Adding a change resistance layer to integrated system models using root cause analysis and problem decomposition

Abstract

Inspired by the iconic World2 and World3 system dynamics models, why has a long series of increasingly sophisticated integrated system models (ISMs), such as Threshold21, DICE, and iSDG, largely failed to lead to successful solution of the environmental sustainability problem, as epitomized by the climate change crisis? The paper proposes the main reason is these models suffer from a boundary problem, by excluding the critical component of political system change resistance and its root causes. To begin the conversation for filling this gap, the paper presents a submodel to demonstrate how a change resistance layer can be added to an ISM, using World3 as an example. Scenario policy changes now go through the layer, which provides the necessary resistance. The use of root cause analysis and problem decomposition to create an effective layer is described.

Illuminating a critical opportunity

A long series of system-dynamics-based ISMs (World2, World3, and successors, as described by (Pedercini et al., 2020)), has failed to led to successful solution of the environmental sustainability problem. Yet in theory, system dynamic modeling should be able to solve this problem (or any difficult large-scale social problem). Models with "aggregated human actions" as well as other aggregated behaviors "are at least potentially better representations that any others" for solving social system problems (D. Meadows, 1980, p. 26). Social scientists do not seek perfect solutions, but those good enough to bring system behavior up to an acceptable level that reasonably optimizes the common good.

Why has this theoretical potential not been achieved? A long series of increasingly more sophisticated models that began fifty years ago with World2 (Forrester, 1971) and continued with models like World3 (D. Meadows et al., 1972), the Triple Value Model (Fiksel, 2012), Threshold21 (Barney, 2002), DICE (Nordhaus, 2018), and iSDG and IFs (Pedercini et al., 2020), as well as global models focused on climate change, like C-Roads (Sterman et al., 2012), should have led to policies that mostly solved the environmental sustainability problem by now. Or they should have at least identified strategic insights that are on the verge of being operationalized into practical solutions. However, they have not.

ISMs have excelled in problem definition and input to goal setting, such as the Sustainable Development Goals and the Paris Agreement. There have even been some gains, like local pollution and solution of the stratospheric ozone depletion problem. However, "decades of scientific monitoring indicate that the world is no closer to environmental sustainability and in many respects the situation is getting worse" (Howes et al., 2017). Such lack of progress indicates something in the policy analysis portion of these models needs considerable improvement. Something fundamental is missing.

Business managers have long faced the same problem. Continually confronted with one novel difficult problem after another for centuries, business men and women invented thousands of new problem-solving tools and methods, and then refined them as necessary. While science gave the world the supremely powerful problem-solving tool of the scientific method (which solved the problem of how to create reliable new cause-and-effect knowledge), business gave the world equally powerful problem-solving innovations like double entry accounting (how to correctly manage financial planning), mass production (how to scale production to large volume), and root cause analysis (how to solve any causal problem).

Given that the sustainability problem is a causal problem, and that no ISM we are aware of employs explicit root cause analysis, we propose that *the* missing two tools for construction of ISMs are root cause analysis and one of its key tools, problem decomposition.

Without knowledge of a difficult problem's root causes, problem solvers tend to fall into the Superficial Solutions Trap. This occurs when people assume intermediate causes are root causes. It's a common trap, as Forrester (1971, p. 95) describes: (italics added)

> *The intuitively obvious 'solutions'* to social problems are apt to fall into one of several traps set by the character of complex systems. ...people are often led to intervene at points in a system where *little leverage exists* and where effort and money have but slight effect.
>
> ...social systems are inherently insensitive to most policy changes that people select in an effort to alter behavior. In fact, *a social system draws attention to the very points at which an attempt to intervene will fail*. Human experience, which has been developed from contact with simple systems, leads us to look close to the symptoms of trouble for a cause. But when we look, we are misled because the social system presents us with an *apparent cause* that is plausible according to the lessons we have learned from simple systems, although this 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's "apparent cause" is what root cause analysis calls the intermediate cause. "Little leverage exists" if problem solvers assume the apparent cause is the root cause, because that leads to pushing on low leverage points.

This, we hypothesize, is what has occurred with ISMs. Despite integration of natural and human components, these models have "drawn attention to the very points at which an attempt to intervene will fail." Policies based on ISMs have unfortunately largely failed, indicating modelers have unknowingly fallen into the Superficial Solutions Trap. These policies attempt, in vain, to resolve "apparent causes" instead of root causes, as did the four conventional urban management policies that Forrester (1969) analyzed with his urban dynamics model. Contrary to expectations, none made the problem better. Some, particularly the most popular solution of the four, low-cost housing, made the problem substantially worse, a profoundly counterintuitive discovery.

However, by including factors and feedbacks that had not been considered before, Forrester showed that high leverage point policies that had long been overlooked existed. Pushing on the system's high leverage points (such as with "demolition of slum housing and replacement with new business enterprise", p71) resolved the problem's root cause(s), which were "being produced by the feedback loop dynamics of a larger system."

The analogy just described, of the urban decay problem and model versus the environmental sustainability problem and ISMs, illuminates a critical opportunity and a means for achieving it. If ISM builders can innovate as Forrester did and enlarge their model boundaries to include factors containing the problem's main root causes, then the sustainability problem appears solvable.

The remainder of this paper addresses this opportunity. We begin with taming the extreme complexity of the sustainability problem by adapting the powerful business tool of RCA to fit social problems, which results in the RCA-based ISM modeling process. This is followed by using the process to construct a model that includes the missing change resistance layer and the root causes of that resistance. We end with discussion and conclusions.

Adapting the *business* tool of RCA to fit *social* problems

Root cause analysis (RCA) is the systematic practice of finding, resolving, and preventing recurrence of the root causes of causal problems. The RCA paradigm rests on several core concepts. Drawing from a diversity of sources, e. g. (Andersen & Fagerhaug, 2006; George et al., 2005; Ishikawa, 1986; Okes, 2019; Pyzdek, 2003; Tague, 2005), a root cause is the deepest cause in a causal chain (or the most basic cause in a feedback loop structure for more complex problems) that can be resolved. A causal problem occurs when problem symptoms have causes, such as illness or a car that won't start. Examples of non-causal problems are math problems, scientific discovery problems, information search/organization problems like criminal investigation, and puzzle solving. All causal problems arise from their root causes.

The sustainability problem is a causal problem. It can therefore only be solved by resolving its root causes, whether root cause terminology is used or not. RCA employs hundreds of supporting tools and techniques. RCA is generic and for difficult problem use must be wrapped in a process tailored to the problem class.

Strong definition of root cause

For the class of difficult large-scale social problems like sustainability, a strong definition of root cause is required: A root cause is that portion of a system's feedback loop structure that, using the checklist below, explains why the system's structure produces a problem's symptoms. The checklist allows numerous unproductive root causes (particularly intermediate causes posing as root causes) to be eliminated. The five requirements of a root cause are:

1. It is clearly a (or the) major cause of the symptoms.
2. It has no worthwhile deeper cause. This halts the asking of "Why did this occur? What is its cause?" at an appropriate point.
3. It can be resolved, by pushing on its high leverage point(s) to initiate the desired mode change in complex problems, or to merely change the node with the root cause in simple problems. (Mode change versus node change) Resolved means the problem will probably not recur due to that root cause.
4. Its resolution will not create other equal or bigger problems. Side effects must be considered.
5. There is no better root cause. All alternatives have been considered to the point of diminishing returns.

The first three requirements are from [reference omitted]. In the spirit of continuous process improvement, two more have since been added.

Social force diagrams

Figure 1 shows a customized form of RCA designed to fit difficult large-scale social problems, called social force diagrams. The standard terminology and concepts of root cause analysis are employed. The conceptual organization of the diagram encourages asking the right WHY questions. The strategy is to first learn from the past to construct the superficial layer. WHY did past solutions fail? That leads to the intermediate cause, confirmed by identification of the low leverage point and the superficial solutions that seemed promising, but have failed to solve the problem. Next one asks WHY does the intermediate cause occur? What is its deeper cause? That line of questioning will lead to penetration of the hard-to-see fundamental layer, where the root causes may be found. Resolving the root causes by pushing on high leverage points with fundamental solutions will initiate the desired mode change, causing the system to escape lock-in to the present undesired mode and rapidly self-evolve to the desired mode of behavior.

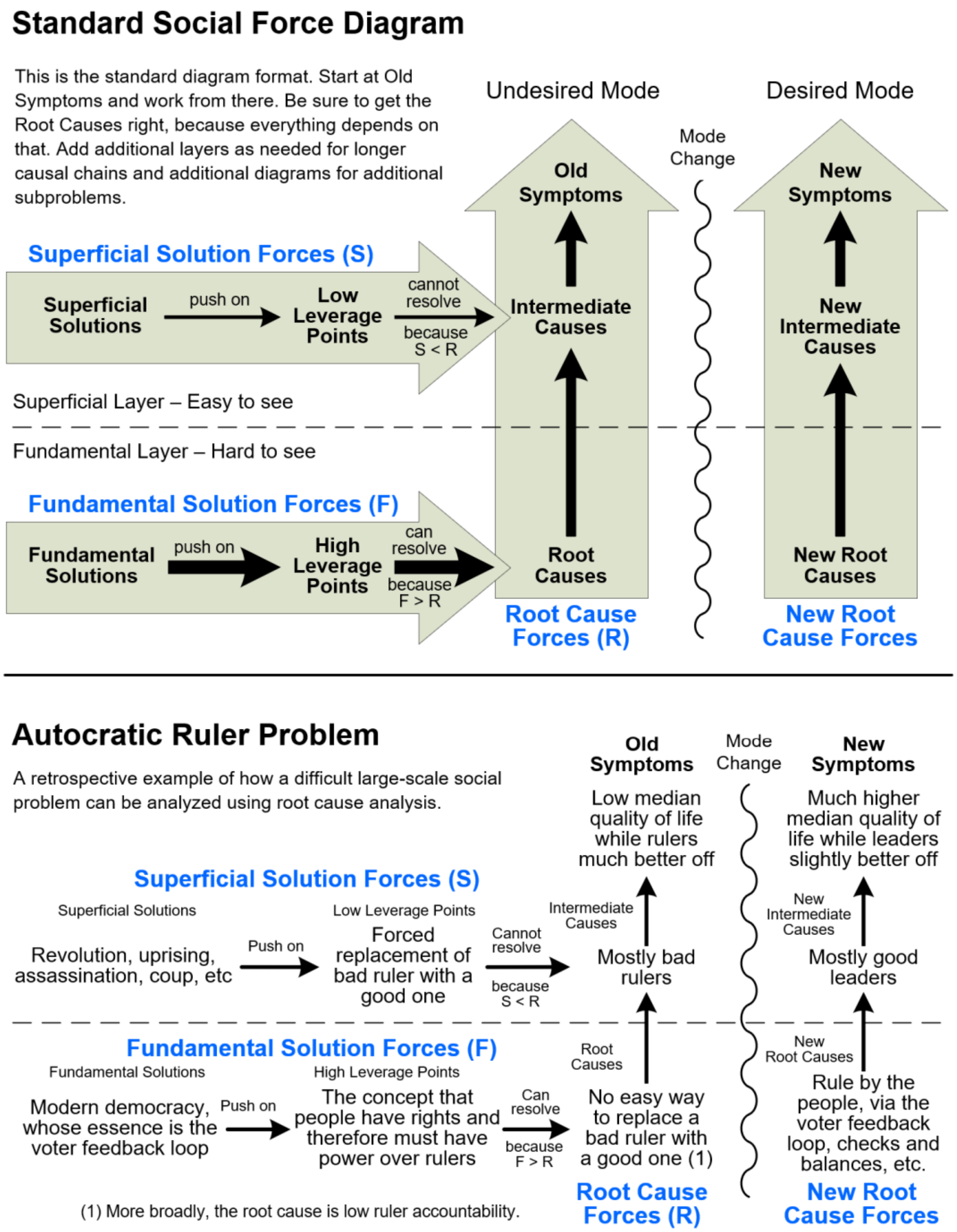

Figure 1. Standard social force diagram and an illustrative example. Use of standard terminology and the diagram organization shown greatly facilitates model construction and communication.

The central role of lock-in in the environmental sustainability problem has long been noted, most famously by Hardin (Hardin, 1968): “Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited." In difficult large-scale social problems (defined as those where serious solutions have failed for 25 years or more and involve political systems with millions or billions of people), some portion of the human system is locked into an undesirable mode and is unable to easily change to the desired mode. Lock-in occurs due to the unrelenting strength of a problem's dominant feedback loops. The desired mode change requires reengineering the system's feedback loop structure such that when force F is applied, a new root cause force R is created, and the system's current dominant feedback loops are replaced by new ones, causing the mode change to occur.

Problem decomposition into subproblems

In complex problems, typical RCA practice decomposes the one big original problem into smaller and hence easier to analyze subproblems. In our work on the sustainability problem, we found that without proper decomposition the problem was impossible to analyze, since difficult problems usually arise from multiple root causes. Each subproblem contains zero or more root causes. Without proper decomposition, the analyst falls into the trap of unknowingly attempting to analyze multiple problems and their root causes all at the same time.

The most efficient approach to problem decomposition is standard subproblems. For example, industry uses these standard subproblems, sometimes in the form of fishbone diagrams:

The four Ps of marketing: Product, Place, Promotion, Price (McCarthy, 1960).

The original four Ms of manufacturing: Materials, Methods, Machines, Measurement (Ishikawa, 1986, p. 19).

The nine Ms of quality control: Markets, Money, Management, Men, Motivation, Materials, Machines and mechanization, Modern information methods, Mounting product requirements (Feigenbaum, 1991, p. 59).

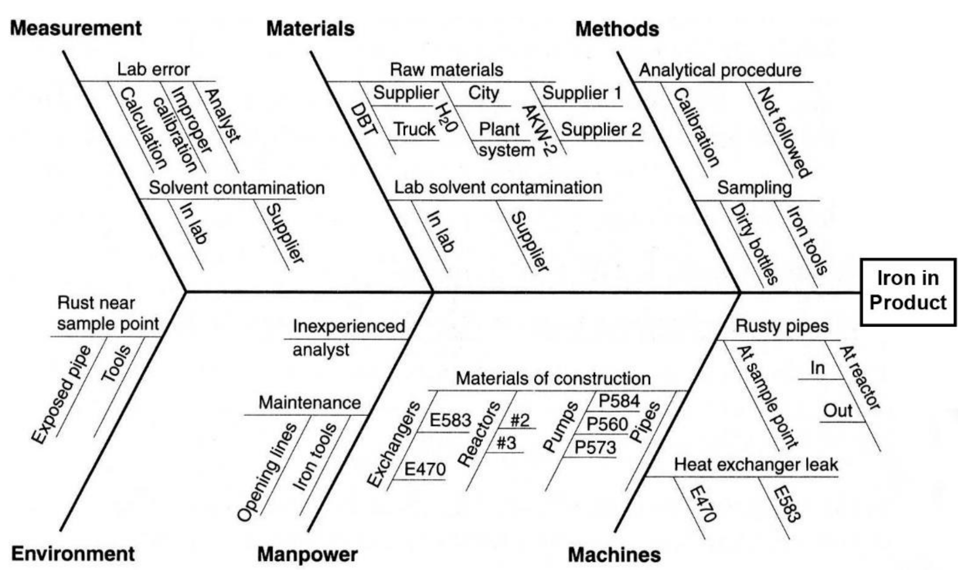

Figure 2. Fishbone diagram example using standard subproblems. Use of problem decomposition is so common in root cause analysis that fishbone diagrams are used for rapid analysis and to create simple causal diagrams. (Tague, 2005, p. 248)

For difficult large-scale social problems, we found the minimum standard subproblems to be:

1. **The original problem**. Such as environmental sustainability or climate change.

2. **How to overcome systemic change resistance**. If serious solution efforts have failed repeatedly and the problem is solvable, then high systemic change resistance must be present. *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." [reference omitted] Change resistance differs from policy resistance (Sterman, 2000, pp. 5–12). Change resistance refers to resistance to *proposed* solutions, while policy resistance refers to resistance to *implemented* solutions.

   We argue that on difficult large-scale problems like sustainability, change resistance is by far the most important type of resistance, a viewpoint shared by Forrester (2007). In his now classic "aimless plateau" paper, he noted that while there are many applications of system dynamics in government, "there is very little penetration into the big issues" and asked: "Why is there so little impact of system dynamics in the most important social questions?" Forrester then proceeded to take the first steps toward meeting that challenge with a further question: "How often do you see a paper [with a system dynamics model] that shows all of the following characteristics?" The last two were: "8. It examines why the proposed policies will be resisted. 9. It recognizes how to overcome antagonism and resistance to the proposed policies." Social force diagrams combined with decomposition into the three standard subproblems meets both requirements.

3. **How to prevent problem recurrence**. Difficult problems tend to recur unless a strong recurrence prevention function is present. After initial solution success, "don't be too hasty to declare victory. The last battle has yet to be fought. The battle against creeping disorder, the battle against entropy. The battle to ensure the gains you made are permanent" (Pyzdek, 2003, p. 649). In industry this is known as process control and is not covered in this paper.

The basic RCA-based ISM modeling process

When faced with a difficult large-scale social problem, the above components lead to the high-level process for ISM construction shown in Figure 3.

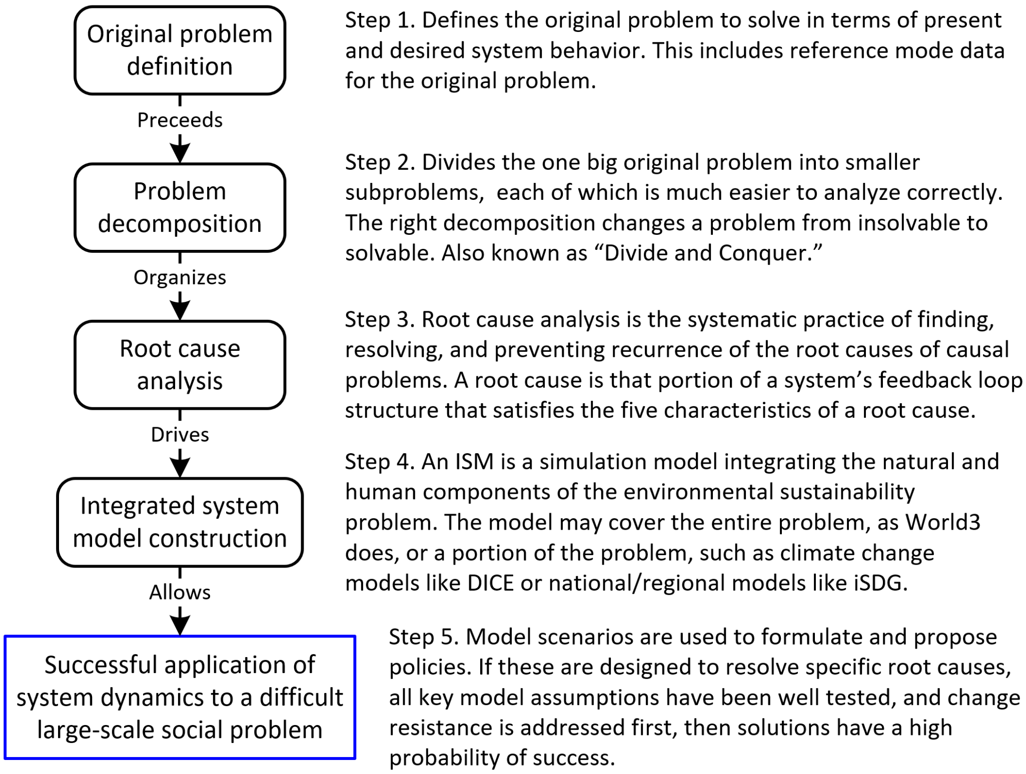

Figure 3. The RCA-based ISM modeling process, showing the five high-level steps for taming extreme problem complexity. The diagram summarizes the thesis of this paper. Current practice for constructing ISMs lacks an explicit approach to steps 2 and 3. The steps are sequential and iterative.

The WorldChange model

Model purpose and change resistance layer architecture

This paper extends a previous work [reference omitted], which found that systemic change resistance is the crux of the environmental sustainability problem and must be solved first, by resolving the root causes of that resistance. Systemic change resistance runs so high that the world's nations have been unable to overcome that formidable barrier, one result being that the SDGs and the Paris Agreement goals are voluntary. On the climate change crisis, UN Climate Change (2021) reports that, as of February 2021 the projected reduction of countries total emissions will be less that -1% in 2030 compared to 2010. The IPCC found that meeting the maximum rise goal of 1.5 degrees Celsius requires a reduction of -45%, indicating very high change resistance. In a talk celebrating the 40th anniversary of *The Limits to Growth*, Jorgen Randers presented a telling slide: "The root cause of current [solution] delays: We know the solution. But we don't like it" (Smithsonian, 2012).

This resistance must be modeled. To illustrate in a simple manner how this may be done, we have extended the World3_03 model from the third edition of *The Limits to Growth* (D. Meadows et al., 2004).

The lower large box in Figure 4 shows how present ISMs assume proposed policy changes will be implemented. These models are basically highly integrated IPAT equation models (Chertow, 2001). The IPAT paradigm lacks any concept of change resistance. Consequently, so do current ISMs. This behavior can be added with a change resistance layer.

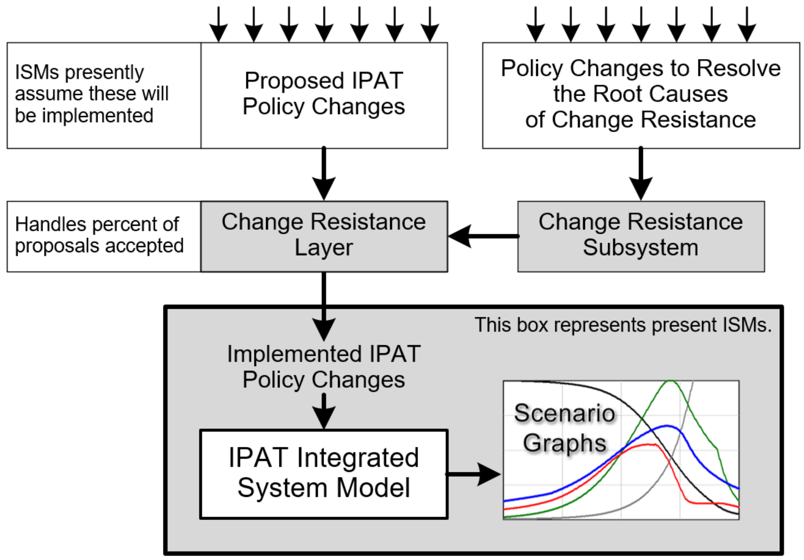

Figure 4. How the change resistance layer works.

For scenario inputs, present ISMs have only those shown on the diagram as *Proposed IPAT Policy Changes*. Addition of a Change Resistance Layer and a Change Resistance Subsystem allows a second set of inputs: *Policy Changes to Resolve the Root Causes of Change Resistance*. Once the root causes are resolved, systemic change resistance will switch from high to low, the system will accept a high percentage of *Proposed IPAT Policy Changes*, and *Scenario Graphs* can realistically show how much of the problem is solved.

Problem decomposition and root cause analysis

For sustainability ISMs, Forrester's World2 model defined the problem as how the human system can flourish within *The Limits to Growth* imposed by the greater system it lives within, the environment. Forrester saw the "primary cause" of the world's *problematique* as being exponential growth in population and the use of energy and resources (D. H. Meadows, 2007). Consequently, unsustainable growth from an IPAT perspective is what World2, World3, and all subsequent ISMs have modeled. This work used only steps 1 and 4 of the Figure 3 process.

However, by adding steps 2 and 3 we have concluded that is *not* the primary cause. The additional steps led to the question: WHY are popular solutions failing? This led to discovery of systemic change resistance as a distinct and separate problem to solve, allowing focused RCA of the *How to overcome change resistance* subproblem. The main root cause, *low political truth literacy*, explains that change resistance is high because politicians can successfully deceive voters into voting against their own best interests, and instead voting for politicians representing powerful special interests, particularly large for-profit corporations (aka *Corporatis profitis*) and their owners, the rich. The result is that special interests rather than common good interests have mostly controlled the world's democratic systems. This behavior is well documented (Beder, 2002, 2006; Korten, 2015; Shamir, 2005).

Then we asked WHY are special interests so relentlessly motivated to exploit the power of change resistance? What can explain this?

This led to discovery of an additional subproblem: *How to achieve life form proper coupling*. 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 main root cause of this subproblem is mutually exclusive goals between the two dominant life forms in the human system, *Corporatis profitis* and *Homo sapiens*. *Corporatis profitis* is dead set against solving the environmental sustainability problem and is winning, because of its overwhelming control of the human system, superior financial power compared to mere citizens, and its obsessive goal of short-term profit maximization. This goal conflicts with the goal of *Homo sapiens*, which is the long-term optimization of quality of life for people. These goals are mutually exclusive.

Because *Corporatis profitis* dominates the system and drives capitalism, its goal prevails and has become *the wrong implicit goal of the system*. Peter Senge (1990, p. 88) warns that when this occurs, "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." Donella Meadows (2008, p. 113) phrases her warning differently: "Such resistance to change arises when goals of subsystems are different from and inconsistent with each other."

The causal structure of these two subproblems was analyzed as shown in Figure 5. Highlights are the intermediate causes and the low leverage points that popular solutions have been pushing on (in vain), and the root causes and the high leverage points for resolving them.

The key insight is subproblem B causes subproblem A, which prevents solution of the original problem. Both subproblems must be solved before proposed solutions to the original problem will be mostly accepted.

The key good news is that no serious large-scale solutions have ever pushed on the high leverage points, since attention has been attracted to low leverage point solutions. If this hypothesis is sound, then the sustainability problem is solvable and can be solved considerably faster than presently assumed.

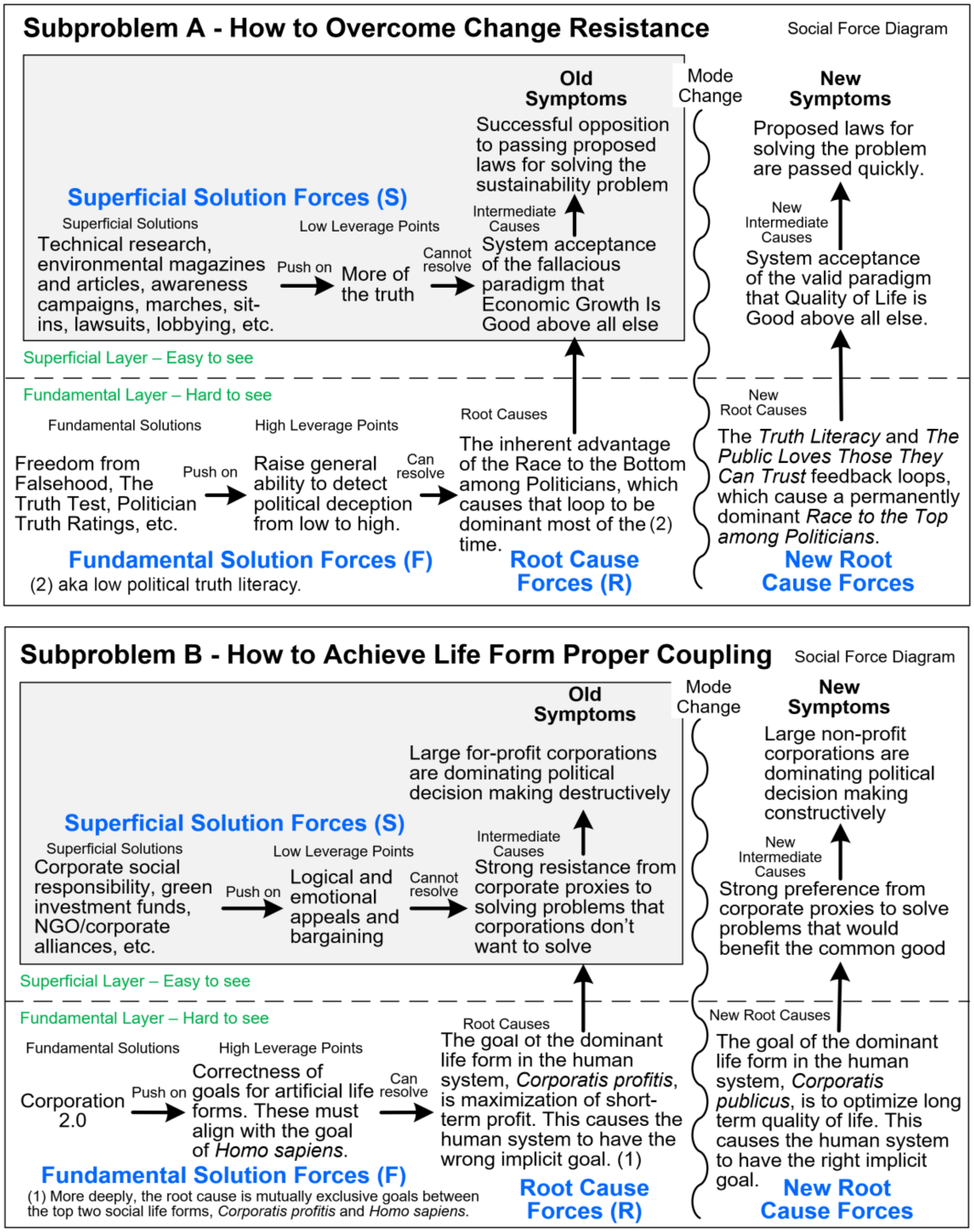

Figure 5. Social force diagrams for the two subproblems. The two gray boxes are all environmentalists can presently see, which has led to superficial solutions.

Reflecting later on the birth of World3, Donella Meadows (2007) wrote that: (italics are in the original)

> [Because] Aurelio Peccei …was worried about what he saw, he pulled together a group of distinguished friends for a meeting in Rome in 1968. The loose network they founded was named the Club of Rome after the place of its first meeting. The job they took on was to define what they called the world's *problematique*.
>
> By 1970 the Club of Rome had expanded to 75 members and had extended the *problematique* to 66 "Continuous Critical Problems." Poverty, war, pollution, crime, oppression, resource depletion, terrorism, economic instability, racism, and drug addiction

> were on the list. The Club was made up of problem solvers, men of action. They wanted more than a list of problems, they wanted *solutions*. How to tackle this nest of woes? Presumably the problems are interrelated, but how? Are there fundamental underlying causes [which RCA calls root causes] that can be dealt with, without having to take on each problem separately?

According to root cause analysis, yes. The systemic change resistance emanating from the root cause of subproblem B applies to any problem whose solution would benefit the common good and not the uncommon good of *Corporatis profitis*. It thus applies to the entire *problematique*. The pattern in the "nest of woes" problems is *Corporatis profitis* has no motivation to solve them, and in fact is motivated to *not* solve many of them. War and preparing for it is highly profitable. So are the bubbles and long run-ups to recessions, and the resulting government bailouts of large firms. So is poverty, because then *Corporatis profitis* and the rich have more. So is pollution, because that externalizes large costs. And so on.

Therefore, we can logically anticipate that once ISM builders revise their models to include the two subproblems (or something like them) and switch to model design and scenarios based on resolving root causes, the policies generated for solving the subproblems will lead not only to the human system "wanting" to solve the environmental sustainability problem as much as it doesn't want to solve it now. It will also lead to the system wanting to solve any problem whose solution would benefit the goal of *Homo sapiens*, which includes the entire "nest of woes" of the global *problematique*. If the main root causes of the two subproblems presented here (and additional root causes identified by ISM builders in more detailed models) are reasonably correct and can be resolved by policies generated by models built by thoughtful adherence to the principles of good system dynamics, that outcome is not fantasy. It is a practical meta-solution strategy, built one brick at a time by applying the tools of RCA and problem decomposition, just as the business world has done for a century. This should serve as some indication of the potential transformational power of RCA-based ISMs.

Submodel: The Change Resistance Subsystem

A Vensim version of World3_03 was modified in 2008 so that the *scenario* slider (not shown) controls behavior of the changes required to run World3 scenarios 1 to 10. This makes it *much* easier to work with World3. [name omitted] gave the model to Bob Eberlein (then working at Ventana Systems), who improved the modification by adding the Scenario Inputs page and putting the *scenario* node there, along with its effect on model nodes.

Analysis of the two subproblems produced a system dynamics model of *The Dueling Loops of the Political Powerplace*. The model was simplified and incorporated into World3 in 2013 on a separate page. In 2021, after the Truth Literacy Training study (discussed later) was complete and its implications understood, the submodel was further improved. After removing 17 less significant nodes for clarity (all were constants except for Time), the current submodel is shown in Figure 6.

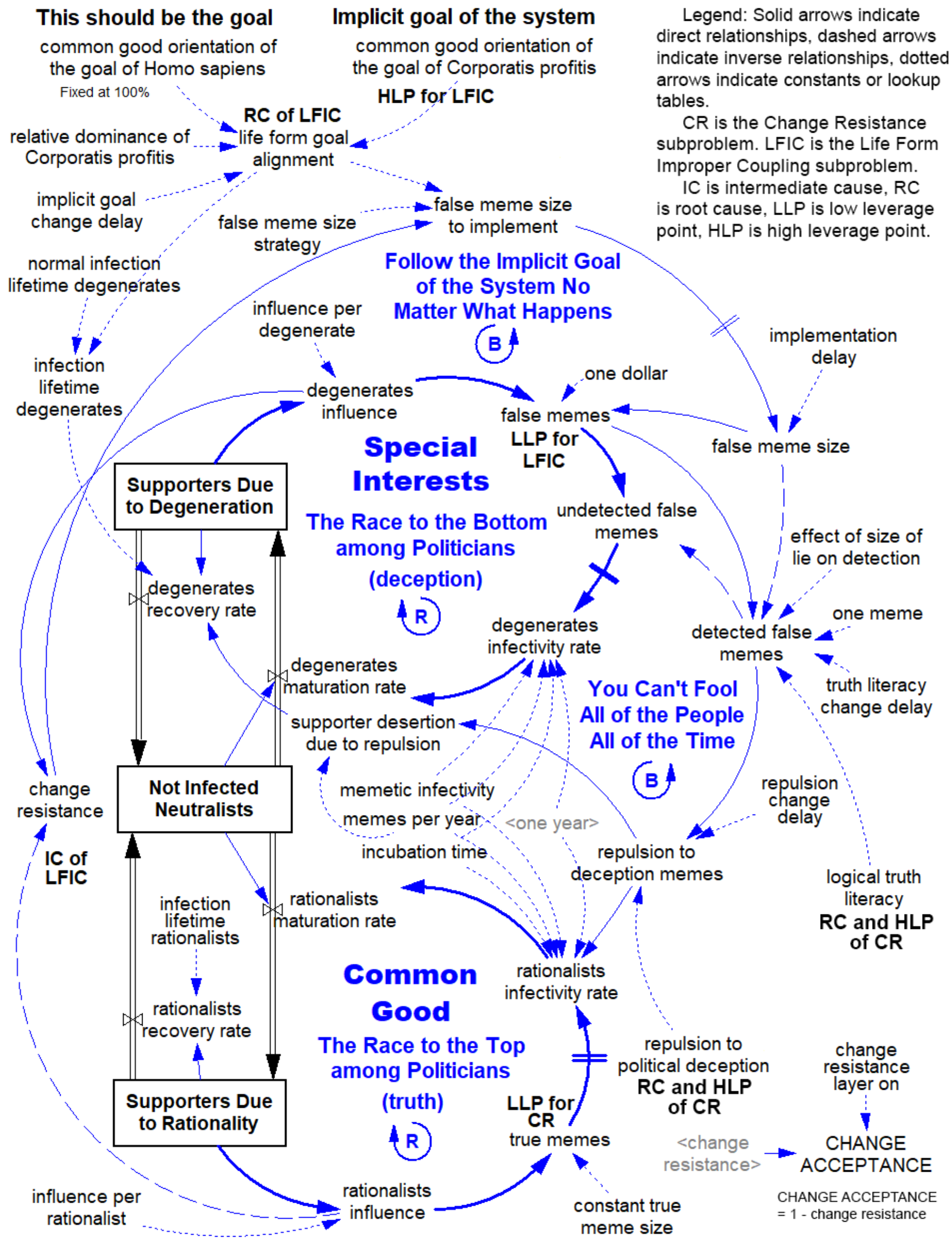

Figure 6. The change resistance subsystem, with key causal nodes identified. Scenarios 5 to 8 push on the 3 high leverage points.

The actual submodel hookup was made by inserting the CHANGE ACCEPTANCE node in the 12 places where World3's scenario solutions changed model behavior. Acceptance ranges from zero to 100%. World3 equations were edited such that the amount of acceptance determines the amount of the change implemented, thereby mimicking real world behavior.

The upper diagram in Figure 5 identifies problem symptoms as "*successful opposition to passing proposed laws for solving the sustainability problem*." WHY does that occur? We found the main intermediate cause to be "*system acceptance of the fallacious paradigm that Economic Growth Is Good Above All Else*." Herman Daly, referring to his reading of *The Limits to Growth* in 1972, wrote that "it is now forty years later and economic growth is still the number one policy goal of practically all nations; that is undeniable" (Randers, 2012, p. 73). Jacobs (1996, p. 117) found that "Over the last 50 years, growth has become the main objective of politics, regarding not just as the source of wealth creation, but as the automatic solution to all other problems."

Continuing to trace the causal diagram, the reaction of environmentalists has been to attempt to resolve the intermediate cause with a "*more of the truth*" strategy. This strategy is implemented with solutions like "*technical research, environmental magazines and articles, awareness campaigns, marches, sit-ins, lawsuits, lobbying, etc*."

Despite leading to much new environmental legislation at the national level and a string of international summits on environmental sustainability and climate change, these solutions have largely failed. WHY? Because they are superficial solutions pushing on a low leverage point to resolve an intermediate cause. WHY has the fallacy that Economic Growth Is Good Above All Else become so universally accepted? By employing system dynamics, we found the main root cause was "*the inherent advantage of the Race to the Bottom among Politicians, which causes that loop to be dominant most of the time.*"

Model structure centers on a perpetual duel between the Race to the Top versus the Race to the Bottom. This captures a particular aspect (power based on use of political deception versus the truth) of the left/right political spectrum. This must be done, since "global politics is first and foremost a debate between the left and the right," where the left favors equality and the right favors inequality via hierarchy and preservation of the power status quo (Noel & Therien, 2008, p. 3). Capturing this tension adds significant realism to the model, as "Power dynamics are critically important in decision making, particularly when it comes to formulating and implementing policies supported by system dynamics modelling. According to Houghton, any true systemic approach needs to include issues of politics, power or coercion because they impact the area of concern" (Cavana et al., 2019).

"The central problem facing conservatives, once their country's [voting] franchise had been extended to include most adult men, was that it was unclear why most voters would want to vote for them" (Ware, 1996, p. 32). If a conservative politician cannot appeal to voters on the basis of the truth, the only alternative is deception. Successful deception allows manipulative politicians (working on behalf of entrenched powerful special interests) to deceive a majority of voters into voting against their own best interests. Jeremy Bentham, the father of utilitarianism, in his handbook of political fallacies published in 1824, describes the practice: "…it is impossible by fair reasoning ...to justify the sacrifice of the interests of the many to the interests of the few.... It follows that for effecting this purpose they must have recourse to every kind of fallacy, and address themselves, when occasion requires it, to the passions, the prejudices, and the ignorance of mankind" (Larrabee, 1925, p. xxi).

The Race to the Bottom's inherent advantage occurs because the size of a falsehood (and hence its attractive power) can be inflated, but the size of the truth cannot. A politician can tell a bigger lie, like budget deficits don't matter. But they cannot tell a bigger truth, such as I can balance the budget twice as well as my opponent, because once a budget is balanced, it cannot be balanced any better. From a mathematical perspective, the size of a falsehood can be inflated by saying that 2 + 2 = 5, or 7, or even 27, but the size of the truth can never be inflated by saying anything more than 2 + 2 = 4. Inflation is used to create fear when there is nothing to fear, doubt when there is nothing to doubt, the false promise of I can do so-and-so for you when I really cannot, a large flaw in one's opponent when there is only a small flaw, and so on.

In the Race to the Bottom, deceptive politicians use *undetected false memes* to infect *Not Infected Neutralists*, causing them to become *Supporters Due to Degeneration*. (Model nodes are italicized in this paper.) In the Race to the Top, truth-telling politicians do just the opposite, by using *true memes* to infect neutralists, thus increasing *Supporters Due to Rationality*.

Because the size of a falsehood can be inflated (by telling a lie) but the size of the truth cannot be inflated, the Race to the Bottom contains an inherent advantage and is the dominant loop most of the time in the world's political systems. We know this to be so because of such strong prolonged change resistance to solving common good problems like sustainability, including the entire *problematique* "nest of woes." Thus, the main root cause of successful change resistance is "*the inherent advantage of the Race to the Bottom among Politicians, which causes that loop to be dominant most of the time*." The inherent advantage of the Race to the Bottom only exists if political truth literacy is low, so a shorter (but less accurate) term for the root cause is "*low political truth literacy.*"

It follows that the high leverage point for resolving the root cause is "*raise general ability to detect political deception from low to high.*" The analysis developed nine sample solution elements for doing this, such as "*Freedom from Falsehood, The Truth Test, Politician Truth Ratings, etc.*"

The Truth Literacy Training Study

Good system dynamics and RCA require testing of all key assumptions. How much confidence can we have in the assumption that political truth literacy is low and can be raised to high in a practical manner, which forms the bedrock of the change resistance model?

To answer this question the Truth Literacy Training study was run using a Prolific online panel[1] and our own software for the questionnaire. 93 US subjects (age range 22 to 51, average age 31, 49% male) were randomly assigned to three groups. Group 1 received training on a neutral topic. Group 2 received training on how to tell if a political claim (embedded in a political statement) was true or false, by spotting the pattern of fallacy or non-fallacy used. Group 3 received the same training as group 2 plus training on how to vote correctly (given the perceived level of truth of a claim) by applying two rules: Reward the Truth Teller and Penalize the Deceiver. Figure 7 summarizes study results.

Political truth literacy contains two components: logical and vote. *Logical truth quotient* (LTQ) is the ability to logically tell if a deceptive claim is true or false, and was measured by the percent correct for the truth questions for deceptive statements. *Democratic truth quotient* (DTQ) is the ability to vote correctly given a deceptive statement made by a politician, and was measured by the percent correct for the vote questions for deceptive statements. DTQ measures voting truth literacy, while LTQ measures logical truth literacy. Deceptive statements contained seven fallacies we found common in political appeals: cherry picking, flawed application of the Strong Evidence Rule, ad hominem attack, appeal to emotion, strawman, false dilemma, and false fact lie.

[1] See https://www.prolific.co.

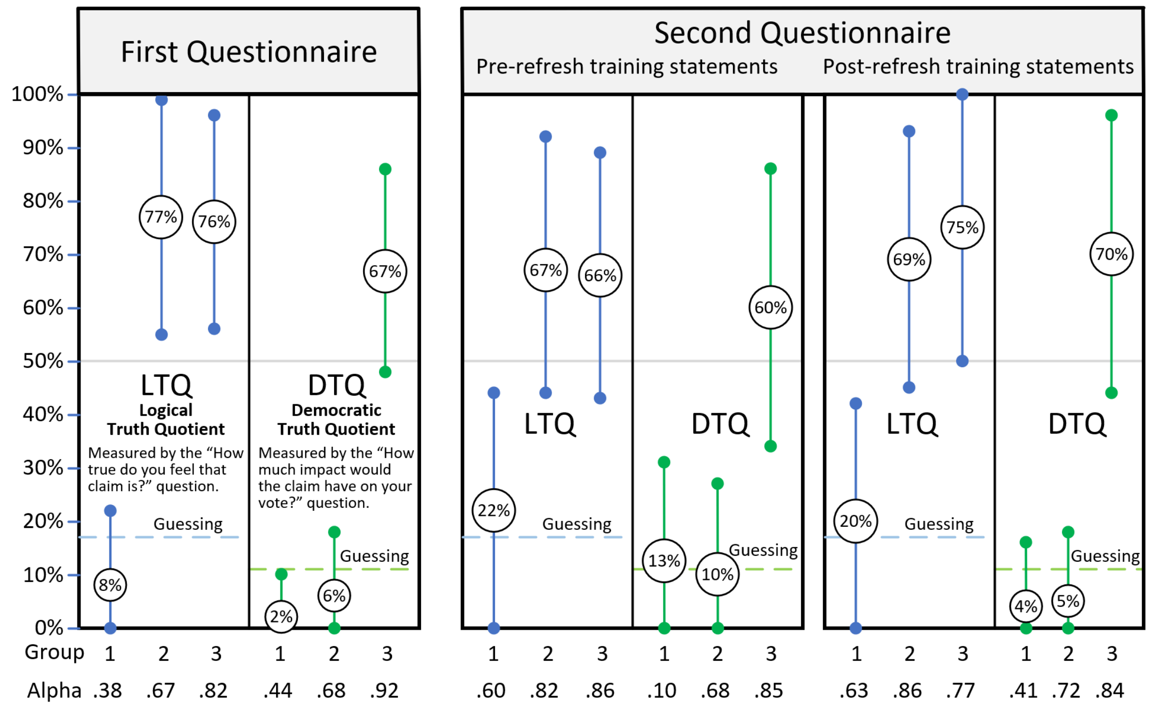

Figure 7. Results of the Truth Literacy Training study. Average scores and 95% confidence intervals for answers to deceptive statements are shown, with guessing levels and Cronbach's alpha. Treatment groups were:

1 – Trained on neutral topic
2 – Trained on claims
3 – Trained on claims and vote

LTQ is naturally low, at 8% for group 1. Voters not trained in logical truth literacy can spot a fallacy in a deceptive political statement an average of only 8% of the time. DTQ is also naturally low, at 2% for group 1. Both are crucial findings and appear to explain why change resistance to solving common good problems, including sustainability, is so stubbornly high. While the study cannot say 8% and 2% are accurate measures, we feel the results indicate political truth literacy is low instead of medium or high.

DTQ for group 2 was 6%, a deeply counterintuitive discovery. We expected it to be low, but not that low. The 6% means that even if voters have been trained on how to tell if a deceptive claim made by a politician is true or false, they are unable to correctly translate that knowledge into how to vote correctly. Group 2, which received claim training but not vote training, averaged spotting deception 77% of the time, but could translate that knowledge into voting correctly only 6% of the time. The claim training made almost no difference on voting correctly. This is why the vote training of group 3 is required.

The key data is DTQ for groups 1 and 3. The large increase, from 2% to 67%, a 65-point rise, suggests that Truth Literacy Training and other solution elements will be capable of resolving much of the root cause of change resistance: low political truth literacy. Group 3 training took only about one hour, indicating that Truth Literacy Training, such as in education systems and online training, will not require that much of a person's time.

A follow up study 26 days later using different statements found DTQ for group 3 had declined from 67% to 60%, a 7-point fall. After an average of 30 minutes of refresh training, DTQ for group 3 rose to 70%, indicating regular refresh training of some type can work and will be required. Or it may be that like reading and writing literacy, once truth literacy matures and becomes the reasoning default and is exercised often enough, little decline will occur.

However, LTQ for group 1 was 22% and 20% for the pre-refresh and post-refresh training statements, versus 8% for the first questionnaire. This indicates spotting deception was substantially easier in the second questionnaire statements, and suggests there was more than the 7-point decline noted above and that the refresh training may not have worked as well as the 70% indicated. The second questionnaire statements were developed after the first questionnaire was run. Without realizing it, we structured them slightly differently and frequently omitted stating how strongly supported the premises were. This caused the second set to be substantially easier than the first set, as it made fallacies easier to spot. This problem is easily corrected.

Truth Literacy Training employs the preemptive aspect of inoculation theory using fallacy pattern recognition instead of misinformation correction as in fact checking (Cook et al., 2017). Our approach goes one step further than Cook's by introducing vote training and improves training effectiveness by adding a catalog of common fallacies and the Personal Truth Test. This approach can nullify the deceptive power of motivated reasoning, a well-established theory explaining how political decision-making works. "In short, citizens are often partisan in their political information processing, motivated more by their desire to maintain [often false] prior beliefs and feelings than by their desire to make 'accurate' or otherwise optimal decisions." (Lodge & Taber, 2013, p. 149)

The hypothesis that political truth literacy is currently low and can be fairly easily raised from low to high was supported.

Causal points in the Change Resistance Subsystem

The main root cause of the change resistance subproblem is modeled by the *logical truth literacy* and *repulsion to political deception* nodes. These two nodes capture the logical and vote aspects of political truth literacy, as discussed in the study. When both are low, the root cause force of these two nodes causes the Race to the Bottom to be the dominant loop most of the time. The high leverage point is to raise both from low to high.

Environmentalists, however, have not been pushing on these high leverage points. Their solutions have been directed toward the low leverage point of *true memes*. Unlike *false memes*, these have a *constant true meme size* of one. Because pushing here cannot significantly inflate the attractive power of the truth and does nothing to resolve the root cause, it cannot resolve the intermediate cause of "*system acceptance of the fallacious paradigm that Growth Is Good above all else*," not shown on the model.

The intermediate cause of the life form improper coupling subproblem is "*strong resistance from corporate proxies to solving problems that corporations don't want to solve*." This is modeled in the *change resistance* node, which equals *degenerates influence / (degenerates influence + rationalists influence)*.

The main root cause of the life form improper coupling subproblem is "*mutually exclusive goals between the top two social life forms, Corporatis profitis and Homo sapiens."* This root cause is captured in the *life form goal alignment* node. As discussed earlier, *Corporatis profitis* so dominants society that its goal is the implicit goal of the system. This dominance is measured by the *relative dominance of Corporatis profitis* node, whose value is 90%. Using relative dominance as goal weight, we arrive at this equation:

```
life form goal alignment = common good orientation of the goal of Homo sapiens *
( 1 - relative dominance of Corporatis profitis ) + common good orientation of the goal of
Corporatis profitis * relative dominance of Corporatis profitis
```

The common good orientation of the goal of *Homo sapiens* is fixed at 100%. That of *Corporatis profitis* is initially 20%. This leads to an initial value of 28% for *life form goal alignment*, which is low.

The high leverage point for resolving the root cause is clear: change the goal of *Corporatis profitis* to be much more in alignment with the goal of *Homo sapiens*.

Change resistance behavior arises endogenously from the structure of the change resistance subsystem. The model was tuned to give realistic behavior using constant and lookup table estimates, since this data has never been measured, particularly on a global scale. This satisfies the purpose of the exploratory model: to identify and demonstrate behavior of the root cause forces behind systemic change resistance.

High leverage point scenarios

These demonstrate how adding a change resistance layer to ISMs gives significantly more realistic behavior and can lead to more productive policy insights. The eleven scenarios are displayed in Figures 8 and 9.

Unlike the three editions of *The Limits to Growth* which ran the model from 1900 to 2100, the scenarios presented here run from 1900 to 2200. Fifty-one years have passed since the first version of World3 in 1972. Long term system behavior is impossible to determine without a one century extension. While World3 was not designed for this extension and Dennis Meadows has cautioned [name omitted] on this practice, its behavior holds up quite nicely for our purpose, indicating how well built the model is.

Scenario 1. This duplicates scenario 2 of the World3 model. The result is collapse sometime between 2000 and 2100. This "business as usual" scenario (and similar scenarios generated by other ISMs) is widely seen as the problem to solve.

To be conservative on such an important estimated parameter, World3 scenario 2 begins with twice the *nonrenewable resources* of scenario 1. Scenario 2 rather than 1 is seen as the problem to solve because that's what the three editions of *The Limits to Growth* have done. All use scenario 2 as their starting point for subsequent scenario-based attempts to solve the problem. Rather than a solution starting in 2002, scenario 2 is a change to initial model parameters. Scenario 2 is the de facto reference mode for World3.

Scenario 2. This duplicates scenario 9 of the World3 model. Solution policies were applied in 2002. Collapse is avoided, with a long, apparently sustainable high level of *population* and *human welfare index*. However, examine the *nonrenewable resources* curve. Its downhill trend indicates collapse has only been postponed. World3 scenario 9 is used in all the following scenarios.

Scenario 3. The change resistance layer is turned on. *Now the model exhibits realistic behavior*. Because of high systemic change resistance to solution policies, only 20% are implemented. The result is collapse, though it's not as severe as scenario 1 because 20% of the policies were implemented. This *was* the problem to solve in 2002, the solution start year used in the 2004 version of the World3 model (D. Meadows et al., 2004).

Scenario 4. Reference Mode. However, we are now in 2023. Solutions and change resistance alleviation policies cannot be implemented immediately. If the call to action begun in the three editions of *The Limits to Growth* and repeated in countless publications like this paper is finally taken seriously, the earliest they could start is about now. This scenario thus moves the solution start year from 2002 to 2023. *This is the real problem to solve* and serves as our reference mode. Note how the collapse is significantly larger than scenario 3, as seen in the *population* and *food* curves.

To reflect that change resistance is currently high, the initial values for *repulsion to political deception*, *logical truth literacy*, and *common good orientation of the goal of Corporatis profitis* are all low, at 20%. The model is tuned so that *change resistance* is initially 80%. This causes *CHANGE ACCEPTANCE* to initially be 20%, which allows only 20% of the effect of World3's scenario 9 parameter changes to pass through to model behavior. Given the low amount of progress made on implementing solutions to the global environmental sustainability problem, especially climate change, this approximates actual system behavior. *Near-term collapse is probable and we see no realistic way to avoid it,* with a possible exception. But the amount of collapse can be reduced and the final outcome greatly improved if change resistance can be fully overcome.

The exception would be if the effect of pushing on high leverage points, such as those shown here, can somehow be radically accelerated. This is critical, since World3 contains no equivalent of the ecological tipping points that will soon be triggered by the effects of climate change.

Scenario 5. Now that we've created our reference mode, we can show the effects of pushing on the two high leverage points associated with change resistance. This scenario pushes on a high leverage point for resolving the root cause of the change resistance subproblem, by raising *logical truth literacy* from 20% to 50%.

As expected, *change resistance* falls some. But it falls slowly. Population collapse is not avoided, but a population rebound appears as reduced change resistance takes effect. Quite worrisome is this rebound reduces nonrenewable resources dramatically.

Scenario 6. This scenario rolls back the increase in *logical truth literacy* to what it was before, 20%, and pushes on the other high leverage point associated with change resistance. *Repulsion to political deception* is raised from 20% to 50%. The result is similar to scenario 5, though the reduction in *change resistance* is considerably less. This indicates *logical truth literacy* has higher leverage.

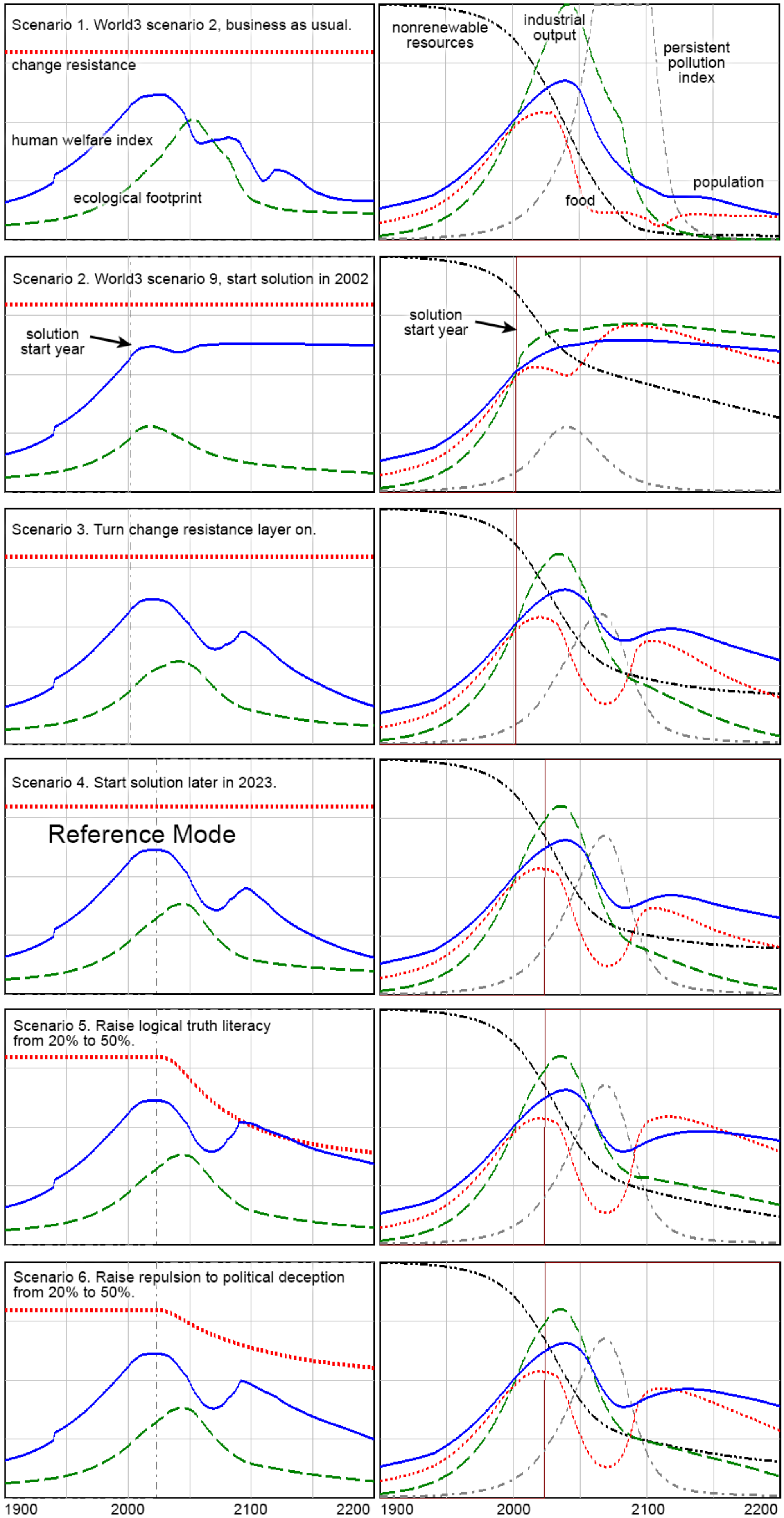

Figure 8. Scenarios 1 to 6.

Scenario 7. The Truth Literacy Training study provides empirical evidence that *both* change resistance subproblem high leverage points must be pushed on to raise political truth literacy from low to high. This scenario does that by raising *logical truth literacy* and *repulsion to political deception* from 20% to 50%, which raises them from low to medium. We would like to raise them to high, but prefer a conservative, more achievable scenario.

The result is a much faster and larger reduction in *change resistance*. Population collapse still occurs, but collapse is smaller and population rebound is slightly higher. The *human welfare index* rebounds fully, a happy result.

However, new ominous behavior has appeared. *Food* and *industrial output* encounter catastrophic collapse around year 2150 (this is not an exact prediction). This is triggered by *nonrenewable resources* depletion. Higher *industrial output* has caused higher resource use over such a long period of time that the depletion effect built into World3 now appears. (What a wonderfully robust model!) Once *nonrenewable resources* fall to 10%, the cost of further resource extraction soars exponentially. Our central scenario planning question now becomes how can we avoid catastrophic collapse due to nonrenewable resource depletion?

Scenario 8. Scenario 7 resolved the root cause of the change resistance subproblem. With that subproblem solved, the human system can now realistically resolve the root cause of the life form improper coupling subproblem, which this scenario does by pushing on the high leverage point of raise the *common good orientation of the goal of Corporatis profits*. This scenario raises that from 20% to 60%. We avoid raising it higher to follow the rule that estimated model parameter should be conservative rather than optimistic, though we suspect all three high leverage points can be raised higher than done in these scenarios. Since it will take time for scenario 7 to take effect and allow scenario 8, the change in *life form goal alignment* has a 10-year delay.

Change resistance now falls slightly faster. More importantly, *it falls eventually to zero.* While this scenario still does not solve catastrophic collapse caused by the all-important nonrenewable resource depletion problem, it opens the door to further scenarios that could. These are impossible in today's world due to high change resistance. But in the WorldChange model, where the root causes of systemic change resistance are modeled and resolved, they now become tantalizingly possible. Examples are explored in scenarios 9, 10, and 11. These three scenarios start in 2033, since transition from high to low systemic change resistance will take time.

Scenario 9. Bowing to the insights of Thomas Malthus and the IPAT equation, this scenario reduces *total fertility* from about 2 to 1.3 children per family. The 1.3 is what the population growth program in China achieved in 2004 in urban areas and compares favorably to rates of 1.04 in Singapore, 1.38 in Japan, and 0.91in Hong Kong (Hesketh et al., 2005), as well as 1.32 in Cyprus, 1.35 in Greece, 1.26 in Spain, and 1.29 in Italy (EurostatFertility, 2020). The population collapse problem is solved. Instead, a managed population decline occurs, which reduces resource depletion enough that the catastrophic collapse of scenarios 7 and 8 is avoided.

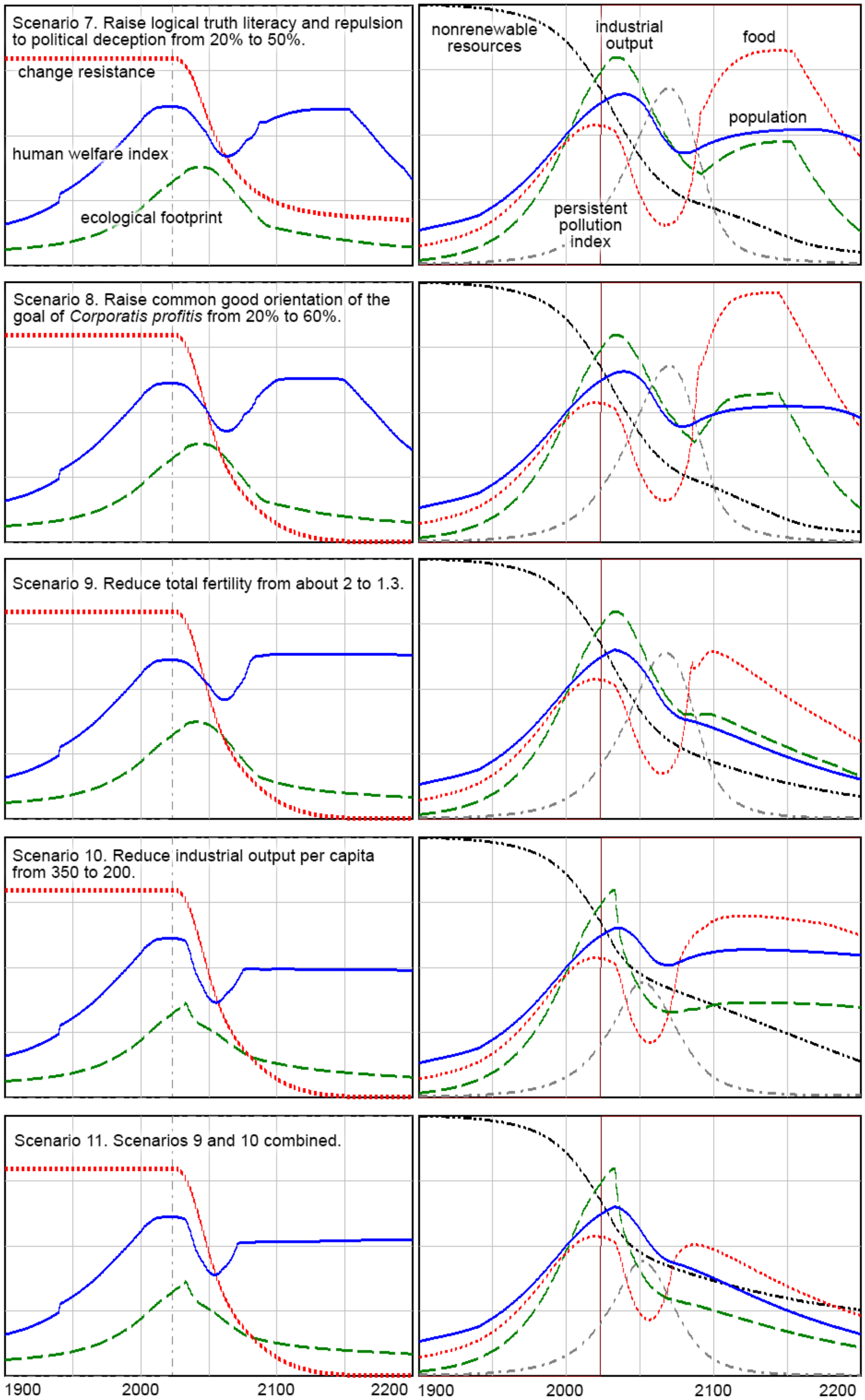

Figure 9. Scenarios 7 to 11.

A managed population decline differs entirely from population collapse. In a managed decline, population falls due to voluntary reduction of average family size (a pleasant world, where quality of life and *joie de vivre* reign supreme), rather than falling due to starvation and conflict (a dystopian world, one reminiscent of the Hunger Games).

Scenario 10. Low systemic change resistance allows another scenario that was also impossible before. This scenario rolls back the change made in scenario 9. Instead, *industrial output per capita* is reduced from 350 to 200, reflecting a cultural change from a quantitative mode (which benefits *Corporatis profits)* to a qualitative mode (which benefits *Homo sapiens* and is the only sustainable path forward). "…John Stuart Mill was right, that populations of human bodies and accumulation of capital goods cannot grow forever, that at some point quantitative growth must give way to qualitative development as the path of progress" (Daly, 1996, p. 7).

This results in no population decline while also avoiding catastrophic collapse. The 200 allows a high *human welfare index* and is what *industrial output per capita* was in 1969, so this scenario involves nothing draconian. However, as in scenario 9, *nonrenewable resources* are falling fast and collapse is merely postponed.

Scenario 11. Scenarios 9 and 10 are combined. The effect is large reductions in the P and A of the IPAT equation. The T was already drastically reduced by World3 scenario 9, which cut persistent pollution by 90%.

The satisfactory result is a managed population decline and *nonrenewable resources* of about 25% in 2200 (this is not an exact prediction). While resources are still declining, the rate is slow. There is now ample time for *Homo sapiens*, working with what has become *Corporatis publicus*, to devise and implement a long-term solution to the environmental sustainability dimension of the Anthropocene.

Conclusions

The paper explored the question of why a long series of ISMs, while making *the* crucial contribution to problem identification, has largely failed to lead to solution of the environmental sustainability problem.

Based on the work reported here, we offer the following conclusions for ISM modelers. These apply to the class of difficult large-scale social problems like sustainability, which includes the all-important climate change problem:

1. Reliably and efficiently finding root causes requires a process similar to the one in Figure 3. In particular, the process must produce analysis artifacts and models with distinct subproblems and their specific root causes.
2. How to overcome systemic change resistance is the most important subproblem. The sustainability problem must therefore be decomposed into at least the original problem and how to overcome change resistance.
3. The simplest and fastest way to get started is to add a change resistance layer to existing ISMs.
4. Once systemic change resistance is overcome, solutions that are impossible in today's world become realistically possible, as discussed in scenarios 8 to 11.

These conclusions can be summarized: Adding a change resistance layer to ISMs that addresses the root causes of systemic change resistance has the potential to transform the environmental sustainability problem from insolvable to solvable.

Beginning with World2, system dynamics models have been extremely helpful in bringing the environmental sustainability problem to the world's attention, providing detailed proof of the severity of the problem, and providing the range of forecasts needed for goal setting. With incorporation of the above conclusions, system dynamics can be even more helpful and lead the way to *achieving* those goals.

Supplementary materials

The RCA-based process presented here is a simplified version of a larger one. For full description of the process, an analysis of the sustainability problem using the process, the study, and twelve sample solution elements, please see the book *Cutting Through Complexity: The Engineer's Guide to Solving Difficult Social Problems with Root Cause Analysis*, available at Thwink.org.

The WorldChange model may be found in the online version of this article at the publisher's website as well as at Thwink.org.

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