The need for a standard high yield process for solving difficult social problems using system dynamics

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The potential of system dynamics for solving society's toughest problems was proven long ago, by classic analyses like Forrester's *Urban Dynamics* and the Club of Rome's *Limits to Growth*. But since then widespread success has eluded the field. This paper proposes the reason is the field's foundation is incomplete. Solving difficult social problems is still too dependent on luck and the brilliance of the modeler, mainly because the field lacks a high yield, repeatable process. An example of one that could serve the role of a first iteration is presented, along with a sample application of the process. To engineer a mature process the field will need to follow a long term process improvement program.

In a recent article, *System dynamics—the next fifty years*, Jay Forrester presented our field with a sobering question: "Why is there so little impact of system dynamics in the most important social questions?" (Forrester, 2007) This paper proposes that the fundamental reason is the field lacks a mature, repeatable process for system dynamics based problem solving, such as the way Japanese business uses Kaizen, a formal process for continuous incremental improvement.

> "Kaizen strategy is the single most important concept in Japanese management—the key to Japanese competitive success. In business, the concept of Kaizen is so deeply ingrained in the minds of both managers and workers that they often *do not even realize* that they are thinking Kaizen. [An] important aspect of Kaizen has been its emphasis on process. Kaizen has generated a process-oriented way of thinking, and a management system that supports and acknowledges people's process-oriented efforts for improvement." (Imai, 1986, pages xxix and xxxiii. Italics are in the original.)

Applying the principles of Kaizen to a failed American auto manufacturing plant they took over, in 4 years Toyota reduced quality defects from 12 to 1 per vehicle and dropped the time it took to assemble a car by an eye popping 50%. All with the same equipment and 85% of the same employees. The only real difference was a totally new process. (May, 2007, pages 61 to 65) Applying his principles of motion analysis to bricklaying, Frank Gilbreth reduced motions per brick from 18 to 5 and increased the number of bricks laid per hour from 125 to 350. (Gilbreth, 1997)

The same quality and productivity breakthroughs can come to the practice of simulation modeling, which is not that much different from manufacturing or bricklaying. At first glance it seems quite different. But from a process viewpoint it's not. *With the right process steps driving it, modeling is a re-*

peatable exercise, regardless of the problem domain, because more than anything else, good modeling is the result of defect reduction.

Every flaw in a model is a defect. A defect can be the presence of something that's *not* needed, the absence of something that *is* needed, an incorrect node equation, a false conclusion or justification, a missing scenario, a misleading loop name, and so on.

A model is mostly descriptive. The lower the defect level, the better the descriptive power of the model, because the better it describes real world behavior and the more it includes those aspects necessary for solving the problem. The same holds for the prescriptive part, since most or all of this follows logically from the descriptive part.

The most important part of a problem model is the root cause, which is purely descriptive. The second most important part is the high leverage points. Unless these are extremely novel and require invention, these too already exist and are descriptive. The third most important part is the low leverage points problem solvers are currently pushing on. These always exist and hence are also descriptive. Because good models are so highly descriptive, creating them is a repetitive process, one easily improved by defect reduction.

Is It Time to Apply Six Sigma to System Dynamics?

Radical process improvement routinely leads to extraordinary levels of defect reduction. This strategy has become so central to so many businesses that Six Sigma has emerged as a standard method of defect reduction. Most companies start at about 6,210 defects per million, which is four sigma. (Pyzdek, 2003, page 5) By applying process improvement principles, they routinely cut that to 3.4 defects per million, which is six sigma. There is no reason why the field of system dynamics cannot do the same.

Six Sigma means 99.99966 percent of your transactions are acceptable. That's the level of quality needed to solve difficult problems, because every time a defect creeps into a model, it causes further defects as you build the model further. If each step of model construction is not rock solid, then by the time you have added the final step the model will be crumbling, because it rests of a foundation of sand.

For a series of process steps the overall yield is the product of the yields of the steps. This paper presents a process with a total of 22 steps and argues this is the minimum process for the problem domain. Because modelers are unaware of these steps they are performed intuitively, in what popular processes describe as "formulation of dynamic hypothesis" and similar loose terms that require large intuitive leaps. This results in low process yield, which I'd estimate averages about 80% to 90% per step or lower. 80% times itself 22 times is a dismal 0.7%. 90% times itself 22 times is 9.8%. This explains why the field has been unable to reliably solve difficult social problems.

But if the field used a well engineered process with a high yield per step, the total process yield would be high enough to solve those tough problems. Just getting it up to 99% per step would be enough, as 99% times itself 22 times is 80%. At that quality level we could solve about 80% of the problems we faced. And if, after many years of process improvement we hit Six Sigma, then 99.99966% times itself 22 times is 99.9925%, which is perfection. That is the level we must shoot for if we are serious about the responsibility of solving a certain problem that has the clear potential to cause *Homo sapiens* to undergo catastrophic collapse or extinction if the problem is not quickly solved.

Popular Processes and Lack of the Right Process

Today's popular modeling process can be roughly described as:

1. Define the boundary of the system/problem.
2. Duplicate the system behavior so that the problem symptoms appear, as the result of endogenous causes in the model.
3. By examination of the model, hypothesize solutions.
4. Use the model and the real world to test these solutions.
5. Evolve the model as necessary to select the best solution.

The process has been formalized in works such as Sterman's "Steps of the modeling process," (Sterman, 2000) whose main steps are listed below:

1. Problem articulation (boundary selection)
2. Formulation of dynamic hypothesis
3. Formulation of a simulation model
4. Testing
5. Policy design and evaluation

But this has not been enough. Even with easy to use software like Vensim and IThink, plenty of system dynamics training and good books and articles, festering mega problems like poverty, war, discrimination, mal-distribution of wealth and environmental sustainability continue to plague humanity. The field has seen no breakthroughs in this area since Forrester's urban decay model (Forrester, 1969) and the *Limits to Growth* (LTG) World3 model (Meadows et al, 1972). So where have we gone wrong?

In the process. A prime example is construction of the World3 model followed the popular process. The model has withstood the scrutiny of the years well and remains a popular example of the power of system dynamics. But yet the problem it analyzed, global environmental sustainability, remains unsolved. So where did this highly influential model go wrong?

In the process. The World3 model did duplicate the problem symptoms "as endogenous consequences of the feedback structure," as one popular process recommends (Sterman, 2000, page 86). *But due to lack of the right process, the model did not dig down to the root causes*. The model stopped at the intermediate causes, the loops associated with the PAT in the IPAT equation. (Meadows et al, 1974, page 14) In the IPAT equation, environmental Impact = Population x Affluence x Technology. The units are impact = population x consumption/person x impact/unit of consumption. The modelers apparently did not ask what is causing the PAT forces to grow.

Because the LTG analysis gained such international fame and was first to market, people assumed it had framed the problem correctly and was suggesting the correct strategic solutions: that the PAT factors needed to be lowered to a sustainable level. This is exactly what humanity proceeded to attempt to solve the problem, with population control programs to address the P and environmental treaties and national initiatives to address the AT factors. But these efforts have mostly failed, because the root causes, not being identified, were never resolved.

Meanwhile, the urban decay model did find the root causes. The root cause of stagnation was that once the urban area is filled by the growth phase, “new construction is suppressed by lack of land within the fixed and fully occupied area.” (Forrester, 1969, page 43) This insight allowed radical new solutions to be easily spotted, communicated, and tried. The result was a sea change in the way the urban decay phenomenon was managed and dramatic progress on solving the problem.

A Process for Difficult Social Problems

In mid 2001 I began working on the global environmental sustainability problem, arguably the most important, difficult, novel, and systemic problem *Homo sapiens* has ever encountered. (For example, see Ward, 1972) As a systems engineer and process consultant, I knew that if I didn’t first design a process that fit the problem and then continuously improve it as I went along, I too would fail. So I designed the System Improvement Process (SIP) from scratch. It’s designed to solve any difficult social problem. Its four main steps are:

1. **Problem Definition** – Identify the problem
2. **System Understanding (Analysis)** – Analyze the problem/ system until key cause and effect relationships are understood. This step is so important it has 5 substeps.
3. **Solution Convergence** – Use that knowledge to converge on a solution.
4. **Implementation** – Implement the solution.

Step 1. Problem Definition – Difficult complex system problems are best defined starting with this format: *Move system A under constraints B from present state C to goal state D by deadline E with confidence level F.* A problem is “solved” when a solution is created that will move the system to goal state D by deadline E with confidence level F.

Limits to Growth states that the project was not trying to solve the sustainability problem. It was only trying to identify it and alert the world. But there was such a gigantic vacuum for an analysis that readers soon assumed the project *was* the analysis they needed. The second and third editions began to fulfill these expectations, by adding chapters like “Transitions to a Sustainable System” and “Tools for the Transition to Sustainability.” (The third edition, Meadows, 2004) The tools were networking, truth-telling, learning and loving. But all this was done without actually changing the analysis. The model remained nearly completely untouched. What was happening is that, due to lack of a formal process that fit the problem, the LTG team was acting intuitively. They assumed their model was good enough and recommended solution strategies based on that. (This is not to subtract from the immense contribution the LTG team made in identifying the problem. The first step is usually the hardest.)

Step 2. System Understanding (Analysis) – The goal of this step is to understand the problem/system so well that its leverage points become obvious. This will cause two supremely powerful insights about the problem to emerge. The first is that because the system's *low leverage points* are now so clearly revealed, it becomes perfectly obvious why we have been failing to solve the problem. The second is that because we can now see where the *high leverage points* are, how to solve the problem becomes a relatively simple matter of determining how to best push on the correct leverage points. To execute this strategy, problem solvers should spend approximately 80% of their time in this step. (This assumes 0% to implementation, which is generally not done by specialized problem solvers, but by decision makers.)

This step is so important it has its own subprocess, contained in these five substeps:

A. Find the feedback loops that are currently dominant.

B. Find the root cause of why they are dominant.

C. Find the low leverage points and symptomatic solutions.

D. Find the feedback loops that should be dominant.

E. Find the high leverage points to make them go dominant.

Now we can begin to see where the LTG modelers went wrong. Even in the second and third editions, they never performed substep B. This prevented them from reaching the other substeps, with the result that as good as it was for problem identification, the World3 model was relatively useless for solving the problem. But the urban decay model did make it through these steps, apparently due to a longer and more thorough analysis phase by Forrester.

Looking back at the popular process, we see the steps: "By examination of the model, hypothesize solutions", "Formulation of dynamic hypothesis" and "Policy design." Even with the additional detail in Sterman, these mental leaps are too large to be performed reliably by most people. By breaking these large leaps up into the five little leaps above, plus the Solution Convergence step, plus the three subproblems as explained later, modelers are able to perform the process much more reliably. Small strokes fell great oaks.

Let's examine the five substeps:

A. Find the feedback loops that are currently dominant. – These are the feedback loops it takes to reproduce the symptoms. These loops are the immediate or proximate cause. This step is relatively easy, because immediate causes are so obvious.

B. Find the root cause of why they are dominant. – Starting with the immediate cause loops, you keep asking why until you arrive at the root cause, which is those portions of the system that most deeply explain why the system's emergent behavior produces the problem symptoms. For simplicity we say "root cause" when actually it is usually plural.

This step eliminates the common pitfall of stopping when the first plausible or satisfying cause of the symptoms is found, as in the World3 model. By framing the modeling challenge as finding why the loops in step A are dominant, we stop thinking in terms of generalities like a dynamic hypothesis, and more in terms of Kaizen, with a system dynamics touch. The five whys of Kaizen (Imai, 1986, page 50) are all about asking WHY until you arrive at the so called root cause.

Unless you have an easy problem this step is difficult. *It is the most important step in the analysis, so don't shortchange it*. Forrester did not, which is why the urban decay model was so powerfully useful. The root cause of stagnation was that once the urban area is filled by the growth phase, "new construction is suppressed by lack of land within the fixed and fully occupied area." (Forrester, 1969, page 43) This leads to urban decline.

A root cause has three identifying characteristics: (1) It is clearly a major cause of the symptoms (2) It has no productive deeper cause. (3) It can be resolved. Sometimes it's useful to include unchangeable root causes in your model for greater understanding. These have only the first two characteristics.

It takes a lot of iteration to find the root causes. The steps (especially 2E and experimentation in 3) that follow 2B allow you to test whether you have found a satisfactory set of root causes and to iteratively refine them until they are correct enough to solve the problem.

Note how a problem can only be fully solved if its root cause is resolved. If your model lacks the true root cause, then solving the problem will depend on intuition and luck, no matter how good the model is at reproducing the problem or plausibly explaining why it is occurring, no matter how clever the solution, and no matter how hard the solution is applied.

Let's cast our gaze at another model. The CDC diabetes epidemic model, developed by a team of experienced modelers, has a curious omission. (Homer et al, 2004) Early in the paper we see promising signs the analysis is going deep, with phrases like "the need for ecological, system-wide intervention" and "searching actively for an integrative, system-wide perspective that avoids the silo problem." (page 4) But then later (page 11) we discover that "It is notable that the model does not explicitly address the social, economic, and personal determinants behind such factors as caloric intake and the ability to self-manage, but leaves such forces outside the model's boundary." In other words, a decision was made to NOT include the root causes.

I appreciate such honesty, but this is a surefire recipe for failure. Why did they decide this? For two reasons: The first was "There was a lack of supporting evidence for hypothesized relationships…we were delving into areas of speculation." The second reason was "Powerful insights could be gained from [the model we had so far] alone…perhaps as a first step of analysis before delving into behavioral feedback loops." (page 12)

But what if the project was process driven, by an accepted standard process, like PERT or CPM, that said finding the true root cause was mandatory? If your model excluded it, then you would be highly likely to fall into the hypnotic trap of believing that symptomatic solutions can solve the problem.

Then the modeling project managers would have been able to say to CDC management and others that if we "leave such forces outside the model's boundary" then we will fail, and here's why. Or they could have included the root cause and used estimates for the "hypothesized relationships," which is a common practice. They could have run solution scenarios pushing on high leverage points (HLPs) that would resolve the root cause, and scenarios pushing on low or medium leverage points related to intermediate causes, compared the two, and told everyone "this is about how much we are going to fail by." Such a pronouncement may have generated the intended reaction. Or they could have used a more complete model to explicitly make a strong case that someone should be pushing on those HLPs.

But they did not. It is thus a timid model, because it lacks roots deep enough to make it strong. As CDC and the US government proceed with making decisions based on this model and the years roll by (4 have passed already), there will be a tendency to imperceptibly slip from remembering the root cause was deliberately excluded, to thinking that this is the best we can do or this will solve the problem. After all, that is their mandate.

How many other organizations are making the same mistake? And how many millions of lives will be destroyed or lost as a result?

C. Find the low leverage points and symptomatic solutions. – Next we find the attractive but low leverage points that problem solvers have almost invariably been pushing on and the symptomatic solutions they are using to do that. This is necessary, because (as occurred in the urban decay problem) part of the final solution will be to educate problem solvers to stop pushing on those low leverage points and switch to pushing on high leverage ones instead. Several symptomatic solutions and low leverage points have probably already appeared as you collected data on the problem and modeled down to the root cause. Step C is the easiest step of the analysis.

Step C increases your system understanding greatly, by forcing you to determine why past solutions failed. This is true for most difficult problems, because otherwise they would be easy. Step C also gets you started on thinking in terms of leverage points. Solutions fail when they push on low leverage points (LLPs).

A high leverage point is not a place in a system "where a small shift in one thing can produce big changes in everything." (Meadows, 1999, page 1) By popular definitions like this the Kyoto Protocol treaty would be a HLP, because signing the treaty is such a small change and the effect of implementing it would cause a large behavior change. *But what about the effort it takes to get the treaty signed and implemented?* So my definition of a HLP is a place in a system where a small amount of change force (the effort required to prepare and make a change) causes a large amount of predictable, favorable response and resolves the root cause. This is the familiar ratio of input to output. The root cause must be resolved, or the system will resist the solution so strongly and/or circumvent it so well you will be unable to marshal enough force to make your solution work or continue working.

LLPs are attractive, even to modelers, unless they are using something like the five substeps and are fully aware of the correct definition of a HLP. Otherwise there is a tendency to be unable to tell a LLP from a HLP, and they will fall into the trap of symptomatic solutions. As Forrester observed:

> "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, 1971, page 95, italics added)

The importance of pushing on high instead of low leverage points is a preferred strategy, as Forrester implies on page 119:

> "Two quite different kinds of action can be chosen in dealing with a complex system such as an urban area. One is to make a frontal assault with direct-action programs aimed at correcting deficiencies. A quite different approach is to alter the internal system which has created the deficiencies."

D. Find the feedback loops that should be dominant. – In this step you find the feedback loops that, if you could change them to be dominant, would resolve the root cause and solve the problem. These loops usually already exist but are weak. In some cases the loops may not exist at all, such as the way the voter feedback loop did not exist before democracy.

This step takes the modeler into a whole new direction, one missing from the popular process. The location of the LLPs and root causes will offer strong clues as to what loops should be dominant to solve the problem. The mental leap it takes to create the hypothesis of step D is *much* smaller that the mental leap required in the popular process. If fact, the mental leap in popular processes is so large it goes a long way toward explaining why the tool of system dynamics has not achieved its potential.

There were no loops in the World3 model that needed to go dominant to resolve the root cause. There were only those directly causing the problem. By contrast, in the urban decay model Forrester had the needed loops and identified them as those related to employment, new industry, and new housing. "The problem of the stagnant urban area is one of too much housing compared to employment opportunities and too much old industry and housing compared to new." (Forrester, 1971, page 71)

E. Find the high leverage points to make them go dominant. – Once you have found the loops that need to go dominant, step E says find the HLPs that, when pushed, will make them go dominant. This will solve the problem. Again, this is a small mental leap.

This step takes some ingenuity and contemplation, because you have so many points to choose from. *The trick is to take your clues from where the loops that need to go dominant are.* The HLPs should be close by. If not, you are veering toward a solution strategy that is going to be tenuous, because it will depend on too many structural connections from HLPs to dominant loops. Your modeling assumptions behind each connection have to be correct. The connections have to hold throughout the life of the solution. The path of connection has to be such that it is not easily circumvented by clever agents, or destroyed by disruptions to the system. The longer the path, the more likely it is that model behavior will differ from that in the real world, and the more work you will have to do to reduce that uncertainty to an acceptable level.

So try to pick short paths from the high leverage points to the loops that need to go dominant to solve the problem.

In the urban decay model the root cause was "new construction is suppressed by lack of land within the fixed and fully occupied area." This causes business decline, so the HLP is creation of land within the urban area, which would cause new business construction.

But in the World3 model there was no root cause. The model thus lacked any easy clues that would have led the LTG team or others to the HLPs. Even if the HLPs were found or added, there would be no way to use the model to prove they would resolve the root cause.

This completes review of the five substeps of step 2. Next is step 3.

Step 3. Solution Convergence – The System Understanding step builds a model and finds the right high leverage points. Using that knowledge, the Solution Convergence step *converges* on a solution to push on those points.

Thus Solution Convergence starts with the strategy that we know WHERE to push on the system. We just don't know HOW to push. But knowing WHERE to push makes this step several orders of magnitude easier. It's like:

> …the old story of the ocean liner engine that broke down. The ship's owner's called in one expert after another, but none of them could fix it. Finally they tried an old tinkerer who knew everything there was to know about ship's engines, especially big, old, cranky steam engines. He brought in a great big bagful of tools, plopped them down, and began inspecting the engine from top to bottom, climbing all over it. He was, however, dead silent as he worked. Finally, after about 30 minutes he reached inside his bag, pulled out a hammer, and gently tapped the engine somewhere. The engine instantly roared into life.
>
> A week later the old man sent the owner's a bill for ten thousand dollars. The owners were so upset they demanded an itemized bill. Another week went by and the itemized bill arrived in the mail. Here's what it said: "Tapping with a hammer, 2 dollars. Knowing where to tap, 9,998 dollars." (Urban, 2007)

There's a lesson in that story, and that lesson has been incorporated into the System Improvement Process. Step 2 is all about finding WHERE to tap. Step 3 is figuring out HOW to tap.

Tapping is pushing on one or more of the right high leverage points. Knowing WHERE to tap makes Solution Convergence ten times as easy as it normally is. Gone is all this nonsense of trying to brainstorm solutions out of thin air, or researching the literature, or consulting the so called experts. That doesn't work on difficult social system problems, *because their behavior is so* *complex and counter intuitive*. You have to go out and study the actual system and model it. There is no other way.

Because we know WHERE to push, the only question left is HOW to push. Usually there are several ways to push on a high leverage point. To find them you list the known ways, invent a few more if you have to, select the best, test then with experimentation, refine them a little, pick your final solution elements, and you're done. It's not quite that easy, but it's infinitely easier than the alternative of no HLPs to guide you as you scratch your head and wonder what you should try this time….

Because the HLPs have not been yet identified for the sustainability problem, environmentalists don't know where to push. This has forced them to try a host of intuitive solutions. But as the curve below shows, this has had negligible impact. (World Wildlife Fund, 2006)

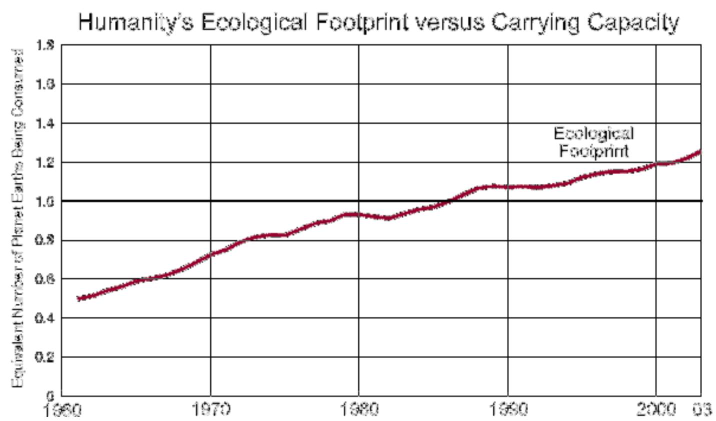


Figure 1

Step 4. Implementation – This step implements the solution in a rather clever way. The experiments that were used to test and prove the key assumptions of step 3 are simply scaled up to the size it takes to actually solve the problem. This is about as smooth and seamless as implementation can be, with the result that what's usually the hardest step, getting a solution to work, is the easiest. If you take a model and leverage point centric approach like the above steps and substeps, then you do not have to rely on brute force, rare genius, and lucky breaks to make step 4 work.

The real strength of the urban decay model was its behavior stemmed from the true root cause. Since the root cause was so well understood, the HLPs and solutions were easy to find and implement.

As the inventor of system dynamics and an accomplished analyst, Forrester was able to perform the above steps intuitively, without a formal process. But the rest of us need a tenacious "process elf" sitting on our shoulders, asking the right question at each fork in the road. SIP provides those questions, and you provide the answers.

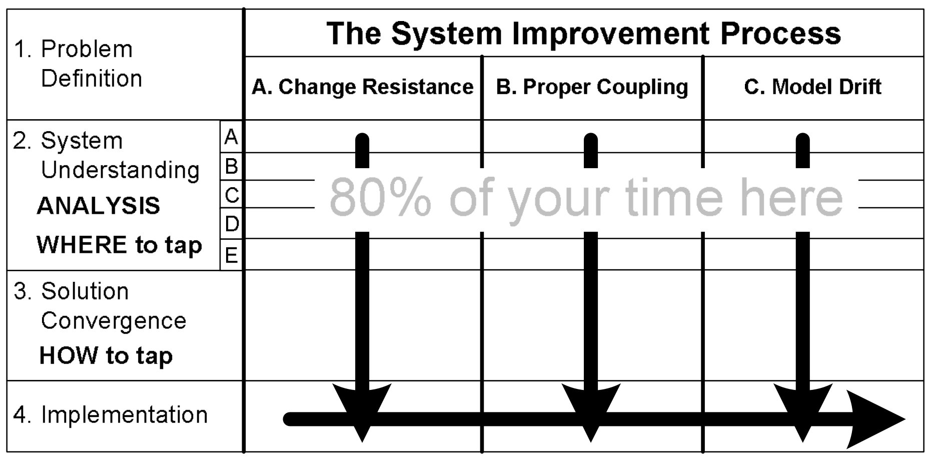
The Three Subproblems

There is a class of social problems so intractable they will not yield to the above process. This includes the long unsolved problems mentioned earlier: systemic poverty, war, discrimination, mal-distribution of wealth, and environmental sustainability. To solve problems like these, or even lesser problems like the diabetes epidemic, we need to add a second dimension to the process.

Earlier we argued that substep B, finding the root cause of why the dominant loops are dominant, is the most important substep of them all. It is the crux of your analysis, because if you have not found the true root cause, you will be unable to resolve it and thus cannot fully solve the problem.

Digging for root causes is so tricky and fraught with potential for hair pulling, frustration and failure that the System Improvement Process offers *three reusable subproblems*. These are the three columns in the process grid below. Each subproblem has a *much* easier to find root cause, because you are no longer attempting to find the root cause of all three problems simultaneously without realizing it. The same holds for the LLPs and HLPs.

Figure 2



The total problem only has to be defined once. Each column has 7 steps. This gives the process 22 highly organized sequential steps, each of which builds on what came before it. This carefully engineered decomposition is what gives SIP its raw analytical power.

This approach capitalizes on the old rule of “divide and conquer.” We’ve chopped one big problem up into three carefully designed little ones, which makes the total problem an order of magnitude easier to solve. First we overcome *change resistance* to changing the status quo. Then we solve the *proper coupling* problem, which is what actually eliminates the problem symptoms. After that we move on to the long term consideration of eliminating *model drift* to avoid solution obsolescence and problem recurrence. Because most people consider column B to be “the problem” and are unaware of columns A and C, they rarely solve column A first and they usually have great trouble solving the problem permanently.

You have the option of formulating your own subproblems, as well as tackling the subproblems somewhat in parallel. Here’s how the standard three columns work:

A. Change Resistance – Change resistance is the tendency for a person, organization, or system to resist change even when a surprisingly large amount of force is applied. Change resistance occurs when workable solutions (proper coupling practices) are conceived by problem solvers but not adopted. Thus if change resistance is high a problem will be difficult. You can try many solutions, and it seems some of them *should* work, but they don't. The system is resisting change.

In the urban decay problem, after the proper coupling model and analysis was complete, Forrester's group encountered change resistance. Because it was low, an informal analysis was sufficient to perform the system understanding step of column A. Forrester concluded that the root cause of change resistance was people did not understand the simulation model. The HLP was not a complete explanation of how the model worked, but an explanation of how popular solutions were making the problem worse, and how unconventional solutions could make it better. The solution itself was education about the analysis.

But in the environmental sustainability problem, things did not turn out as well.

The transformation of society to environmental sustainability requires three steps: The first is the profound realization that we must make the change, because if we don't our descendants are doomed. The second is finding the proper practices that will allow living sustainably. The third step is adopting those practices.

Society has faltered on the third step. By now the world is aware it must live sustainably, which is the first step. There are countless practical, proven ways to do this, which is the *technical side* of the problem and the second step. But for strange and mysterious reasons society doesn't want to take the final step and adopt these practices, which is the change resistance or *social side* of the problem. ***Therefore change resistance is the crux of the problem.***

In the global environmental sustainability problem it's easy to see we must live sustainably and that we (mostly) already know how to do that. But the world is not doing it. For example, in 1999 the US Senate voted an amazing 95 to zero against ratifying the Kyoto Protocol. Not a single senator could be persuaded to support the treaty, despite a democratic President and a strongly pro-environmental Vice President, Al Gore.

The sustainability movement has never explicitly tried to solve the change resistance subproblem. Blissfully unaware it must be solved first, they have instead focused on solving the proper coupling subproblem. Until this error is rectified the sustainability problem will remain unsolvable. That is, until a wake up call catastrophe so large occurs, or appears imminent, that society instinctively overcomes its own change resistance overnight. But by then it will be too late to avoid the consequences of prolonged overshoot….

B. Proper Coupling – Once change resistance is overcome, the system will "want" to solve the proper coupling part of the problem. Proper coupling means that two or more systems are properly coupled to each other, using the appropriate feedback loops, so the systems work together in harmony.

For example, if you never got hungry you would be improperly coupled to the world around you, and you would starve to death. The hunger feedback loop would be missing.

In large social problems two or more systems are improperly coupled to each other. In the environmental sustainability problem the human system is improperly coupled to the greater system is lives within: the environment. In the systemic poverty problem the two systems are people (each person is a system) and the rest of the human system. In the war problem there are three improperly coupled systems: those who benefit from war, those who are unaffected, and those who suffer from it. And so on.

In the urban decay problem the typical urban area was improperly coupled to the environment around it. This caused insufficient investment and the wrong mix of people to be attracted to the urban area in the stagnation phase. Forrester's concept of "relative attractiveness" [Forrester, 1969, page 18) describes the strength of the coupling forces between the two systems.

C. Model Drift – Excessive model drift occurs when, due to changes in a problem, a solution model drifts too far from what's needed to solve the problem. Once this occurs the solution will no longer work. Since all social systems are constantly evolving, excessive model drift must be prevented. The solution must be self-managing and self-evolving. Otherwise you are solving the same problem over and over, and are over taxed if you are facing multiple problems.

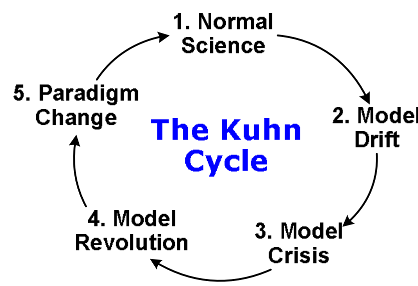


Figure 3 – Model drift is the second phase of the Kuhn Cycle. (Kuhn, 1962) Model drift has been added to the four phases Kuhn describes to make the cycle more fine grained and to allow that phase to be used as the third subproblem of SIP. Currently the field of system dynamics is in early model revolution.

In the sustainability problem the model we want to keep from drifting too far is the *social control model* nations use to run themselves. This model consists of a constitution, an accumulated body of laws, and the many unwritten cultural norms affecting political decisions. This is the democratic model (for most countries). Its goal is to optimize the common good. Clearly the model is broken and in crisis, because otherwise the sustainability problem would have been proactively solved long ago. Thus even if we are able to solve the change resistance and proper coupling parts of the problem, we need to change the social control model or the solution will be temporary.

Why was the urban decay problem never completely solved? Because the analysts were unaware of the need to solve the model drift subproblem. It was never addressed. As a result the new approach initiated by the Urban Dynamics project stagnated. The solution never became continuously self-evolving and self-improving. Sadly, the urban decay crisis was merely downgraded from a crisis to a problem. It was never entirely solved. Yes the riots in the US stopped. But we still have urban blight in most old large cities, all over the world, and we still have occasional riots, such as those in France in 2005 and 2007.

Applying SIP to the Sustainability Problem

Now that we've covered the entire process, let's take a whirlwind tour of how SIP has been applied to the global environmental sustainability problem, except for step 4. The summary of results is shown below.

Figure 4

1. Problem Definition	The System Improvement Process		
	A. Change Resistance	**B. Proper Coupling**	**C. Model Drift**
2. System Understanding **ANALYSIS** **WHERE to tap**	- **Root cause** is inherent structural advantage of the race to the bottom among politicians - **High leverage point** is general ability to detect political deception	- **Root causes** are low maturity of property rights and low quality of servant design, plus an unchangeable root cause. - **High leverage point** is motivation for the New Dominant Life Form to be sustainable	- The model of interest is the social control models that nations use to run themselves - **Root cause** of excessive model drift is quality of political decision making is too low - **HLP** is the process of political decision making
3. Solution Convergence **HOW to tap**	- Six solution elements - Works by strengthening an existing feedback loop: **You Can't Fool All of the People All of the Time**	- Ten solution elements - Works by strengthening the **Corporate Benevolence** and **Corporate Cooperation** loops	- Politician decision ratings - Works by providing voters with a missing feedback loop: **Politician Ratings**
4. Implementation	- Need to implement first - Will succeed if steps 2 and 3 are done well	- Best implemented after change resistance is resolved, because after that the system will want to be properly coupled	- Usually last, but do sooner if change resistance is overcome earlier than usual and it will speed up proper coupling

The power of the process is evident in the biggest surprise of the project: the results in all three columns are *generic*. They apply to far more than the sustainability problem. They apply to any problem whose solution would benefit the common good. If further work and experimentation proves the key *sample* conclusions to be sound, then these results may be of some interest.

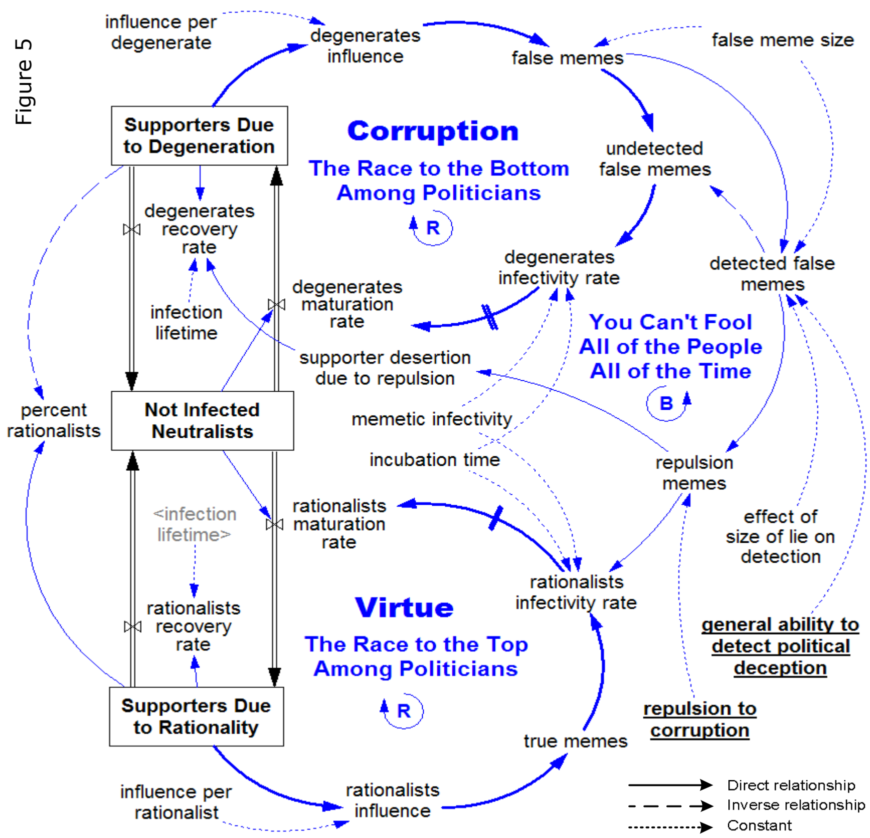
We say *sample* because none of this should be interpreted as *the* analysis or *the* solution, or even *the* process. It's only *an example* of a better way forward.

The results are so generic because the process guided the analyst step-by-little-step all the way, transforming one big monster of an impossible problem into 22 itty bitty problems that were so small and structured they were easily solved, *and solved at the deepest level of abstraction possible*. This is what made them generic and therefore much more likely to work.

Let's take a brief look at each column to see how this was done.

The Dueling Loops of the Political Powerplace

Figure 5



Above is the basic analysis model for column A. The driving question is how to overcome change resistance to adopting the proper practices needed to live sustainably. Analysis shows the dominant loop causing change resistance is **The Race to the Bottom among Politicians**. (**Substep A**) The structural features of the loop allow special interests, notably corporations and the rich, to control politicians, who in turn control their supporters with falsehoods and favoritism. The root cause (**Substep B**) of dominance of the race to the bottom is its inherent structural advantage over its opposite, the race to the top. The size of false memes can be inflated but the truth (true memes on the model) cannot. (A meme is a mental belief you learned from others. See Dawkins, 1976.) For the same amount of effort a corrupt politician can win more supporters than a virtuous one. This inherent advantage causes the race to the bottom to be the dominant loop most of the time.

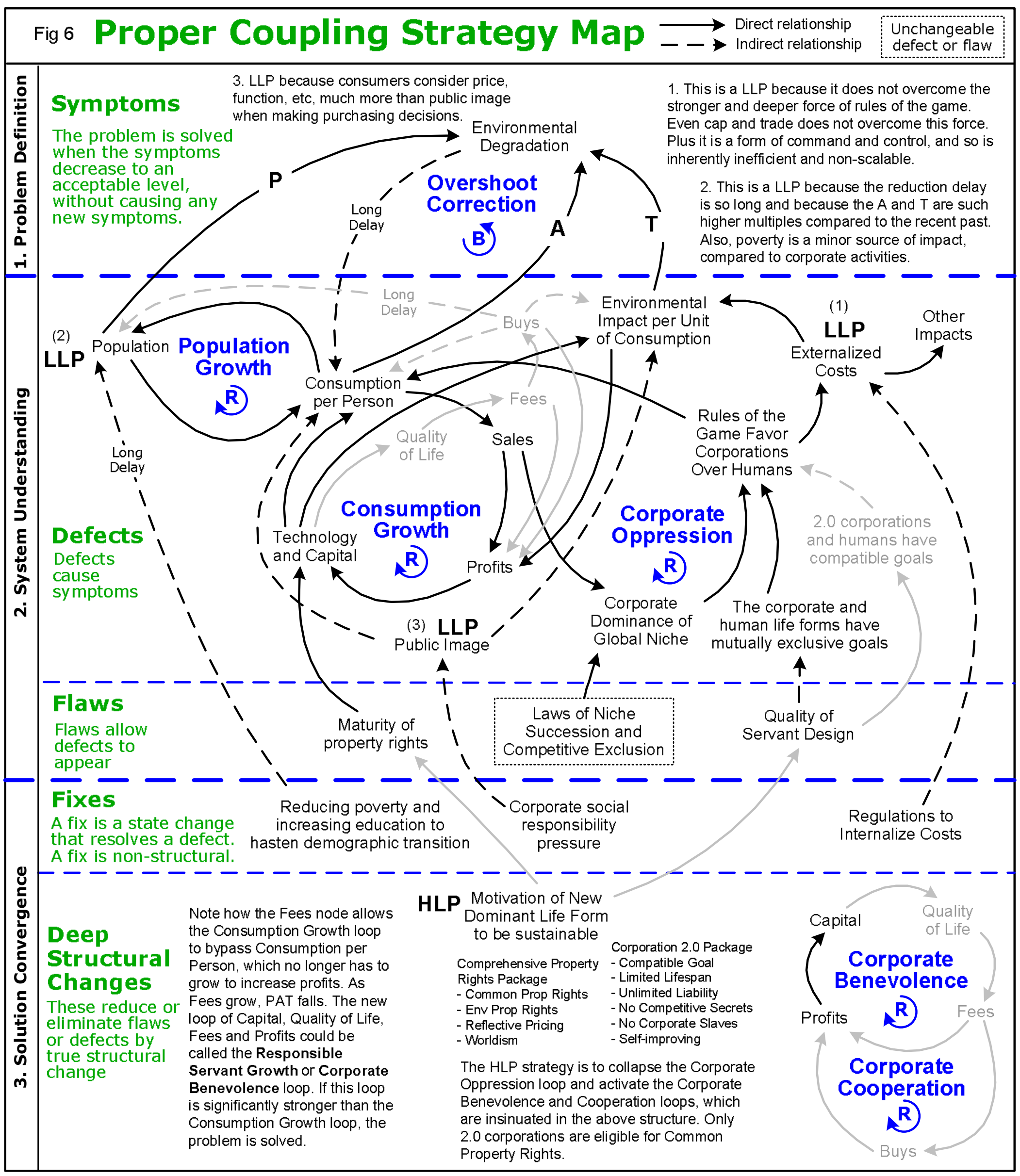
The race to the top contains the attractive LLP environmentalists have been pushing on for decades without realizing it: the true meme node (**Substep C**) Problem solvers have been pushing there with a solution strategy of "more of the truth," which fails because of the inherent advantage of the race to the bottom. The race to the top needs to go dominant to resolve the root cause. (**Substep D**) The HLP that can do that is general ability to detect political deception. (**Substep E**) Presently this is low. It needs to be high to flip the system into a dominant race to the top.

The Proper Coupling Strategy Map

Figure 6 is the strategy map (derived from Kaplan, 1996) used to execute the process on column B. The generic version of work in progress is shown.

You start at the top of a blank SIP strategy map and work down. The dominant loops produce the symptoms. The root causes are the flaws allowing defects to appear. The LLPs attempt to resolve the defects directly. The fixes are the symptomatic solutions. The HLP resolves the root causes, by changing the flaws such that the motivation of the corporate life form now includes being sustainable. Solution convergence leads to the solution elements that will provide the deep structural changed need to resolve the root causes.

The strategy map approach lets you summarize all of SIP steps 2 and 3 on a single page. This makes it much easier to manage the conceptual integrity so necessary to preserve the quality of the work effort. The first pass does not require simulation modeling. When you're done the map summarizes your analysis, models, the rationale behind them, and your solution strategy.

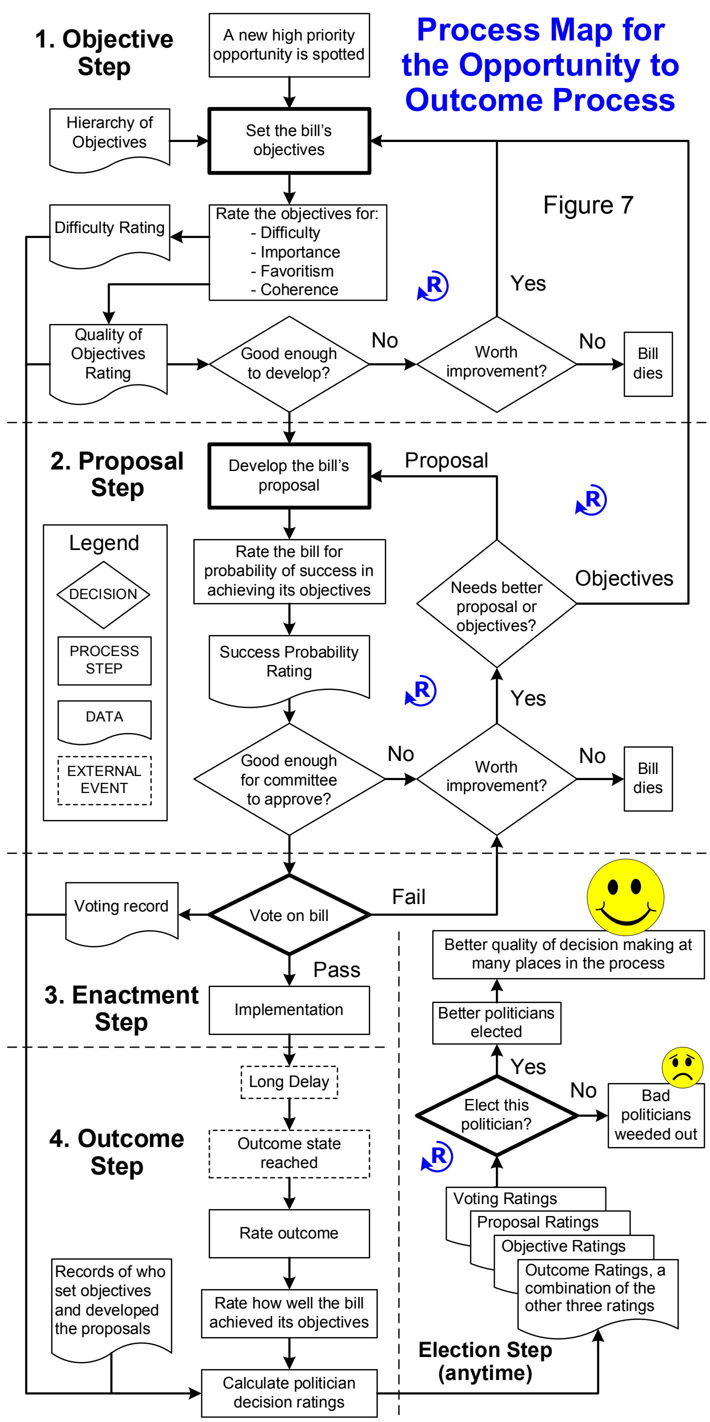


Solving the Model Drift Subproblem

Extension of the Dueling Loops model shows the root cause of model drift is quality of political decision making is too low. The HLP is the process of political decision making. Solution convergence reveals one way to push on the HLP is politician decision ratings. Their objective is to improve the political decision making ability of governmental social control models, to the point where: (1) the models are self-improving so future model drift is avoided, and (2) the models can routinely proactively solve difficult problems like sustainability. How decision ratings could be implemented is shown in figure 7.

Today's governments have nothing like this. Governmental decision making processes lack the feedback loops necessary for citizens to make rational dsecisions about who deserves the credit for good outcomes and the blame for bad ones. Worse yet, governments themselves lack this vital information. *The result is that leaders are elected or selected based mostly on their ability to sell themselves, rather than on actual ability to manage a political system*. The result is low quality management, so low it cannot reliably solve difficult problems proactively and cannot adequately evolve tricky solutions, which leads to excessive model drift.

Compare this to the way corporations pick their leaders. The performance feedback loops are extensive. Hard number on outcomes and contributions are available for manager's entire careers. The result is leaders are selected based on proven ability to manage, difficult problems are routinely solved proactively, and they usually stay solved, due to low model drift.



Summary and Conclusions

The process grid illustrates how all three subproblems are required for a comprehensive, mature process capable of producing breakthroughs:

Column A: Without the principles that *change resistance is the crux of most difficult social problems* and *a problem cannot be solved without resolving its root cause,* what may be the root cause of inability to solve the sustainability problem would have never been found.

Column B: Without the principles that *improperly coupled systems will not work together in harmony* and *a problem cannot be solved without resolving its root cause,* problem solvers will probably never discover the true root cause of improper coupling, and the world may never discover coupling solutions (like those on the strategy map) that work an order of magnitude better than the popular, intuitively derived solutions of today.

Column C: Without the principle *if model drift is not eliminated a difficult social problem will probably recur*, global society will find itself unable to simultaneously solve the many major problems it faces, only one of which is the environmental sustainability problem. Society may never discover the crucial need to radically improve political decision making ability.

These findings should vividly illustrate the potential of a standard high yield process to produce the breakthrough insights necessary to solve difficult social problems. By following a process that fits the problem, we have arrived at a radically deeper and more correct level of understanding. In fact, if further work shows the work of columns A, B and C to be sound or leads to new analyses that are, then the sustainability problem has switched from insolvable to solvable.

Both the conclusions in this paper and the path that took us there are so far from conventional wisdom they qualify as a new paradigm. *It is deep, massive paradigm change like this that is required if the field of system dynamics is to successfully lead the charge to solving the world's most pressing social problems.* Otherwise the field will continue to wonder on an "aimless plateau," (Forrester, 2007) and will continue its long slide into irrelevance.

There will be paradigm change resistance within our field. There always is, once the turbulence of the paradigm revolution phase of the Kuhn Cycle has begun in earnest. This is why Arthur Schopenhauer, the 19th century German philosopher, allegedly said:

> "All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as self-evident."

The process must fit the problem. The more difficult the problem the better the process must be. These two principles, combined with the realization we are starting out at low process yield, should serve to answer the question now haunting our field: "Why is there so little impact of system dynamics in the most important social questions?"

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