

The Development of Social Complexity: Models of Collapse, Resiliency, and Sustainability

Joseph A. Tainter
Rocky Mountain Research Station
Albuquerque, New Mexico, U.S.A.

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Allow me to begin by referring to two common trends in contemporary thought. One is the tendency of policy-makers, managers, and journalists, at least in my country, to look only to the recent past in seeking to understand the origins of today’s problems. The other is the idealistic belief that the threats to humanity’s future arise from our consumption of biophysical resources, and that sustainability can arise from using less of these.

I begin my discussion of the first trend by referring to the research of Bette Denich, an anthropologist who has worked in the Balkans. She was in Yugoslavia in the late 1980s, during the crisis that led ultimately to the breakup of the country and a decade of war. Her observations on the causes of that war strike me as particularly astute. After the quadrupling of oil prices in 1973, banks, suddenly awash in petrodollars, made billions of dollars in questionable loans. Yugoslavia, like many nations, assumed massive foreign debts. The leaders of the constituent republics invested these funds in construction projects that would have uncertain economic returns. A boom in the 1970s was followed by a repayment crisis in the 1980s. Economic contraction soon coincided with high rates of inflation. Many Yugoslavs still prospered by such strategies as becoming guest workers in western Europe. Yet the economy was permeated with debt at the same time that the ideology of Titoism was being supplanted by that of ethnonationalism. Young adults seeking to enter the work force, and establish families, are among the most vulnerable in such a crisis. Thousands of economically marginalized young men

found a role in the Slovene, Croatian, Bosnian, Albanian, and Serb armed forces that fought the Yugoslav wars.

Denich's account is more nuanced than simple economics. She shows how economic crisis coincided with political and ideological transformation to produce the Yugoslav conflict. What I find most compelling in her account, and most chilling, is the image of thousands of young men fighting this war without comprehending its origin in an economic transformation that took place at the time of their births.

Denich's account of the breakup of Yugoslavia illustrates why we should never be satisfied to search only the recent past to find the reasons for today's challenges. Every so often the world produces a prescient individual who can not only connect the present to the past, but the present to the future as well. In 1919, Wil Dyson published in *The Daily Telegraph* a cartoon of the Paris Peace Conference that was then underway. In this extraordinary cartoon, he not only foresaw that the peace conference would produce World War II, he predicted the date to within a year.

These anecdotes are telling, but they illustrate processes that have lags of only a generation. In fact I hope to show today that the factors that produce sustainability in a society, or its absence, may develop over periods extending from decades to centuries. We cannot comprehend whether or not we are sustainable, I argue, unless we understand these historical trends and our position within them.

My second theme concerns the common assumption that the key to future sustainability is lower consumption of resources. To avoid possible misunderstandings, I will say that I am sympathetic to this view. My criticism arises from its simplicity. The relationship of environmental condition to human sustainability is complicated and indirect. The relationship is

mediated by human capacities in problem solving. Sustainability is not the achievement of stasis, nor is it a passive consequence of producing fewer people or consuming more limited resources. One must work at being sustainable. The challenges to sustainability that confront any society are, for practical purposes, endless in number and infinite in variety. If we could somehow reduce our *per capita* resource consumption to that of our hunter-gatherer ancestors, we still could not guarantee sustainability. Sustainability is an active condition of problem solving, and it is the effectiveness of problem solving that we must comprehend.

Long-term changes in problem solving influence, or even determine, the success or failure of sustainability efforts in the long run. Problem solving can have subtle and deleterious effects, for a solution that is successful now may set the stage for future failure. The success or failure of problem solving, I argue, is in part a function of the complexity of the effort.

We usually think that our success as a species comes from such characteristics as upright posture, an opposable thumb, and a large and richly-networked brain. We are successful in large part because these features allow us rapidly to increase the complexity of our behavior. At the same time, we are paradoxically averse to complexity. In the full spectrum of hominid history—four million years or so—complexity is recent and rare. This is because every increase in complexity has a cost. The cost of complexity is the energy, labor, money, or time that is needed to create, maintain, and replace systems that grow to have more and more parts, more specialists, more regulation of behavior, and more information. The anthropologist Leslie White once estimated that a society based primarily on solar energy could generate only about 1/20 horsepower per capita per year. This is all the energy such a simple society needs. Today such a quantity of energy would not suffice for even a fleeting moment of complex, industrial life.

Before the development of fossil fuels, increasing the complexity and costliness of a society meant that *people* worked harder.

There is a simple yet powerful aspect of cultural complexity that is uniquely human: *people give meaning to complexity*. We assign value to it. People care about how complex their lives are, and whether their government and other institutions are worth what they cost. No other living system has this characteristic. Neither Darwin's finches, nor chimpanzees, nor any other organism or population contemplates abstractly the complexity of its behavior. We are the only species that can increase the complexity of its behavior, and then debate whether we were right to do so. The human capacity to give meaning to complexity is closely linked to its costs. We are often averse to complexity precisely because of its costs. The reasoning behind sayings like “Keep it simple” is universally understood. The so-called “complexity of modern life” is a favorite topic of journalists and their readers. One reason why we have low participation in elections is that the value of a single vote does not appear to offset the cost of mastering complex issues.

The dilemma of problem solving arises from the unremarkable tendency to develop solutions that are simple before those that are complex, adaptations that are labor-sparing before ones that are intensive, and strategies that are inexpensive before those more costly. We see this tendency in cultural evolution: We have changed from societies that were undifferentiated and egalitarian to ones that are specialized, hierarchical, and highly integrated. We have changed from labor-sparing foraging to labor-intensive agriculture, to today's industrial agriculture that consumes more energy than it produces.

Humanity has developed this way because complexity—by which I mean differentiation in structure and organization—is a primary problem-solving tool. We regularly respond to

challenges by developing more complex technologies; adding more specialists or bureaucratic levels; increasing organization or regulation; or gathering and processing more information. Complexity is effective in part because such changes can be implemented rapidly. Our problem-solving institutions are powerful complexity generators. Complexity tends to be cumulative, always adding to what was developed before. When problems are addressed, increments to complexity may seem small and affordable. Unforeseeable cumulative effects do the damage.

Viewing complexity as an economic function, in which costs are assumed for benefits to be gained, allows us to understand how problem solving leads to sustainability or collapse. As problem solving grows in complexity and costliness inevitably it reaches diminishing returns, where increments to complexity produce increases in costs that fail to yield commensurate returns. Historical societies that have progressed far down a path of diminishing returns to complexity have experienced disaffection of the support population and fiscal weakness, where ordinary problems can no longer be overcome. A prolonged period of diminishing returns to complexity in problem solving can make a society unsustainable.

While this process sounds mechanistic, history rarely is. Long-term developments in problem solving can have divergent outcomes, which are illustrated in the fifth century collapse of the Western Roman Empire, the revival of the Byzantine Empire in the seventh century, and European warfare of the past half millennium. These cases are especially useful because they clarify possible outcomes for present and future problem solving.

The economics of an empire such as the Romans assembled are seductive but illusory. The returns to any campaign of conquest are highest initially, when the accumulated surpluses of the conquered peoples are appropriated. Thereafter the conqueror assumes the cost of

administering and defending the province. These responsibilities may last centuries, and are paid for from yearly agricultural surpluses.

The Roman government was financed by agricultural taxes that barely sufficed for ordinary administration. When extraordinary expenses arose, typically during wars, the precious metals on hand frequently were insufficient. Facing the costs of war with Parthia and rebuilding Rome after the Great Fire, Nero began in 64 A.D. a policy that later emperors found irresistible. He debased the primary silver coin, the denarius, reducing the alloy from 98 to 93 percent silver. It was the first step down a slope that resulted two centuries later in a currency that was worthless and a government that was insolvent.

In the half-century from 235 to 284 the empire nearly came to an end. There were foreign and civil wars almost without interruption. The period witnessed 26 legitimate emperors and perhaps 50 usurpers. Cities were sacked and frontier provinces devastated. The empire shrank in the 260s to Italy, the Balkans, and North Africa. By prodigious effort the empire survived the crisis, but it emerged at the turn of the fourth century A.D. as a very different organization.

In the late third and early fourth centuries, Diocletian and Constantine designed a government that was larger, more complex, and more highly organized. They doubled the size of the army. To pay for this the government taxed its citizens more heavily, conscripted their labor, and dictated their occupations. Villages were responsible for the taxes on their members, and one village could even be held liable for another. Despite several monetary reforms a stable currency could not be found. As masses of worthless coins were produced, prices rose higher and higher. Money-changers in the east would not convert imperial currency, and the government refused to accept its own coins for taxes.

With the rise in taxes, population could not recover from plagues in the second and third centuries. There were chronic shortages of labor. Marginal lands went out of cultivation. Faced with taxes, peasants would abandon their lands and flee to the protection of a wealthy landowner. By 400 A.D. most of Gaul and Italy were owned by less than a dozen senatorial families.

From the late fourth century the peoples of central Europe could no longer be kept out. They forced their way into Roman lands in western Europe and North Africa. The government came to rely almost exclusively on troops from Germanic tribes. When finally they could not be paid, they overthrew the last emperor in Italy in 476.

The strategy of the later Roman Empire was to respond to a near-fatal challenge in the third century by increasing the size, complexity, power, and costliness of the primary problem-solving system—the government and its army. The higher costs were undertaken not to expand the empire or to acquire new wealth, but to maintain the status quo. The benefit/cost ratio of imperial government declined. In the end the Western Roman Empire could no longer afford the problem of its own existence.

The Eastern Roman Empire (usually known as the Byzantine Empire) survived the fifth century débâcle. Efforts to develop the economic base, and to improve the effectiveness of the army, were so successful that by the mid sixth century Justinian (527-565) could engage in a massive building program and attempt to recover the western provinces.

By 541 the Byzantines had conquered North Africa and most of Italy. Then that year bubonic plague swept over the Mediterranean for the first time. Just as in the fourteenth century, the plague of the sixth century killed from one-fourth to one-third of the population. The loss of taxpayers caused immediate financial and military problems. In the early seventh century the

Slavs and Avars overran the Balkans. The Persians conquered Syria, Palestine, and Egypt. Constantinople was besieged for seven years.

The emperor Heraclius cut pay by half in 616, and proceeded to debase the currency. These economic measures facilitated his military strategy. In 626 the siege of Constantinople was broken. The Byzantines destroyed the Persian army and occupied the Persian king's favorite residence. The Persians had no choice but to surrender all the territory they had seized. The Persian war lasted 26 years, and resulted only in restoration of the status quo of a generation earlier.

The empire was exhausted by the struggle. Arab forces, newly converted to Islam, defeated the Byzantine army decisively in 636. Syria, Palestine, and Egypt, the wealthiest provinces, were lost permanently. The Arabs raided Asia Minor nearly every year for two centuries, forcing thousands to hide in underground cities. Constantinople was besieged each year from 674 to 678. The Bulgars broke into the empire from the north. The Arabs took Carthage in 697. From 717 to 718 an Arab force besieged Constantinople continuously for over a year. It seemed that the empire could not survive. The city was saved in the summer of 718, when the Byzantines ambushed reinforcements sent through Asia Minor, but the empire was now merely a shadow of its former size.

Third and fourth century emperors had managed a similar crisis by increasing the complexity of administration, the regimentation of the population, and the size of the army. This was paid for by such levels of taxation that lands were abandoned and peasants could not replenish the population. Byzantine emperors could hardly impose more of the same exploitation on the depleted population of the shrunken empire. Instead they adopted a strategy that is truly rare in the history of complex societies: systematic simplification.

Around 659 military pay was cut in half again. The government had lost so much revenue that even at one-fourth the previous rate it could not pay its troops. The solution was for the army to support itself. Soldiers were given grants of land on condition of hereditary military service. The Byzantine fiscal administration was correspondingly simplified.

The transformation ramified throughout Byzantine society. Both central and provincial government were simplified, and the costs of government were reduced. Provincial civil administration was merged into the military. Cities across Anatolia contracted to fortified hilltops. The economy developed into its medieval form, organized around self-sufficient manors. There was little education beyond basic literacy and numeracy, and literature itself consisted of little more than lives of saints. The period is sometimes called the Byzantine Dark Age.

The simplification rejuvenated Byzantium. The peasant-soldiers became producers rather than consumers of the empire's wealth. By lowering the cost of military defense the Byzantines secured a better return on their most important investment. Fighting as they were for their own lands and families, soldiers performed better.

During the eighth century the empire re-established control of Greece and the southern Balkans. In the tenth century the Byzantines reconquered parts of coastal Syria. Overall after 840 the size of the empire was nearly doubled. The process culminated in the early eleventh century, when Basil II conquered the Bulgars and extended the empire's boundaries again to the Danube. The Byzantines went from near disintegration to being the premier power in Europe and the Near East, an accomplishment won by decreasing the complexity and costliness of problem solving.

Arms races are the classic example of diminishing returns to complexity. Any competitive nation will quickly match an opponent's advances in armaments, personnel,

logistics, or intelligence, so that investments typically yield no *lasting* advantage or security. The costs of being a competitive state continuously rise, while the return on investment inexorably declines.

In Europe of the fifteenth century, siege guns ended the advantage of stone castles. Fortifications were developed that could support defensive cannon and that could also survive bombardment. These new fortifications featured low, thick walls with angled bastions and extensive outworks. They were effective but expensive: Siena built such fortifications against Florence, but was annexed anyway when no money was left for its army.

Open-field warfare also developed greater complexity. Massed archers and the pike phalanx made the armored knight obsolete. These were soon superseded by firearms. Effective use of firearms took organization and drill. Victory came to depend not on simple force, but on the right combination of infantry, cavalry, firearms, cannon, and reserves.

War came to involve ever-larger segments of society and became more burdensome. Several European states saw the sizes of their armies increase tenfold between 1500 and 1700. Yet land warfare became largely stalemated. The new technologies, and mercenaries, could be bought by any power with money. When a nation threatened to become dominant, alliances would form against it. Defeated nations quickly recovered and were soon ready to fight again.

Warfare evolved into global flanking operations. The development of sea power and acquisition of colonies became part of stalemated European warfare. Yet expanding navies entailed further problems of complexity and cost. In 1511, for example, James IV of Scotland commissioned the building of the ship *Great Michael*. It took almost one-half of a year's income to build, and ten percent of his annual budget for seamen's wages.

In 1499 Louis XII asked what was needed to ensure a successful campaign in Italy. He was told that three things alone were required: money, money, and still more money. As military affairs grew in size and complexity finance became the main constraint. The cost of putting a soldier in the field increased by 500 percent in the decades before 1630. Nations spent more and more of their income on war, but it was never enough. The major states had to rely on credit. Even with riches from her New World colonies, Spain's debts rose 3,000 percent in the century after 1556. War loans grew from 18 percent interest in the 1520s to 49 percent in the 1550s.

European competition stimulated great complexity in the form of technological innovation, development of science, political transformation, and global expansion. To subsidize European competition it became necessary to secure the produce of foreign lands, and later fossil and nuclear fuels. New forms of energy, and non-local resources, were channeled into this small part of the world. This concentration of global resources allowed European conflict to reach heights of complexity and costliness that could never have been sustained with European resources alone.

These cases illustrate divergent outcomes to long-term problem solving, and different scenarios for the success or failure of any problem solving system. The scenarios are collapse; resiliency and recovery through simplification; and sustainable problem solving based on increasing complexity subsidized by new resources. These scenarios provide models for the development of problem-solving institutions.

In the *Roman Model*, problem solving drives increasing complexity and costs that cannot be subsidized by new sources of energy. In time there are diminishing returns to problem solving. Problem solving continues by extracting higher levels of resources. Fiscal weakness and disaffection of the population in time compromise problem solving and initiate collapse.

In the *Byzantine Model*, the institution, perhaps no longer having resources to increase complexity, systematically simplifies. Costs are reduced and the productive system is enhanced. It is a resilient strategy that in the Byzantine case allowed for fiscal recovery and eventual expansion. This is also the strategy employed by many American firms over the past 20 years, where simplification of management and elimination of costs contributed to competition and recovery.

Finally, there is the *European Model*, in which we still participate. Problem solving produces ever-increasing complexity and consumption of resources, regardless of long-term cost. The Europeans succeeded in part through competition-induced ingenuity, but also through luck. Over the horizon they found new resources that could be turned to European advantage. Today we fund complexity and problem solving through fossil and nuclear fuels. We have sustained this strategy to date, but it is important not to downplay the role of luck. Had European luck proved otherwise, the world today would be a very different place.

The framework linking social complexity to sustainability, and these historical studies, convey several lessons about sustainability in a human system. These are:

1. Sustainability is an active condition of problem solving, not a passive consequence of consuming less.
2. Complexity is a primary problem-solving tool, including problems of sustainability.
3. Complexity in problem solving is an economic function, and can reach diminishing returns and become ineffective.
4. Complexity in problem solving does its damage subtly, unpredictably, and cumulatively over the long term. Sustainability must therefore be a historical science.
5. A society or other institution can be destroyed by the cost of sustaining itself.

6. Sustainability may require greater consumption of resources rather than less. One must be able to afford sustainability.

7. The members of an institution may resort to resiliency as a strategy of continuity only when the option of sustainability is foreclosed.

The overriding lesson is that a primary characteristic of a sustainable society is that it will have sustainable institutions of problem solving. These will be institutions that give stable or increasing returns, or diminishing returns that can be subsidized by energy supplies of assured quality, quantity, and cost. Problem-solving systems follow trajectories that take decades, generations, or centuries to complete. Problem solving can produce stable, increasing, or diminishing returns, or it can produce all three at different points in time. Complexity that emerges through problem solving is vital for sustainability, yet may also undermine it. The difference between these outcomes emerges in part from where the problem-solving system lies on an evolving benefit/cost trajectory.

Part of understanding whether or not we are sustainable lies in what I call “knowing where we are in history.” If sustainability is a function of problem solving, and complexity influences the effectiveness of problem-solving efforts, then it becomes important to understand where specific problem-solving institutions lie on an evolving benefit-cost trajectory. As examples of the effects of complexity today, I will briefly discuss the evolution of problem solving on a small scale, a government bureau, and much larger scales. First consider my own agency, the U.S. Forest Service. Land management efforts today are frequently impeded by the public. Public opinion is diverse and often self-serving, and in a democracy there are many opportunities to suggest, appeal, and litigate governmental decisions. As a consequence, a land managing agency today achieves much less environmental management per unit expenditure

than was the case a generation ago. Public participation in government decisions generates a competitive spiral, much like an arms race. The more the public disputes decisions the more agencies must invest in justifying decisions, in training their employees in public relations, and in litigation. As agencies get better in the public arena and in court, those challenging decisions must themselves invest more resources in their cause, and devote more effort to securing those resources. It becomes more complex and costly both to promulgate decisions and to dispute them. Yet in a democracy, not to allow public participation is unthinkable. Complexity in decision-making is part of the cost of democratic politics. Some people argue that the decisions made by this tortuous process are better than they would be otherwise. This may often be so, but to satisfy ourselves with better decisions is to miss an important point. Are today's decisions *better enough* to warrant the extra complexity and cost? We do not know, but if they are not then environmental management is producing diminishing returns and is a less efficient problem-solving institution.

We may also use these principles to understand much larger problems that we face. Consider first the response in the United States and elsewhere to the attack of September 11, 2001. Much of the immediate response to the problem of preventing future attacks has involved increasing the complexity of public institutions, by establishing new agencies, absorbing existing ones into the federal government, and expanding the scale and degree of control over realms of behavior from which a threat might arise. Such changes can be implemented more rapidly than can changes in the technology to detect explosives in air travel baggage, in military technology, or in the technology and other techniques of espionage. There has been, in the U.S., little public discussion of the *total* economic cost of enhanced security. When a major sector of public investment, such as security, increases suddenly in its complexity and costliness, the share of

economic product available to other sectors declines. This ultimately affects the standard of living.

In the investigation of the attack, it was learned that suspect organizations were moving money through the investment vehicles known as mutual funds. In response, mutual fund corporations are now required to check the identity of new investors, and ensure that they are not on a master list of suspects. The cost of opening an account will grow. This is an example of how complexity develops: It grows by small steps, each necessary, each a reasonable solution to a problem. The extra costs of solving the problem seems affordable. The damage comes from cumulative costs, which are typically unrecognized as such.

Consider next the complex of transformations in climate and environment that are known collectively as global change. Nothing before in our history equals contemporary global change in magnitude, speed, and numbers of people affected. In the research that we need to comprehend it, in the economic dislocation that it will entail, in the new technologies that we will need, and in increasing government centralization and regulation, global change will require increases in the complexity of problem solving, and in societal expenditures, that are presently beyond calculation. As was the case with the later Roman Empire, we will undertake these expenditures merely to maintain the status quo, raising the possibility that adjusting to global change will produce a lower standard of living.

This may be the future of many of our investments: ever-higher expenditures merely to maintain what we have. It is possible to foresee this in major sectors of societal investment, such as replacing infrastructure, health care, retirement pensions, and military expenditures. Such expenditures are part of the cost of complexity. One danger of a future filled with such expenditures is the conflict between an ideology of endless bounty and opportunity (as people in,

for example, the U.S. believe) and the reality of a standard of living that may stagnate or decline. People in such a situation are vulnerable to demagogues. We must recognize that one possibility in such a future is Yugoslavia on a wider scale. The obvious question is: How might we avoid this? There is no simple prescription for doing so, however much I might wish that I could offer one. I suggest that the first step is to understand how, over the long-term, inevitably-increasing complexity may enhance or undermine sustainability, and to begin now realistically to assess the future of our problem-solving institutions.