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**Title:** System Dynamics, Alternative Futures, and Scenarios

This paper explores the intersection of system dynamics and futures studies with particular emphasis on the application of system dynamics modeling for identifying and developing alternative futures. This paper proposes that, consistent with the emergence of scenario planning to describe planning based upon alternative futures, the system dynamics community should use the term sensitivity analysis to describe testing of models through variation of parameters and reserve the term scenario analysis (or similar verbiage) to describe work involving alternative structures (and futures).

### Some Questions for the Reader

**Do you consider the future to be more like:**

- a) **a roller coaster** *with dips and turns, but if you know where you are and how fast you are going you can predict where you will be in the future*
- b) **a hot air balloon ride** *you may have some influence but you are basically at the mercy of the wind such that the future becomes chance*
- c) **a canoe on a river** *the banks define your possible path but your decisions and actions give you some ability to determine your path within those bounds*
- d) **a sailboat at sea** *if you know where you are and where you want to go, you can go pretty much anywhere, but the path will not be straight and you should expect to have to make adjustments along the way*

Your answer to this question provides insight into how you approach the future. As practitioners of system dynamics I would hope that all of us would answer either c) or d). Responding that the future is like a roller coaster implies that the future is unavoidable and unchangeable. The future is defined by the tracks. As system dynamics gives insight into behavior to provide insight for decision making and setting policy, it is implied that the future can be influenced. Responding that the future is totally chance implies that current actions have little or no influence on the future, making study futile. As system dynamic professionals I would hope that we all believe that our work can proactively influence the future, making the canoe or the sailboat the most appropriate selection.

A second question provides additional insight.

**Do you believe it is possible predict the future?**

To some extent this is certainly true. Short term events over which you have substantial control can often be reliably anticipated. As the time window of the prediction shifts forward, as the complexity of the issue rises, and as control declines, the reliability of predictions falls dramatically. Similarly, the accuracy of predictions declines as the

specificity of the prediction rises. Economists, tabloid prognosticators, corporate planners, and weathermen serve as icons to the futility of long range prediction.

### **The Fallacy of Forecasting**

The success of Newtonian thinking in advancing scientific research and knowledge built an expectation of predictability, reductionist problem solving, and expectations that our ability to predict was only limited by our knowledge of a situation. Frederick Taylor's writings on Scientific Management brought reductionist thinking into business management and arguably provided a basis for the booming economic success of U.S. manufacturing in the twentieth century. The belief in predictability inherent in this thinking led economists and business planners to form singular "most likely" forecasts. When forecasts failed, the failure undoubtedly resulted from "not having enough information or adequate accuracy in the data."

For the past hundred years, forecasts have been typically based upon historical data, emphasizing current trends and conditions, and projecting forward with singular "most likely" values for key parameters. In more sophisticated circles uncertainties about key values provided a basis for sensitivity analysis.

### **System Dynamics Modeling**

Typical system dynamic modeling projects evolve toward models based upon a single group-consensus structure. While this can be satisfactory for many purposes, I find the single structure an exciting basis for exploring the paradigms and assumptions of the group and for considering the events, issues, and trends which could "break" the model as new structures assume dominance. In my experience this does not mean "varying the parameters in the existing model (which is more properly referred to as sensitivity analysis) but rather involves testing the assumptions of the model from a futurists perspective of trends, issues, and alternative futures. (Note: The assumptions in system dynamics model can be found in both the structures included in the model and those excluded from the model.) The following sections provide insight into the futures studies approach to the future.

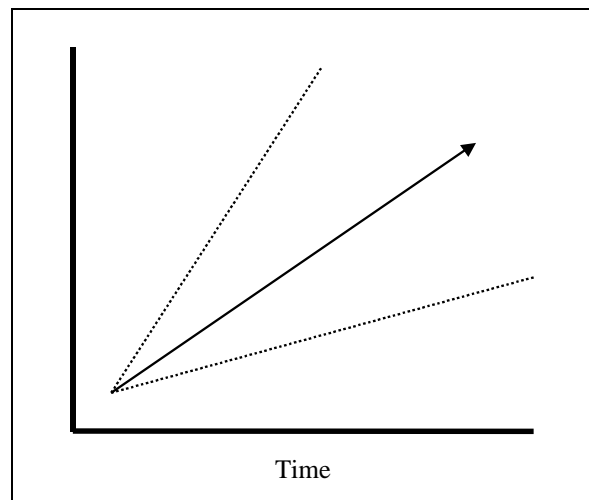
### **The Basis of Alternative Futures**

In the late 1940's the United States military recognized that conventional forecasting and planning were not working, particularly with respect to technological forecasting with respect to weapons development. Several small groups began to explore alternative methods for forecasting. Over time these groups developed and refined methods of forecasting which produced much richer and useful visions of the future. In the 1960's and 70's these methods collectively came to be known as futures studies. Systems thinking has contributed significantly to the development of futures studies. Some of the key concepts to emerge from this work are:

- **The most probable future IS NOT the most likely future.** The most probable future rarely has a probability exceeding 50 percent making “anything else” the most likely future.
- **Major deviations from the anticipated future typically arise from trends and events outside the vision or awareness of the forecaster.** From a systemic viewpoint, feedback and displacement of effects in time and space often contribute to these impacts.
- **Virtually random events often play key roles in the departure from the anticipated future.** We have all faced decisions where we had little preference between the alternatives, but the outcome shaped our lives. These decisions may seem trivial at the time.

The implication of these concepts is that the “structure” of the future changes over time. The basis for the paradigms of the past cease to function and often impair recognition of the emerging trends, issues, and structures which will shape the future.

Rather than speaking of a single anticipated (or most likely) future, futures studies blends existing trends with uncertainties to create a range of alternative futures. By examining both sides of the uncertainties and considering the cross-impacts of multiple uncertainties a range of possible futures can be identified. Futures studies focuses on the boundaries of the possible future as opposed to the most likely future as indicated by the dotted lines in the graph to the right.



It is my experience in working with clients that, by the time one has a sound model, one also has a relatively strong understanding of the client’s mental regarding the topic of concern. This model typically reflects the “anticipated” future with too much emphasis on historical trends and experience and with too little consideration of trends and issues outside their normal awareness. The mechanisms in the model almost invariably are those of the past. Performing sensitivity analysis on the model can give good insight into where and why the model might break or cease to be valid, but gives little insight into what new structures might emerge, or be needed, to cope with new trends and issues. A futures perspective provides a strong basis for examining system dynamics models.

Futures studies emphasizes identifying trends and issues which may impact on a topic of interest. To stimulate and promote thoroughness in scanning for trends and issues, one is expected to identify pertinent trends in a variety of categories. Among the common acronyms for the categories to be searched is the word STEEP, representing the categories of Social, Technological, Economic, Environmental, and Political. When working with teams a variety of methods are used to surface and evaluate pertinent trends

and issues and to consider the potential impact of the trends and issues upon the topic of interest.

Many of the important trends in any study are likely to be relatively certain. For example, demographic forecasts are often viewed as relatively certain within reasonable confidence limits. (Note: systems thinking provides great insights into trends. In the case of demographics the key variables have to do with fertility, death rates, and migration. The assumptions which shape the demographic forecast are quantifiable and can be directly compared to history.)

Other trends will be much less certain. Many major trends, for example, have counter-trends – small towns are losing population in many areas as the youth move to bigger cities for economic opportunity AND other small towns are booming as people escape the big city and relocate to smaller towns. The underlying contributors to these trends are often not easily or accurately quantified. The outcome and impact of such situations is rarely certain. These uncertainties often serve as departure points for considering alternative futures. Systems thinking can contribute significantly to the interpretation of uncertain trends.

A third category of great interest to futurists are high impact events which are deemed unlikely by the public. Earthquakes, hurricanes, and assassinations are common examples of high-impact “wild card” events. Often the long term probability of a wild card is near certainty, but the public does not want to deal with the issue. Couching the event as a “wild card” often aids in getting the audience to consider troublesome events more seriously.

Systems thinking contributes to recognizing the potential impact of trends. As systems thinkers we know that long-term increases and declines typically have impacts and that eventually new structures can be expected to activate as existing relationships break down. Applying this thinking helps futurists recognize and identify pending problems.

Trends tell us much about the future. The “knowns” provide a backbone and the uncertainties represent departures from the anticipated future for generation of alternative futures. A variety of methods can be used to decide what to consider “known” and “uncertain” and for evaluating the cross-impacts of multiple trends. It is not the intent of this paper to present those methods, but rather to give insight into the futurist perspective and the concept of alternative futures.

### **Scenario Planning**

Scenario planning generally represents an approach for developing a set of rich stories about the future. A good set of scenarios will bound the anticipated future in a way that encourages consideration of broad ranges of issues, trends, and decision points which are likely to be encountered as the future evolves. Each scenario features different drivers and

key events which create significantly different futures which, from a system dynamics perspective, feature different structures.

The use of scenario planning has grown rapidly as companies and teams find the approach provides richer perspectives for dealing with uncertain futures. The stories personalize visions of the future and generate increased awareness of the dynamic features of the possible future.

The word scenario is associated with concepts such as plot or script, implying structural features. Within the system dynamics community the term scenario analysis has been occasionally used to represent the process of exploring models via sensitivity analysis. I would propose that, given the definition of scenario and the growing use of scenario planning, that the concept of scenario analysis should be reserved for exploring the structure of the model.

### **Scenario Analysis of System Dynamics Models**

From a futures perspective scenario analysis should involve a testing of the structures of a model against a range of futures. Doing so implies a substantial knowledge of the trends, issues, certainties, and uncertainties. I would not suggest that system dynamicists should devote substantial effort into researching trends and issues. Rather, I suggest that those modelers/facilitators who wish to help their clients understand the limits to their models should strive to be aware of what is being discussed within the futures community and use this information for testing models.

The ten following trends and issues are among those that I find most useful in considering the boundaries of the future (directed at the United States but globally significant) over the next fifteen years or so. Please recognize that these are “macro” trends with many contributors/sub-indicators/implications. I have included brief analysis and comment on each. Many are heavily interconnected and the systemic implications are manifold. Some of the items on this list are virtual certainties. Others are highly speculative. I encourage you to consider the systemic implications of each of the trends as space precludes my exploration of the implications. In no particular order:

1. **The Browning of America.** Anglo children are currently less than 50% of the births in the United States. In the next five years non-Hispanic Anglos will be a minority (though the largest ethnic group) in the 0-20 age group. Europe will face similar forces. Strong implications for education, workforce, consumer patterns, racial tension and eventually government..
2. **The Aging of America.** The “over 60” age group is the fastest growing age group in the United States. Researchers are seriously anticipating extending lifespans to the 150 to 200 year range. (This seems rather optimistic, but a major step in longevity is likely.) The demographic implications are HUGE. Implications for workforce, government, travel and entertainment, families, health care.

3. Globalization. Lots to discuss here, but in a communicationally connected world isolation will be impossible. Trading blocks may emerge but... I tend to take my cue from the computational biologists who find that as systems get more interconnected the fitness landscape squeezes to the median. In other words, fifty years ago the economic condition of the United States was relatively indifferent to that of Mexico. Now, with more interconnection and interdependence, the United States cannot be healthy if Mexico is not healthy. The maximum peak may be the same, but for all conditions except Mexico is healthy the United States health is diminished. This also tends to say that it will be very difficult to maintain US wages at elevated levels relative to the rest of the world (wages should squeeze to the middle). Strong implications for government, corporate competition, and wages. In addition many believe global communication will diminish the power and control of governments and promote anarchy with a myriad of potential impacts.
4. Declining Disposable Income. Disposable income and per capita income have been trending downward for over twenty years in the United States (evidence in part from 3). This is evident in skilled laborers in steel mills being displaced and moving into lower paying service industries and older professionals being laid off and finding jobs in new fields at 60% of their former salary. I find this trend very troublesome. The public (particularly the affluent) are in denial of this trend, but I believe it is a powerful force in society, forcing more dual income families, diminishing involvement with children, etc. This trend must eventually be broken (not easy as the pressure is likely to be downward) or there will be major turmoil. This is also reflected in a growing have/havenot gap. Major implications for government, social tension, education, and workforce.
5. Rising Concern with Quality of Life. A quality of life movement seems to be gaining momentum. This is one of the stronger positive trends and holds a great deal of hope if declining income doesn't drive social behavior to the edge. Major implications for workforce, family, local government, consumer behavior, etc.
6. Technology and Productivity. Productivity gains have held prices increases down in the United States. Computers, management methods etc. have let televisions, computers, stereos and many other items decline in real price. In 1970 it took 21 workers at Ford to build an automobile. Now it is almost down to 2. (This is partially why labor costs are declining. Some of the 19 displaced workers went to work for suppliers, about half wound up in the service industry). I believe the productivity improvements are stagnating. Benefits from computers will continue, but when robots replace the cook at your pizzeria and the delivery boy, service jobs will become...what? I suspect we will eventually see inflation as global resource pressure drives up costs which rising technology will not be able to offset. Combine with globalization and you have a formula for turmoil in developed countries. Material science and nanotechnology hold the potential keys to offsetting the resource limits.
7. Increasing Movements for Independence. Just as the Soviet Union represented a country composed of historically diverse countries which could not stick together under more democratic philosophies, I believe all countries which have artificially defined boundaries, do not follow historical boundaries, and contain strong ethnic divisions are likely to be candidates for independence movements and fragmentation.

This includes much of eastern Europe and Africa. I also see a weakening of the strength of central governments (without the use of anarchy). It probably won't happen in the next ten years but I do not consider a multiple division of the US by 2030 as out of the question (probably four or five countries). (Example: The southwest might merge with northern Mexico in some form).

8. Polarization. For many trends/impacts you can reasonably predict there will be a counter movement. For example, for people moving to smaller towns there will be movement to larger cities. The losers are likely to be the middle. I.e., we will see the number of larger and smaller companies grow but the number in the middle will shrink.
9. Disasters. People and companies persist in refusing to plan for disasters which are certain making disasters a good point for testing most system dynamics models. Earthquakes, hurricanes, deaths of key individuals are virtual certainties in many situations. Considering such disasters can jump start the subliminal process of preparing for alternatives. Choosing the disaster for a given model is often relatively straightforward.
10. Energy Shortage. While I anticipate that there will be no long term energy shortfall over the next twenty years, I do expect another oil crisis - most likely as a result of some form of disruption in the Middle East. Most futurists consider some form of Middle East crisis certain. The impact on oil depends upon the nature of the crisis. Few companies in the United States have, in my experience, considered the impact of soaring oil prices on their business. While the duration of the shortfall and related price increase could be as short as six months, the impact could be transformational for many businesses.

### **Testing System Dynamic Models**

I propose that the most effective method for applying the concepts of uncertainty to systems models is to build the model in the normal, facilitative manner, taking note of the assumptions and paradigms encapsulated in the model. Included in the assumptions are the implicit assumptions related to stocks (both in name and structure) in the model. Then test each stock and each assumption by asking what would cause this structure to be invalid. Is that invalidating event viable (or under what conditions would it be viable)? Test the assumption against each of the ten trends and issues listed above or your own list. Would those trends or issues change the behavior or structure of the model? Often the potential impact will be trivial, but serious deficiencies will occasionally surface. An advantageous twist to this process lies in seeking out conditions which would break the model in a manner which would benefit the modeling organization.

I do not suggest that the answers to these questions should always be used to create new models. Even where there is significant impact the biggest benefit is likely to come from recognizing the weakness or boundary of the model. Once the boundaries are defined and the deficiencies noted the group can decide whether exploring the new paradigm is worthwhile based upon the sufficiency of the model details and impact of the uncertainty.

## Summary

As system dynamicists we share an awareness that our models are simplifications of reality which reflect but one of many possible representations of a process or situation and represent the perceptions, paradigms, and assumptions of the modelers. Our models provide a powerful basis for examining and understanding the conditions and alternative futures which would invalidate the models or require new structures to accommodate new developments. Reserving the term “scenario analysis” to represent structural testing and evaluation of models is consistent with the growing use of the term “scenario” in the futures and planning communities.

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## Getting More Information

There is no single source of information which is adequate to make this easy or automatic. You must understand the uncertainties and have your own vision of what they mean and how they are systemically operative before you can apply them. Among the more useful magazines are *The Futurist* and *American Demographics*. *Technology and Social Change* provides more academic articles regarding technology. The best current books on trends and issues that are shaping the future are:

- *The Road to 2015* by John L. Peterson. Waite Group Press, 1994. Lots of trend information
- *The 500 Year Delta* by Jim Taylor and Watts Wacker, Harper Business, 1997. Relatively unconventional and controversial.
- *Probable Tomorrows* by Marvin Cetron and Owen Davies. St. Martin's Press, 1997. Relatively safe.

The internet is increasingly useful for locating futures related information and particularly for scenarios which can provide platforms for testing existing plans. Two recent books on scenarios are particularly likely to be useful:

- *Scenarios: The Art of Strategic Conversation* by Kees Van der Heijden. John Wiley & Sons, 1996.
- *Learning from the Future* edited by Liam Fahey and Robert M. Randall. John Wiley & Sons, 1998. This book includes material relating simulation and systems thinking to the scenario process.