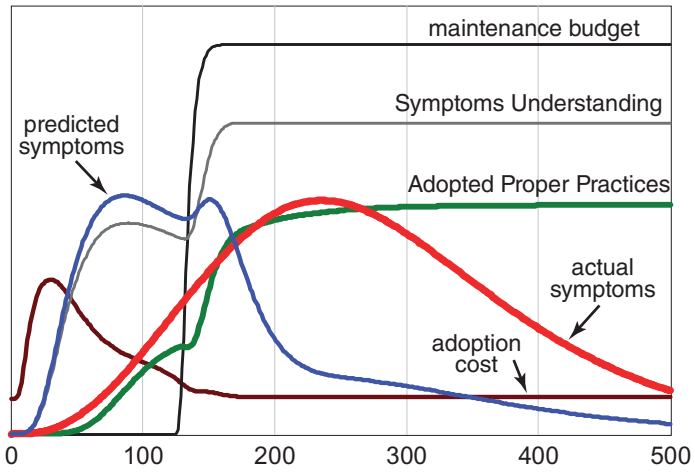

Fig. 5. Run 2: change resistance, effectiveness = 10 percent

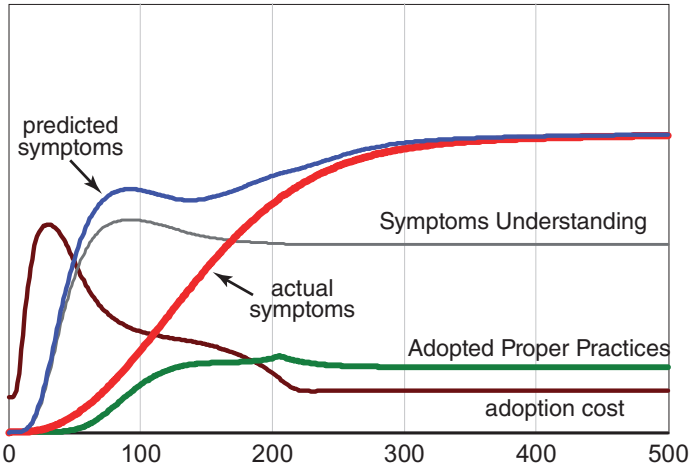

Fig. 6. Run 3: change resistance, effectiveness = 15 percent

the 1960s and 1970s, the significant intermediate causes "started" around the time of the Industrial Revolution in the late 18th century, over 200 years ago. Serious efforts to solve early symptoms of the sustainability problem began about 100 years after that, such as the setting aside of Yosemite Valley and the Mariposa Grove of Big Trees in the USA in 1864, and establishment of the world's first international environmental organization, the Society for the Preservation of the Wild Fauna of the Empire, in the British Colonies in 1903. (McCormick, 1989, p. 18) Thus over 200 years have gone by and we haven't solved the problem yet. The model hypothesizes this is due to high change resistance, a state reflected in run 3 (Figure 6) by raising deception effectiveness from 10 percent to 15 percent.

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Gone is the maintenance budget. Adopted Proper Practices never grow high enough to trigger it. As the actual symptoms arrive, the forces available for solution are eroded faster than those resisting solution, due to the way the weak suffer more than the powerful at first in collapsing social systems. The result is only about 30 percent of the proper practices needed remain adopted, which causes symptoms to reach a steady state of 70 percent of the total size of the problem. The model doesn't show it, but this is more than enough to cause global collapse. Run 3 is the reference mode and represents the problem to solve.

Now that we've presented all three loops, you can see the structural reason for why Classic Activism fails. No matter how classic activists allocate their work they cannot resolve the root causes of change resistance, because Figure 3 contains no arrows running from force committed to solving this problem to the upper loop.

Wakeup call catastrophes

How then have activists and their governments made the progress they have? The history of the sustainability problem shows that most environmental protection legislation occurs as a piecemeal reaction to a recent "wakeup call catastrophe." Examples are the way discovery of the Antarctic ozone hole led to the Montreal Protocol; Australia's seven-year drought and the new administration of Kevin Rudd whose first official act was signing the Kyoto Protocol in December 2007; the U.S. dust bowl of the mid 1930s and its influence on soil conservation laws; the great London smog of December 1952 that killed 4000 people and caused passage of Britain's 1956 Clean Air Act; the acid rain problem, which caused many countries to enact legislation and led to the 1979 Convention on Long-Range Transboundary Air Pollution; Love Canal and Superfund; and the pesticide poisoning and pollution problems described in *Silent Spring* in 1962, which launched the modern environmental movement and along with a series of oil spills and other catastrophes led to creation of the U.S. EPA in 1970 and many other EPAs.

This suggests solution progress is largely reactive rather than proactive. *If so, then reliance on the use of Classic Activism and wakeup call catastrophes to overcome change resistance will not work, because by the time large enough catastrophes occur to solve the complete sustainability problem, it will be too late.* Due to ecological tipping points the system will be in such severe overshoot that short-term corrective action will no longer be possible. In addition, such catastrophes will erode so much of the force available to solve all problems that there will probably not be enough left to solve the environmental sustainability problem, not to mention the many other social and economic problems cascading off that one as collapse begins to occur.

The model explores this behavior by allowing one wakeup call catastrophe (WCC) to occur. If we create a WCC in year 70 with ten years' duration and a size of 10 QOL units/year, we can see the result in run 4 (Figure 7).

The WCC causes the problem to be solved. The predicted symptoms WCC blip is half the height of the actual one, due to Symptoms Understanding having reached only 50 percent at that point. A WCC works by causing a temporary drop in adoption cost. That drop is 50 percent bigger than the jump in actual symptoms, due to the constant of 50 percent for overemphasis of recent events percent. Suddenly lower adoption cost

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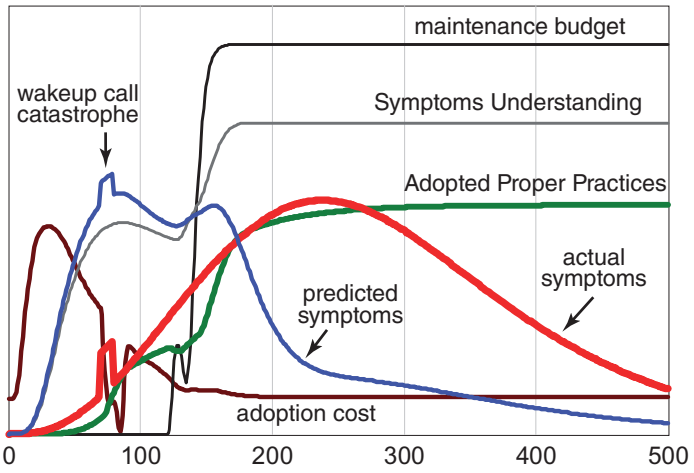

Fig. 7. Run 4: wakeup call catastrophe, year 70

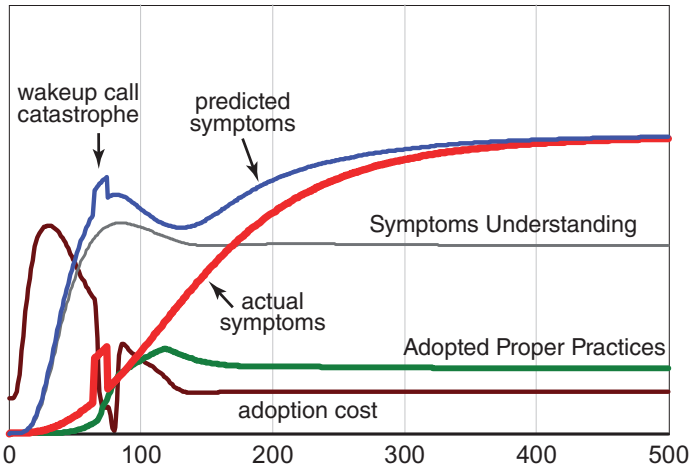

Fig. 8. Run 5: wakeup call catastrophe, year 65

causes a sudden rise in Adopted Proper Practices, which is what triggers the solution sooner.

But there have been no large international WCCs lately. All we've had are the large ones of the past, like acid rain. The recent one of ozone depletion was too small to make much difference. But why didn't the early WCC of acid rain cause nations to scramble to solve the complete sustainability problem? If we move the catastrophe start year from 70 to 65 we can find out in run 5 (Figure 8).

This time the WCC does not trigger solution, because the event occurred too early. Thus the timing of WCCs is critical.

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Further experimentation shows there is a window of opportunity in which WCCs work. They must start in years 70–95. Before that the Adopted Proper Practices are too low to be bumped up enough to trigger solution. After that the catastrophic symptoms erode the force available to solve all problems so much there's not enough left to solve the problem.

Symptom forecasts of the many facets of the sustainability problem are now so well explored that no large WCC is expected soon, in the next 20 years, with at least one ominous exception: carbon emissions are rising much faster than IPCC models expected: "The growth rate of [fossil fuel] emissions was 3.5% per year for 2000–2007, an almost four fold increase from 0.9% per year in 1990–1999. . . . This makes current trends in emissions higher than the worst case IPCC-SRES scenario" (www.globalcarbonproject.org/carbontrends/index.htm, retrieved 14 March 2009). This is clearly a case where society must take action now but has not. Therefore it's unlikely that a WCC, or data signaling one is coming unless we change course quickly, will cause the sustainability problem to be solved in time.

But that's what the system has relied upon in the past to make substantial progress. We must therefore look elsewhere for a dependable way forward.

Beyond the limits ... of Classic Activism

Why does Classic Activism fail on problems like sustainability? Because at the heart of the process lies a crippling false assumption: that change resistance occurs at the level of individuals and can thus be overcome by the inspiration, exhortation and bargaining of step 4. The world's problem solvers appear to have fallen into one of the biggest traps of them all: the *fundamental attribution error*:

> A fundamental principle of system dynamics states that the structure of the system gives rise to its behavior. However, people have a strong tendency to attribute the behavior of others to dispositional rather than situational factors, that is, to character and especially character flaws rather than the system in which these people are acting. The tendency to blame the person rather than the system is so strong psychologists call it the "fundamental attribution error." (Sterman, 2000, p. 28)

This is the trap Kurt Lewin and Peter Senge warned against. In difficult social system problems, change resistance is much more likely to be *systemic* than local or located within individual agents. So where in the system will we be most likely to find the root causes of systemic change resistance?

The root causes cannot reside in the **Forces Favoring Change** or **Problem Commitment** loops, because resistance (whether individual or systemic) does not originate there. The root causes can only dwell in the **Forces Resisting Change** loop. *Problem solvers must therefore abandon the Sisyphean task of trying to strengthen the two lower loops, and change to strategies centering on how to weaken the upper loop.*

The model identifies four places to do this: anticipated net loss per proper practice, competing net loss of other problems, force available to resist change, and deception effectiveness. Drilling down in areas like these should lead to finding the root causes with the highest leverage points.

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Striking at the root: solve one problem and you solve them all

Resolving a root cause set solves all the problems emanating from that set. It follows that for a particular set of problems caused by a root cause set, if you can solve one problem you can solve them all. That's why instead of showing how to solve a specific environmental problem like climate change or freshwater scarcity, this paper hammers home the strategy of finding root causes so systemic that resolving them solves the largest number of problems possible. Otherwise it's too easy to focus on the trees instead of the forest.

Popular consensus sees things like the IPAT factors, the human system's growth loops, economic inequality and poverty, and lack of cooperation and other maladapted values as the root causes of the environmental sustainability problem, when in fact they are *intermediate causes*. These are also known as *proximate causes* or *apparent causes*, where the "apparent cause is usually a coincident occurrence, that, like the trouble symptom itself, is being produced by the feedback loop dynamics of a larger system" (Forrester, 1971, p. 95).

A broad and revealing example of this consensus comes from James Gustave Speth (cofounder of the Natural Resources Defense Council, founder of the World Resources Institute, and administrator of the United Nations Development Programme for six years), who wrote that (Speth, 1992, italics and comments added):

> The [five] transitions I will mention briefly seek to deal with the *root causes* of environmental problems.... The first transition... is the need for a demographic transition to *population* stability [the P in the IPAT equation]... The second transition is... a transition in technology to a new generation of *environmentally benign technologies* [the T in the IPAT equation]... The third needed transition is an economic transition to a world in which *prices reflect the full environmental costs* [a balancing loop to put the brakes on the reinforcing growth loops of the IPAT factors, mostly the A and T, by internalizing externalized costs]... The fourth transition is a transition in social equity to a fair sharing of economic and environmental benefits both within and among countries. Over much of the world, the greatest destroyer of the environment is *poverty*—because the poor have no alternative.... None of these transitions is possible without a fifth—an institutional transition to different arrangements among governments, businesses, and peoples. These institutional arrangements are urgently needed to enlist the tremendous potential of the private sector in what must be an unprecedented *cooperative* effort...

These are pseudo root causes, however. *Why* is it so hard to quickly put the brakes on global population growth by, for example, changing to a worldwide one-child-per-family policy for several generations? *Why* are technologies increasingly harmful to the environment? *Why* is the system so biased towards externalizing costs? *Why* isn't the industrialized world already taking care of those less well off? *Why* aren't governments, businesses, and peoples already cooperating? *Questions like these demonstrate these are in fact intermediate causes.* They are mere starting points for deeper analysis.

A **root cause** is a portion of a system's structure that "best" helps to explain why the system's behavior produces a problem's symptoms. Difficult problems usually have

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multiple root causes. These are found by asking a succession of "*Why* is this happening?" Kaizen-like questions until the root causes are found.

How do you know when to stop? A root cause has three identifying characteristics (compare to Rooney and Heuvel, 2004, who list four characteristics):

1. It is clearly a (or the) major cause of the symptoms.
2. It has no worthwhile deeper cause. This allows you to stop asking why at some appropriate point in root cause analysis. Otherwise you may find yourself digging to the other side of the planet.
3. It can be resolved. Sometimes it's useful to emphasize unchangeable root causes in your model for greater understanding and to avoid trying to resolve them without realizing it. These have only the first two characteristics.

This definition allows numerous unproductive or pseudo root causes to be quickly eliminated.

The important thing is to not stop at intermediate causes. These are plausible and easily found. Working on resolving what are in fact intermediate causes *looks* productive and *feels* productive. Intermediate cause solutions, more accurately called symptomatic solutions, may even work for a while. But until the true root causes are resolved, powerful social agents will invariably find a way to delay, circumvent, block, weaken, or even rollback these solutions, because intermediate causes are symptoms of deeper causes. One must strike at the root.

This we have done. Despite the simplicity of the model, the root causes we are about to present are so deeply systemic (so rooty, we could say) that they appear to be *the source of most large difficult problems whose solution would benefit the common good.* These root causes account for not just the climate change problem, but the entire gamut of environmental sustainability problems listed in the SCOPE study (see note 2) and at least one significant economic sustainability problem: catastrophically large economic bubbles. There are more such problems, in both the economic and social dimensions of sustainability, but identifying them is beyond the scope of this paper.

Resolving the root cause of improper coupling

Sometimes a vivid alternative mental model is required to jolt settled minds into a vision of what is possible.

At first glance what we are about to present may appear impossible. Indeed, this is the way people reacted at first to Jay Forrester's analysis of the urban decay problem (Forrester, 1989, p. 8, italics added):

> The conclusions of our work were not easily accepted. I recall one full professor of social science in our fine institution at MIT coming to me and saying, *"I don't care whether you're right or wrong, the results are unacceptable."* So much for academic objectivity! Others, probably believing the same thing, put it more cautiously as, *"It doesn't make any difference whether you're right or wrong, urban officials and the residents of the inner city will never accept those ideas."*

As one example of a new way of thinking about systemic instead of individual change resistance, as well as digging down to root causes instead of intermediate causes, consider anticipated net loss per proper practice in Figure 3. *Why is this so high?*

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Over the last few centuries the modern corporation has become ubiquitous, especially in advanced economies. A productive way to view this institution is as a memetic life form (Dawkins, 1976, ch. 11: Memes, the new replicators) that follows the same high-level principles of behavior that genetic life forms do.

An abundance of literature (Beder, 2006b; Hartmann, 2002; Korten, 2001; Nace, 2003; Reich, 2007), along with the obvious influence of corporate industrialization on the course of civilization, suggests large for-profit corporations are now *the* dominant life form in the biosphere. The corporate life form's goal is to maximize the net present value of profits, while the goal of *Homo sapiens* is to optimize quality of life for those living and their descendents, which includes protecting the environment on which we depend for life. *These goals are mutually exclusive*, which causes a high anticipated net loss per proper practice for large for-profit corporations. We have thus found one possible root cause, one so pervasive it provides a steady drip, drip, drip that erodes even the best-intentioned efforts to solve common good problems like sustainability.

It's tempting to call this a root cause of change resistance. But it's more accurate to see it as *a root cause of improper coupling*. If the goals of the corporate life form and humans were not mutually exclusive, then the economic system (which corporations dominate) would be properly coupled to the human system and hence the environment.

The related high leverage point is *the rules of the game for the dominant agent in the system*. Let's imagine the modern corporation was reengineered to be a trusted servant of *Homo sapiens*, as was the original intention (Hartman, 2002, ch. 5: The early role of corporations in America). Its new goal would be serving its master as its highest priority, by optimizing components of quality of life as stated in its charter. Some would be general and some would be specific to each corporation, such as optimizing people's health by manufacturing food. Goal achievement would be measured by a *contribution to sustainable quality of life index*. If society cannot provide this index, then we have created a servant without a clear and correct mission. (See Robeyns and van der Veen, 2007, for a "conceptual analysis" of a general "sustainable quality of life" index.)

Such an index would be expressed in percent of goal achieved. A negative amount means a company performed so poorly it should be penalized. Over 100 percent indicates expectations were exceeded. The index would be calculated by each company as part of normal accounting. Using a strategy similar to public utility incentives that decouple profit increases from undesirable behavior, Figure 9 shows how a company's index could be used to calculate percent of net income eligible for retained earnings and dividends.[4] This would cause the sustainable quality of life motive to have a much higher priority than the profit motive. While no index is perfect, a well-designed index would reflect the approximate interests of all major stakeholders. Optimizing stakeholder interests would require such high levels of cooperation that corporate servants will now *constructively cooperate* to achieve quality of life goals, as they transition away from *destructively competing* to maximize shareholder profit.

This is a rough exploratory example. Deeper analysis and extended experimentation will be needed.[5] The index can start simple. Instead of an index other approaches like the Triple Bottom Line (Savitz, 2006) could be used. The new goal must be as simple, unambiguous, measurable, and motivating as the one it replaces: profit maximization.[6] Otherwise it will not have the intended effect.

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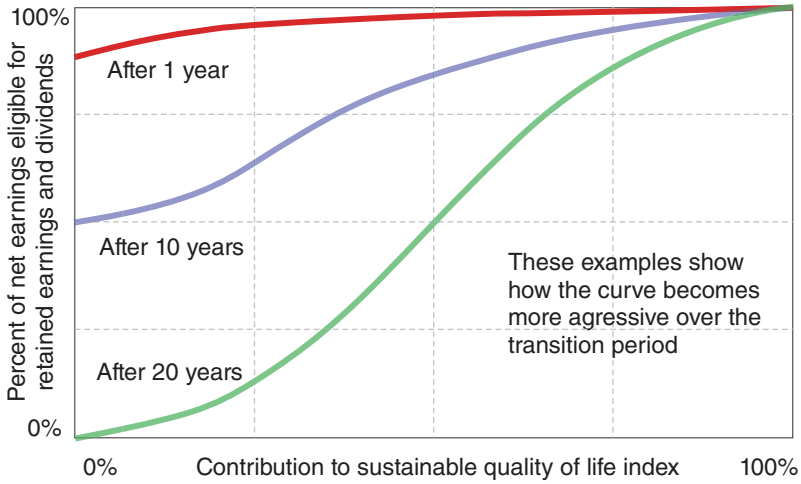

Fig. 9. Sustainable quality of life incentive curve. The new profit calculation could be as simple as: incentive curve (index) × net income = retained earnings and dividends. At first the curve would allow almost 100 percent of normal profits regardless of index results. Over the transition period from Corporation 1.0 to 2.0 the curve would fall to gradually have the desired effect

Goal redesign would give us Corporation 2.0 and could be introduced on a gradual basis, say 10–20 years, so as to not overly shock the system. *All that really matters are the core motivational factors, because they create the feedback loops that drive behavior toward the correct "implicit system goal."* Get the key factors right and the rest will automatically work itself out, because Corporation 2.0 can have the responsibility of continuous self-improvement.

A dominant life form's goal is such a high leverage point that once corporations are on a virtuous cycle of self-improvement, corporate and human goals will become so well aligned that intermediate causes of past misbehavior will automatically be resolved. There will be little need to use symptomatic solutions to push on low leverage points associated with intermediate causes like the influence of corporate money on politics, limited liability, unlimited lifespan, corporate personhood, and lack of employee or community ownership/control. (Corporate redesign efforts are vast and embryonic. See Corporation2020.org and UNGlobalCompact.org for starting points.)

Solving common good problems, because this advances the goal of *Homo sapiens*, would now *benefit* 2.0 corporations. Their anticipated net loss would be zero, causing the change resistance ratio to fall to near zero in industrialized nations. Furthermore, the force available to resist change from corporations would be transferred to the force available to solve all problems. This would have the effect of solving the sustainability problem in the fastest and most efficient manner reasonably possible. Imagine what it would be like for large corporations to work as hard *to solve* the sustainability problem as they have worked in the past to *not* solve it. (For a book-length review of how hard they have worked to not solve it, see Beder, 2002.) Furthermore, think how hard 2.0 corporations would work to avoid other problems like war, institutional poverty, and economic bubbles,[7] because these too cause their masters to suffer.

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This distant but pleasant alternative can be modeled. First let's raise the deception effectiveness to a more realistic level of 40 percent to see how bad change resistance probably really is, and turn off the wakeup call catastrophe.

Run 6 shows adoption cost now spikes so high so fast that Adopted Proper Practices never grow to more than about 15 percent of what's needed to solve the problem. This approximates the very low level of proper practices adopted so far. WCCs now fail to solve the problem, no matter how big they are or what year they occur in. This too approximates the fact that the recent WCC emissions data mentioned earlier did not trigger problem solution.

It's been about 200 years since the "cause" of the sustainability problem (the Industrial Revolution, which greatly accelerated IPAT growth), so let's see what happens if the world switches to Corporation 2.0 in year 200 (with no transition delay for simplicity). In run 7 we assume that half the force resisting change comes from for-profit corporations, which is a conservative estimate. In year 200 half the normal force available to resist change suddenly switches to the normal force available to solve all problems. No change is made to anticipated net loss per proper practice, since that's needed for the adaptive response of other agents resisting change, such as a multitude of developing countries.

Run 7 is just what we need. Adoption cost starts falling immediately. After a slight delay Adopted Proper Practices soar. The maintenance budget is triggered in about 30 years and humanity at last enters the Age of Transition to Sustainability.

Resolving the root cause of change resistance

The reader should review the key assumptions run 7 depends on and verify they are reasonably sound before concluding, as we have, that run 7 is realistically possible—*if* we can overhaul the design of the modern corporation.

That's a big if, because there will be strenuous resistance from the corporate life form to loss of dominance. Large for-profit corporations now control so much of the system that it's they who overwhelmingly influence legislation on their own definition, not people. Activists cannot suddenly say "Please change your charter to Corporation 2.0" and expect corporations and their many supporters to oblige, as demonstrated by the failure of Corporate Social Responsibility (CSR) efforts to have any more than minor impact. (For why CSR fails see Reich, 2007, ch. 5.) How then are we going to push on the high leverage point of changing the goal of the dominant agent if we can't push *directly*? Where is the root cause of change resistance to corporate redesign, so we can push *indirectly*?

The root cause appears to be deception effectiveness high enough to thwart, weaken, or delay changes that run counter to the goal of the corporate life form. Earlier we explained how selfish special interests rely on deception to combat the truth. Deception creates mistaken or false beliefs/values that become premises for further beliefs and/or actions. The more impact a belief causes and the more people who believe it, the greater the total impact. Over the last several centuries two high-impact beliefs have emerged that deserve special attention:

- **Belief 1: corporations are good.** The modern corporation is benevolent and essential to society's wellbeing. We should not change a good thing.

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- **Belief 2: growth is good.** The higher economic growth and the stock market are, the better life will be for people, because gross domestic product (GDP) and the stock market are the best overall indicators of a nation's wellbeing.

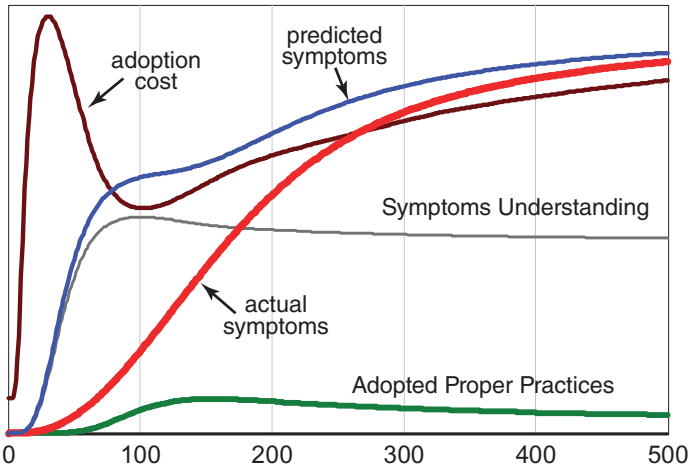

Fig. 10. Run 6: change resistance, effectiveness = 40 percent

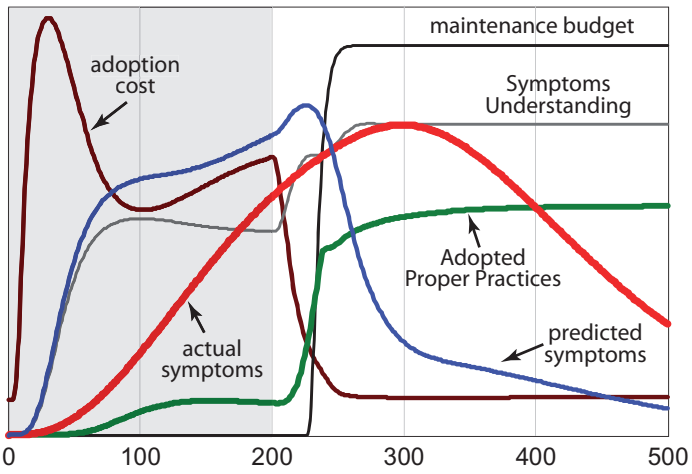

Fig. 11. Run 7: corporation 2.0 introduced in year 200

These are the fundamental axioms behind the dominant paradigm of our age: that free markets, driven by the invisible hand of corporate competition, offer citizens the best of all possible material worlds, regardless of whether a nation is democratic, theocratic, or socialist. (See, for example Reich, 2007, p. 7, who labels this global paradigm "supercapitalism" and argues it has replaced democratic capitalism.) The first belief has

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become so accepted that in 1925 President Calvin Coolidge pronounced that, "The chief business of the American people is business" (Coolidge, 1925). The success of the second may be measured by the prevalence of GDP and stock market index news versus news on quality of life indexes. The former outweighs the latter by several orders of magnitude.

Both beliefs are only half true, however: (1) It's true that corporations are helpful, but it's not true they are providing humans with a net benefit, because wittingly or unwittingly, they are leading the drive against sustainability (Beder, 2002). While something like corporations are essential, their exact definition can be changed. Thus it is only the production role of corporations that is essential, not the way they are currently defined. (2) Higher economic growth benefits corporations via greater sales and profits. It also benefits people by raising our standard of living. But as the inventor of GDP, Simon Kuznets, observed, "The welfare of a nation [can] scarcely be inferred from a measure of national income" (Kuznets, 1934, p. 7). GDP does not measure quality of life once survival and security are assured. Nor does the stock market, which is really more of a shrewd ploy to get as many people as possible to support the goals and behaviors of corporations (Beder, 2006a, ch. 12: Shareholder democracy). Thus both beliefs are fallacious.

But yet modern culture believes both beliefs are true. So true that the worst thing that can happen to a country, short of war, is a recession or depression. Growth must be continued at all costs. Economic growth and technological advances solve all problems, so the mantra goes. But as models like Forrester's World2 showed long ago, this is false. That doesn't matter, however, because deception effectiveness is high enough to convince most of the public, press, and politicians that solving economic problems has a higher priority than solving environmental problems. For the latest proof, look at the world's response to the financial meltdown of 2008, and compare that to the response to the *Stern Review* of 2006 and the fourth IPCC report of 2007.

We have found the possible root cause behind the success of systemic change resistance: high deception effectiveness. Now then, where is the related high leverage point so we can resolve that root cause?

Ever since the Age of Reason in the 17th century, educated people have prided themselves on building theories and making decisions based on reason, rather than intuition, tradition, emotion, or ideology. They don't do it perfectly, but they make reasonable decisions. They suffice.

The model shows how those promoting their own agenda with deception effectiveness have found a way to make history run backward. They have found a way to reliably fool most people into acting against their own best interests, creating a sort of Age of Unreason, whose ultimate end is rapidly becoming mass ecocide. (See for example Frank, 2004, which tries to fathom why people in Kansas consistently vote against their own economic and social interests.)

But history could move forward again if we could push on the related high leverage point of *general ability to detect manipulative deception* (not shown). This can be done many ways, such as: universal education on how to detect common fallacies by something as simple as the Truth Test, which would lead to truth literacy and is just as vital to the health of democracy as reading literacy (see Table 3); independent political truth rating organizations like FactCheck.org, except they would rate politicians over their entire careers to arrive at average truth ratings; corporate environmental responsibility

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Table 3. The truth test

1. What is the argument?
2. Are any common patterns of deception present?
3. Are the premises true, complete, and relevant?
4. Does each conclusion follow from its premises?

The truth test is a simple test designed to tell whether a statement is true, false, or just plain nonsense. This allows voters to tell reality from illusion. They can then answer the question every democracy depends on: Is this truth or deception?
By using pattern recognition you can determine the truth of most political appeals in little more than the time it takes to hear or read them. All that is required is to learn the patterns.
From TruthTest.org [retrieved 20 March 2009].

ratings, at the level of individual corporations, industries and 1.0 versus 2.0 corporations; quality of life and sustainability indexes; and the many more ways activists will discover as they start pushing on this high leverage point.

For example, in 1999 the U.S. Senate voted 95 to zero to reject the Kyoto Protocol, despite a democratic President and a strongly pro-environmental Vice President, Al Gore. The rationale was that "Developing Country Parties" were not included and the treaty "would result in serious harm to the economy" (www.nationalcenter.org/KyotoSenate.html, retrieved 3 March 2009). If the above solution had been in place people, the press, and politicians would have seen this as a blatantly unsound argument for at least three reasons: (1) Stated plans were that developing nations would be included later, and should not be included at first because the bulk of emissions came from developed nations. (2) Whatever harm a solution causes now will be much less than the harm occurring later if the problem remains unsolved. (3) "Serious harm" was an unproven overstated bogeyman and had been a common but false justification of similar previous resistance.

Currently *general ability to detect manipulative deception* is abysmally low. But as it starts to rise, deception effectiveness will start to fall. *Soon it will fall so low the majority of the population will see right through the two fallacious beliefs and many more.* Pilot Corporation 2.0 programs can then be tried and legislation for a transition to Corporation 2.0 passed, eventually at the international level, and scenarios like run 7 can become reality instead of one more pipe dream.

What about developing countries? Isn't their change resistance a major factor that must also be considered?

Less developed countries and industrialized ones have fallen under the same alluring spell: economic growth is good and nothing else matters nearly as much. This highly infective and addictive meme is spread by the corporate life form and ingrained into the global system. Conversion to Corporation 2.0 will remove the tendency to spread this destructive meme and replace it with the urge to spread a beneficial one, such as the concept of moving from growth and efficiency to sufficiency (Princen, 2005). This is the same as "There are two possible routes to affluence. Either produce much, or desire little" (Anon.).

Figure 12 summarizes how this example of systemic root cause resolution could work. The leverage chain threads its way through the system in a manner that allows the relatively small force of public interest activists to be sufficient to solve the problem pro-

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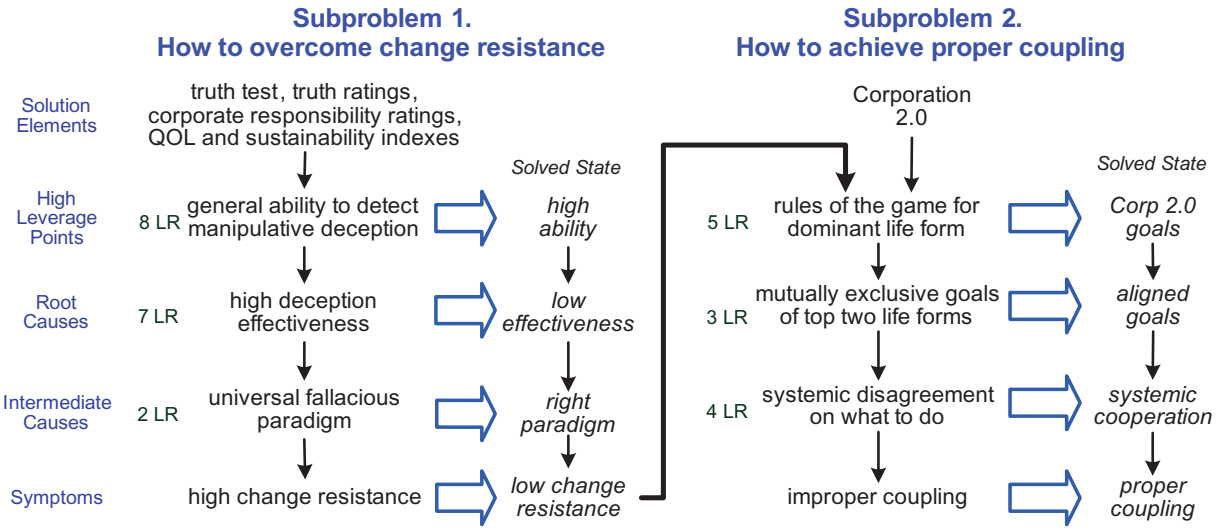

Fig. 12. A leverage chain perspective. Block arrows represent state changes over time. Line arrows are influences. Not shown are the feedback loops essential to keep change resistance in the solved state

actively. The output of solving subproblem 1 becomes *the* critical solution element for solving subproblem 2. Because of aligned goals the system is at last self-organizing in the right direction, which quickly leads to proper coupling.

The leverage ratings (LR) come from Donella Meadows' scale of leverage in Table 1 and are only relative rankings. The lower the number, the higher the leverage. Cooperation is not explicitly mentioned in the scale, but probably rates a 4. If evolution of the system toward proper coupling becomes driven by the right universal paradigm, then the chain as a whole would rate a 2.

As radical as the above may seem, it pales in comparison to what it took to solve the age-old problem of the arbitrary and often horrific rule of dictators, kings, warlords, despots and other oppressive rulers. The solution was inconceivable long ago but is intuitively obvious today: the addition of the voter feedback loop. This could also be called the ruler benevolence feedback loop.

Is the system missing the *corporate* benevolence feedback loop?

Summary and Implications

Change resistance versus proper coupling allows a crucial distinction. Society is aware of the proper practices required to live sustainably and the need to do so. But society has a strong aversion to adopting these practices. As a result, problem solvers have created thousands of effective (and often ingenious) proper practices. But they are stymied in their attempts to have them taken up by enough of the system to solve the problem because an "implicit system goal" is causing insurmountable change resistance. *Therefore systemic change resistance is the crux of the problem and must be solved first.*

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But that is not what environmentalists are doing.

Instead, in every case I've examined so far, problem-solving organizations, from the Sierra Club and the Club of Rome all the way up to the United Nations Environmental Programme and the European Union Environmental Directorate General, are trying to solve only the *proper coupling* part of the problem. The same holds true for researchers. I have yet to find a single individual or organization focusing on the *systemic* change resistance part of the problem, though there must be some. **This shows that problem solvers have spent the last 30 years trying to solve the wrong problem, which is a striking conclusion that should send shockwaves throughout all of environmentalism.**

Consider the old saying "You can lead a horse to water but you can't make him drink." Problem solvers have been working on finding the water (finding proper practice solutions) and leading horses to it (promoting those solutions and tediously putting them under each horse's nose, which is the strategy of changing one mind at a time). But that is not working. What they should be working on instead is *how to get all the horses to simultaneously decide to drink*.

A recent article in *Science* observed that "The civil rights movement provides a better analogy for the climate challenge. Then, as now, *entrenched special interests vigorously opposed change.*" The piece ended with:

> Of course, we need more research and technical innovation—money and genius are always in short supply. But there is no purely technical solution for climate change. For public policy to be grounded in the hard-won results of climate science, *we must now turn our attention to the dynamics of social and political change*. (Sterman, 2008, italics added)

Could this be the next frontier of system dynamics?

Notes

1. The IPAT equation is a simplification of the three factors causing environmental degradation: environmental **I**mpact = **P**opulation × **A**ffluence (consumption per person) × **T**echnology (impact per unit of consumption).
2. By "complete" we mean the top 11 of the 34 issues identified in the Scientific Committee on Problems of the Environment (SCOPE) study, as summarized in the UNEP's Global Environment Outlook 2000 on page 339. We have removed non-environmental degradation symptoms like "poor governance" and "changing social values" because these are potential causes, not symptoms. In order of importance the top 11 are climate change, freshwater scarcity, deforestation and desertification, freshwater pollution, loss of biodiversity, air pollution, soil deterioration, ecosystem functioning, chemical pollution, stratospheric ozone depletion, and natural resource depletion. To date only one of these, ozone depletion, has been solved. If we can solve the top 11 problems we can solve them all. See unep.org/geo2000.
3. We've not found a measurement of general political deception to prove this assertion, but observe system behavior: Think back to any important political decision, whether it was who to elect, what position to support, which party to support, or even what long-term values people should adopt. Of the arguments presented by those trying to influence these decisions, how many were neutral and factual and how many were

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biased and employed rationalizations, fallacies, or outright lies? My own personal estimate is that over 90 percent fall into the second category, because most parties to a political issue are driven by the competitive need to bend the facts and reasoning to suit their own interests. But don't take my word alone for this:

"We live in a world of spin. It flies at us in the form of misleading commercials for products and political candidates and about public policy matters. It comes from business, political leaders, lobbying groups, and political parties. Millions are deceived every day…'Spin' is a polite word for deception" (Jackson and Jamieson, 2007, pp. vii–viii).

"…the history of politics and public opinion in this century can be written in terms of the uses of often deceptive public relations techniques to 'engineer consent' among the governed" (Bennett and Entman, 2000, p. 282).

"The conscious and intelligent manipulation of the organized habits and opinions of the masses is an important element in democratic society. Those who manipulate this unseen mechanism of society constitute an invisible government which is the true ruling power of our country" (the opening lines of *Propaganda*, by Edward Bernays, 1928). Bernays fathered what came to be known as public relations by pioneering techniques for the shaping and manipulation of public opinion, which he labeled the "engineering of consent."

In democracies, most political decision influence energy goes into discourse rather than force, political donations, bribes, etc. If a line of discourse carries favor with the majority of the target decision makers (politicians, voters, reporters, etc.) it usually wins. From this we conclude that "deception appears to play the largest role in influencing political decision making."

4. The non-eligible portion might go to areas like public costs for the index program, helping those hurt by that company's low level of performance, R&D on proper practices, assistance to firms in developing countries, etc. Negative or low indexes would serve as a survival of the fittest gate. Over 100 percent might lead to awards, a share of the non-eligible portion of other corporations, a "surplus fund" to offset future shortfalls, etc. Perverse incentives must be avoided.

   Corporate servant indexes would be included in advertisements and printed on product packaging and literature, so that customers could make more informed decisions. This is a critical new feedback loop.
5. "A recent survey of empirical applications shows that at present, no scholar even has worked out the theoretical foundations of a capability-index of life quality, let alone engaged in the work of operationalizing and testing empirically such a quality index. Thus in the prevailing state of the art, developing a capability-index is a pioneering task" (Robeyns and van der Veen, 2007, p. 57). But so was inventing modern democracy.

   Index calculation is complex, potentially expensive, and fraught with subjective opinion. The index as described may be unworkable. Thus the index and other changes are intended only as a placeholder example. But if we keep it simple at first, there is a way forward.
6. About replacing profit maximization: please don't interpret this to mean we are saying profits are bad. In a modern economy, corporate profits are as necessary as the people profits employees make from selling their labor. It is only the blind or overly selfish pursuit of profit that is harmful.

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7. For example, the immediate causes of the meltdown of 2008 were (roughly) the huge amount of mortgages and other loans that should never have been made, loan resales (which thwarted a key feedback loop), unreliable ratings, and the unhealthy capital ratios of large financial institutions, all mostly in the U.S.A. and Europe. The cause of that was insufficient regulation. The cause of that was the profit motive of 1.0 corporations, which caused them to promote lax regulation and to compete to find evermore exotic ways to keep short-term profits growing, no matter what problems that might cause later.

   See www.nytimes.com/2008/12/20/business/20nocera.html for how one nation, India, avoided these mistakes by not allowing their banking system to be controlled by corporate interests. "Unlike Alan Greenspan, who didn't believe it was his job to even point out bubbles, much less try to deflate them, Mr. Reddy saw his job as making sure Indian banks did not get too caught up in the bubble mentality."

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Biographies

Jack Harich is a systems engineer, BS ISyE Georgia Institute of Technology. After 20 years of small business management and consulting, in 2001 he founded Thwink.org in order to help solve the global environmental sustainability problem and began work as an independent researcher. His work focuses on the importance of process in solving difficult social problems, a comprehensive process-driven analysis of the complete problematique of the sustainability problem, and practical applications of theoretical insights. He is most alive when tinkering with the invisible, the indescribable, and the insolvable.

References

Beder S. 2002. *Global Spin: The Corporate Assault on Environmentalism*. Chelsea Green: London.

Beder S. 2006a. *Free Market Missionaries: The Corporate Manipulation of Community Values*. Earthscan: London.

Beder S. 2006b. *Suiting Themselves: How Corporations Drive the Global Agenda*. Earthscan: London.

Bennett WL, Entman R. 2000. *Mediated Politics: Communication in the Future of Democracy*. Cambridge University Press: Cambridge, UK.

Coolidge C. 1925. Speech to the American Society of Newspaper Editors, 17 January 1925. Available: en.wikiquote.org/wiki/Calvin_Coolidge.

Costanza R, Cumberland JH, Daly H, Goodland R, Norgaard RB. 1997. *An Introduction to Ecological Economics*. St Lucie Press: Boca Raton, FL.

Dawkins R. 1976. *The Selfish Gene*. Oxford University Press: Oxford.

Dent E, Goldberg S. 1999. Challenging resistance to change. *Journal of Applied Behavioral Science* **35**(1): 25–41.

DOI: 10.1002/sdr

Dunlap RE, Van Liere KD, Mertig AG, Jones RE. 2000. Measuring endorsement of the new ecological paradigm: a revised NEP scale. *Journal of Social Issues* Fall. Available: findarticles.com/p/articles/mi_m0341/is_3_56/ai_69391496.

Forrester J. 1971. *World Dynamics*. Wright-Allen Press: Cambridge, MA. Now available from Pegasus Communications, Waltham MA.

Forrester J. 1989. The beginning of system dynamics. Banquet talk at the *International Meeting of the System Dynamics Society*, 13 July 1989.

Frank T. 2004. *What's the Matter with Kansas?* Owl Books: New York.

Hartmann T. 2002. *Unequal Protection: The Rise of Corporate Dominance and the Theft of Human Rights*. Rodale: Emmaus, PA.

Jackson B, Jamieson K. 2007. *UnSpun: Finding Facts in a World of Disinformation*. Random House: London.

IPCC. 2007. *Fourth Assessment Report. Climate Change 2007: Synthesis Report. Summary for Policymakers*. Available: www.ipcc.ch/pdf/assessment-report/ar4/syr/ ar4_syr_spm.pdf. Access date April 8 2009.

IPCC. 2009. www.ipcc.ch/publications_and_data/publications_and_data.htm. Access date August 24 2009.

Jackson T. 2005. *Motivating Sustainable Consumption: a review of evidence on consumer behavior and behavioral change.* Sustainable Development Research Network. Available: www.compass-network.org/images/upload/MotivatingSCfinal.pdf [10 August 2009].

Korten D. 2001. *When Corporations Rule the World*. Kumarian Press: Sterling, VA.

Kuhn T. 1996. *The Structure of Scientific Revolutions* (3rd edn). University of Chicago Press: Chicago, IL.

Kuznets S. 1934. *National Income, 1929–1932*. 73rd US Congress, 2nd session, Senate document no. 124.

McCormick J. 1989. *Reclaiming Paradise: The Global Environmental Movement*. Indiana University Press: Bloomington, IN.

Meadows DH, Meadows DL, Jorgen R, Randers J. 1972. *The Limits to Growth*. Potomac Associates: Washington, DC.

Meadows DH, Meadows DL, Jorgen R, Randers J. 2004. *Limits to Growth: The 30-Year Update*. Chelsea Green: London.

Nace T. 2003. *Gangs of America: The Rise of Corporate Power and the Disabling of Democracy*. Berrett-Koehler: San Francisco, CA.

Princen T. 2005. *The Logic of Sufficiency*. MIT Press: Cambridge, MA.

Reich R. 2007. *Supercapitalism: The Transformation of Business, Democracy, and Everyday Life*. Vintage Books: New York.

Robeyns I, van der Veen RJ. 2007. *Sustainable quality of life: Conceptual analysis for a policy-relevant empirical specification.* Netherlands Environmental Assessment Agency. Available: www.pbl.nl/en/publications/2007/Sustainablequalityoflife.html [10 August 2009].

Rooney J, Heuvel L. 2004. *Root Cause Analysis for Beginners*. Quality Progress, July 2004. Available: www.asq.org/pub/qualityprogress/past/0704/qp0704rooney.html [10 August 2009].

Savitz A. 2006. *The Triple Bottom Line*. Jossey-Bass: San Francisco, CA.

Senge P. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. Currency Doubleday: New York.

Shellenberger M, Nordhaus T. 2004. *The Death of Environmentalism*. A widely available essay released at the October 2004 meeting of the Environmental Grantmakers Association.

Speth JG. 1992. The transition to a sustainable society. *Proceedings of the National Academy of Sciences, USA* **889**: 870–872. February 1992. Available: www.pnas.org/content/89/3/870.full.pdf [10 August 2009].

Sterman J. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* McGraw-Hill: New York.

DOI: 10.1002/sdr

Sterman J. 2008. Risk communication on climate change: mental models and mass balance. *Science* **322**(5901): 532–533.
Stern N. 2006. *Stern Review on the Economics of Climate Change*. Available: www.hm-treasury.gov.uk/d/Executive_Summary.pdf [10 August 2009].
World Commission. 1987. Our Common Future. Oxford University Press: Oxford and New York.

Appendix: model availability and equations

The simulation model may be downloaded from the online version of this article or Thwink.org. A free version of Vensim PLE capable of running and editing the model may be obtained from www.vensim.com/freedownload.html.

adoption delay = 20 years
allocation to discovery = 5%
allocation to magnify = 30%
allocation to promotion = 10%
anticipated net loss per proper practice = 100 $/practice
APP lifetime = 50 years
awareness cost = 50 $/practice
awareness delay = 10 years
budget implementation delay = 10 years
catastrophe duration = 10 years
catastrophe size = 0 QOL units/year
catastrophe start year = year 70
competing net loss of other problems = $10,000
competing unsolved problems = 500 QOL units/year
cost reduction for 100% understanding = 70%
deception effectiveness = 0%
discovery delay = 5 years
effect delay = 3 years
force erosion per symptom unit = 70 $/QOL unit
force needed for maintenance budget = 6000 $/year
max discovery cost = 300 $/practice
maximum adoption unit cost = 5000 $/practice
maximum problem impact = 100 QOL units/year
memory lifetime = 2 years
normal force available to solve all problems = 10,000 $/year
normal force available to resist change = 50,000 $/year
one year = 1 year
overemphasis on recent events percent = 50%
percent solved budget threshold = 40%
proper practices needed for solution = 100 practices
resistance delay = 10 years
solution delay = 30 years
symptoms delay = 200 years
understanding delay = 10 years
understanding lifetime = 50 years

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All stocks are calculated by integrals of inputs minus outputs.

actual symptoms = DELAY3I (intermediate causes, symptoms delay, intermediate causes – intermediate causes) + wakeup call catastrophe
adoption cost adoption unit cost curve (change resistance ratio) × maximum adoption unit cost × effect of catastrophe on adoption cost
adoption rate = MIN (magnify the truth/(adoption cost × (1 – cost reduction)), Well Known Proper Practices/one year)
allocation to understanding = MAX (0, 1 – (allocation to discovery + allocation to magnify + allocation to promotion))
anticipated net loss to affected agents = anticipated net loss per proper practice × (Discovered Proper Practices + Well Known Proper Practices)
awareness rate = MIN (promote the truth/(awareness cost × (1 – cost reduction)), Discovered Proper Practices/one year)
change resistance ratio = DELAY3I (force committed to resisting change × deception effectiveness/magnify the truth, resistance delay, 0)
cost reduction = Symptoms Understanding × cost reduction for 100 percent understanding
discover the truth = DELAY3 (force committed to solving this problem × allocation to discovery, discovery delay)
discovery cost = discovery cost curve (total proper practices/proper practices needed for solution) × max discovery cost × (1 – cost reduction)
discovery rate = discover the truth/discovery cost
effect of catastrophe on adoption cost = DELAY3I (MAX (0, XIDZ (actual symptoms – inflated catastrophe, actual symptoms, 1)), effect delay, 1)
force available to resist change = MAX (0, normal force available to resist change – (actual symptoms × force erosion per symptom unit))
force available to solve all problems = MAX (0, normal force available to solve all problems – (actual symptoms × force erosion per symptom unit))
force committed to resisting change = force available to resist change × motivation to resist solving problem
force committed to solving this problem = (force available to solve all problems × motivation to solve problem) + maintenance budget
forget it's important rate = Well Known Proper Practices/memory lifetime

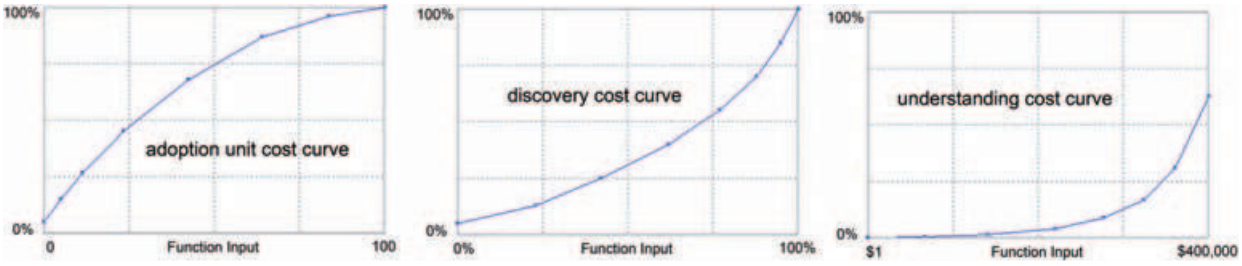

Fig. 13. Lookup tables

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inflated catastrophe = PULSE (catastrophe start year, catastrophe duration × (1 + overemphasis of recent events percent)) × catastrophe size × (1 + overemphasis of recent events percent)
intermediate causes = DELAY3I (1 − percent of problem solved, solution delay) × maximum problem impact
magnify the truth = DELAY3 (force committed to solving this problem × allocation to magnify, adoption delay)
maintenance budget = DELAY3 (IF THEN ELSE (percent of problem solved ≥ percent solved budget threshold, force needed for maintenance budget, 0), budget implementation delay)
motivation to resist solving problem = anticipated net loss to affected agents/(anticipated net loss to affected agents + competing net loss of other problems)
motivation to solve problem = unsolved predicted symptoms/(unsolved predicted symptoms + competing unsolved symptoms)
obsolescence rate = Adopted Proper Practices/APP lifetime
predicted symptoms = (Symptoms Understanding × intermediate causes) + ((1 − Symptoms Understanding) × actual symptoms)
promote the truth = DELAY3 (force committed to solving this problem × allocation to promotion, awareness delay)
SU growth rate = DELAY3 (SU work start rate, understanding delay)
SU work start rate = (force committed to solving this problem × allocation to understanding)/understanding cost
total proper practices = Discovered Proper Practices + Well Known Proper Practices + Adopted Proper Practices
understanding cost = understanding cost curve (SU Work In Progress + Symptoms Understanding)
understanding loss rate = Symptoms Understanding/understanding lifetime
unsolved predicted symptoms = (1 − percent of problem solved) × predicted symptoms
wakeup call catastrophe = PULSE (catastrophe start year, catastrophe duration) × catastrophe size

adoption unit cost curve = [(0,0)-(100,1)], (0,0.05), (5,0.15), (11.5,0.27), (23.5294,0.448399), (42.5882,0.679715), (64,0.864769), (83.7647,0.960854), (100,1)
discovery cost curve = [(0,0)-(1,1)], (0,0.05), (0.23,0.13), (0.42,0.25), (0.62,0.4), (0.77,0.55), (0.88,0.7), (0.95,0.85), (1,1)
understanding cost curve = [(0,0)-(1,400000)], (0,1),(0.167059,1779.36), (0.352941,6049.82), (0.55,17000), (0.694,36300), (0.809412,68327.4), (0.9012,124000), (1,250000)

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