SYSTEM DYNAMICS FOR DISCERNING DEVELOPMENTAL PROBLEMS

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Summary

Developmental problems are invariably perceived as existing conditions, which must be alleviated. This often removes a policy from the factors that created the problem in the first instance. System dynamics method requires that a problem must be viewed as an internal behavioral tendency found in a system so its causes can be determined before a corrective action is initiated. A pattern representing internal dynamics of a system, called a reference mode, must be constructed before developing a model that serves as an apparatus to create a policy design for system change. Such a problem definition process is also appropriate for understanding developmental problems such as food shortage, poverty and insurgence, so their causes rather than only symptoms are

addressed by a developmental policy.

A reference mode is, however, different from a precise time history in that it represents a pattern incorporating only a slice of the history and it requires several learning cycles to construct a reference mode from time history. A learning process based on a well-known model of experiential learning is used to describe the construction of a reference mode, which is illustrated at length by revisiting the problem of food shortage, while reference modes are also suggested for describing the problems of poverty and insurgence. Complex developmental problems of present day are then outlined and the efficacy of using system dynamics to address them is discussed.

1. Introduction

Developmental problems are often perceived as pre-existing conditions, which must be alleviated. For example, food shortage, poverty, poor social services, and human resources development infrastructure, technological backwardness, low productivity, resource depletion, environmental degradation, and poor governance are often defined as developmental problems. In all such cases, the starting point for a policy search is the acceptance of a snapshot of the existing conditions. A developmental policy is then constructed as a well-intended measure that should improve existing conditions. Experience shows, however, that policies implemented with such a perspective not only perform variedly, they also create unexpected results. This happens since the causes leading to the existing conditions and their future projections are not adequately understood. The well-intentioned policies addressing problem symptoms only create ad hoc changes, which are often overcome by the system's reactions.

Development planning must adopt a problem solving approach in a mathematical sense if it is to achieve reliable performance. In this approach, a problem must be defined as an internal behavioral tendency found in a system and not as a snapshot of existing conditions. This behavioral tendency may represent a set of patterns, a series of trends or a set of existing conditions that appear resilient to policy interventions. In other words, an existing condition by itself must not be seen as a basis for problem definition. The complex pattern of changes implicit in the time paths preceding an existing condition would be, on the other hand, a basis for defining a problem.

The solution to a recognized problem should also be a solution in a mathematical sense, which is analogous to creating an understanding of the underlying causes of a delineated pattern. A development policy should then be conceived as a change in the decision rules that would change a problematic pattern to an acceptable one. Such a problem solving approach can be implemented with advantage using system dynamics modeling process that entails building and experimenting with computer models of problematic patterns, provided of course a succinct representation of such patterns has first been constructed. Called a reference mode in system dynamics, such a representation is based on historical information and is often described in a graphical form. It is, however, quite different from point by point description of a historical trends in that it may represent only a few selected organized patterns embodied in the complex and seemingly unorganized profile of the trends. It also encompasses both past and inferred future patterns.

2. Development Planning Based on Recognition of Existing Conditions

Table 1 collects the various developmental problems and the broad policies implemented to alleviate them that one comes across in the economic development literature, although not presented as in the table. However, if one reviews the timeframes of problems and policies, the organization of the table appears to be quite cogent.

The initially perceived problems indeed were hunger, poverty and insurgence that created a threat to security. Since these problems were taken as given, the natural response to alleviate them was to facilitate intensive agriculture so more food could be produced, to foster economic growth so aggregate income could be increased and to strengthen internal security and defense infrastructure so insurgent groups could be suppressed and the threats to security could be minimized.

Initially perceived problems	Policies implemented	Subsequently experienced problems
Food shortage	Intensive agriculture Land development Irrigation Fertilizer application Use of new seeds	Land degradation Depletion of water aquifers Vulnerability to crop failure Population growth Continuing/increased food shortage
Poverty	Economic growth Capital formation Sectoral development Technology transfer External trade	Low productivity Indebtedness Natural resource depletion Environmental degradation Continuing/increased poverty
Insurgence and threats to security	Spending on internal security and defense infrastructure Limiting civil rights	Poor social services Poor economic infrastructure Authoritarian governance Continuing/increased threats to security

Table 1. Developmental problems, policies implemented to address them, and subsequent problems.

The common denominator of those policies was that they attributed the existing conditions to outside factors, as if they came to be as acts of fate. They also assumed that the system is static and not self-regulating. Thus, it was expected that directly attacking symptoms would help alleviate them. Attacking symptoms without knowing how these were created of course also required powerful intervention by an outside hand and entailed an effort to strengthen government infrastructure, which in fact displaced some of the development effort. The subsequently experienced problems were many, but in most instances, these included a continuation of the existing problems.

Thus, food shortages have continued but are now accompanied also by land degradation, depletion of water aquifers, and the threat of large-scale crop failure due to a reduction in crop diversity, and a tremendous growth in population. Poverty and income differentials between rich and poor have in fact shown a steady rise, which is also accompanied by unprecedented debt burdens and extensive depletion of natural resources, and degradation of environment. Insurgence and threats to peace have intensified together with burgeoning expenditures on internal security and defense, which has stifled development of social services and human resources, and have created authoritarian governments with little commitment to public welfare.

The subsequent problems experienced are also more complex than the initial problems and have lately drawn concerns at the global level, but whether an outside hand at the global level would alleviate them is questionable. This is evident from the failure to formulate and enforce global public policy in spite of active participation by national governments, global agencies like the UN, the World Bank, the World Trade Organization, and advocacy networks sometimes referred to as the Civil Society. This failure can largely be attributed to the lack of a clear understanding about the roles of the actors who precipitated those problems, and those whose motivations must be influenced to turn the tide.

The following sections of this paper describes a learning process entailed in creating a reference mode for system dynamics modeling, which can greatly help discern developmental problems. This learning process is illustrated by revisiting the problem of food shortage. Further, the problems of poverty and internal security are redefined as manifestations of internal trends of the system; rather than as acts of fate.

3. Reference Mode Construction as a Learning Process for Defining Developmental Problems

Notwithstanding the assertion that the definition of a developmental problem should depend on historical trends, and not on a snapshot of existing conditions, it must be understood that historical trends in their unfettered form cannot adequately describe a problem, although they might portray it shade better than a snapshot. A succinct problem description is created in system dynamics by constructing a reference mode, which is a fabric of trends representing a complex pattern rather than a collection of historical time series. It may contain variables actually existing in historical data; as well as those summarizing qualitative information from a related body of knowledge, or those concerning policy options to be explored or all three types. Historical data is only a starting point for constructing a reference mode, which is an abstract concept that must be developed very carefully from the historical data, qualitative information, and the inferred future patterns it points toward.

At the outset, while both historical behavior, and a reference mode, can be expressed in either quantitative or descriptive terms, a reference mode is essentially a qualitative, and intuitive, concept since it represents a pattern rather than a precise description of a series of events. A reference mode also subsumes history, extended experience, and a future inferred from projecting the inter-related past trends. It can be seen with the mind's eye as an integrated fabric, although it can be represented on paper only as isolated tendencies. A reference mode will also not contain random noise normally found in historical trends, as this noise lies outside of the deterministic processes underlying our understanding of the system behavior. Finally, a reference mode is an integrated fabric that can only be visualized in the abstract, although it can only be represented in a graphical form on a two-dimensional block. Fortunately, we have an immense experience of visualizing such a fabric due to the constant demand made on our perceptions to convert limited perceptual images of reality into more comprehensive mental images. For example, a two-dimensional vision frame that our eyes construct can be perceived as a three-dimensional mental image by our mind.

4. An Experiential Learning Framework for Constructing a Reference Mode

System dynamics modeling process is best implemented using an experiential learning framework originally proposed by a behavioral scientist named David Kolb. Kolb's model of experiential learning, originally proposed in an organizational learning context, draws on the faculties of observation, concrete thinking, experimentation, and reflection. It requires that an abstract concept be developed through a learning approach calling upon all four faculties as illustrated in Figure 1.

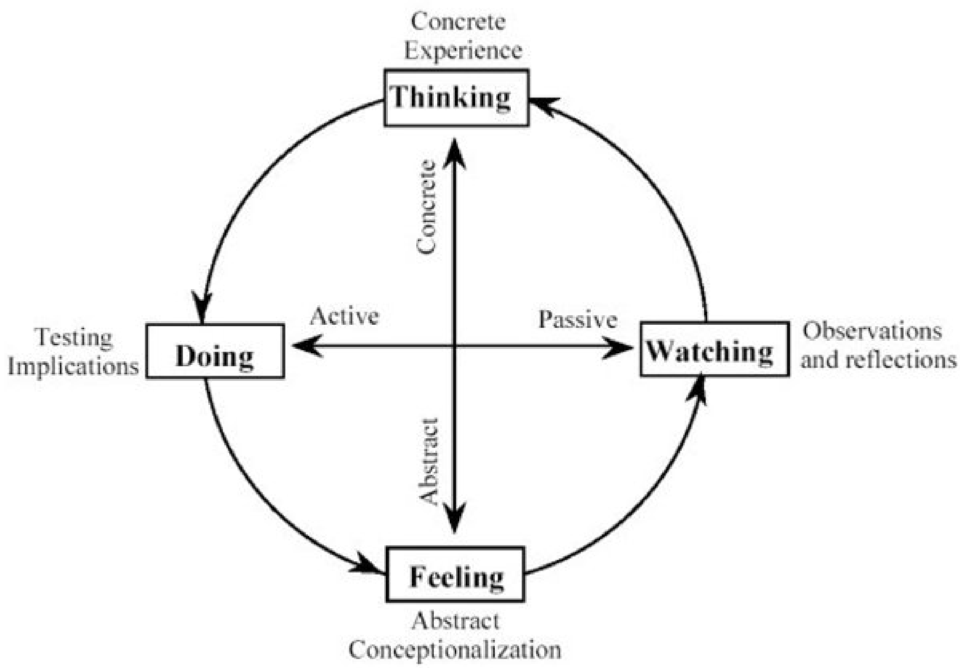

Figure 1. Kolb's model of experiential learning.

Four basic faculties drive Kolb's learning cycle: watching, thinking, doing, and feeling. For the learning process to be effective, watching must result in careful observation of facts, leading to discerning organized patterns. These patterns then must drive thinking, which should create a concrete experience of reality. The implications of the concrete experience must be tested through experimentation conducted mentally or with physical, and mathematical apparatuses. Finally, this experimentation must be translated into abstract concepts and generalizations through a cognitive process driven at the outset by feeling, which would, in turn, create further organization for careful observation thus invoking another learning cycle.

The learning faculties, according to Kolb's model, reside in two basic human functions, physical and cognitive—each integrated along two primary dimensions, which are also illustrated in Figure 1. The first dimension, concerning the physical functions is passive–active. The second, concerning the cognitive functions is concrete–abstract. Thus, the faculty of watching is a passive-physical function, thinking a concrete-cognitive function, doing an active-physical function, and feeling an abstract-cognitive function. Since the mental construction of reality and its interpretation must filter unwanted information, each faculty must be guided by certain organizing principles to affect learning. Additionally, the learner is required to shift constantly between dissimilar abilities to create opportunities for resolving the anomalies, which would appear among the constructs of each ability. This learning process lends itself with great ease to the construction of a reference mode.

The time horizon of reference mode depends on the purpose of the model, but it would invariably be longer than the historical information it is based on, as it would include also information about the inferred future. The development of a reference mode requires integration of four abstract concepts: 1) Delineation of a system boundary. 2) Recognition of a fabric of historical patterns within the defined system boundary. 3) Recognition of past trends for policy related variables missing in historical data. 4) Projecting past trends into future to create a fabric of inter-related patterns that constitutes a reference mode. It is accomplished through implementation of an undocumented process an experienced modeler follows. This process entails sixteen steps built around four learning cycles as shown in Figure 2. They are described below.

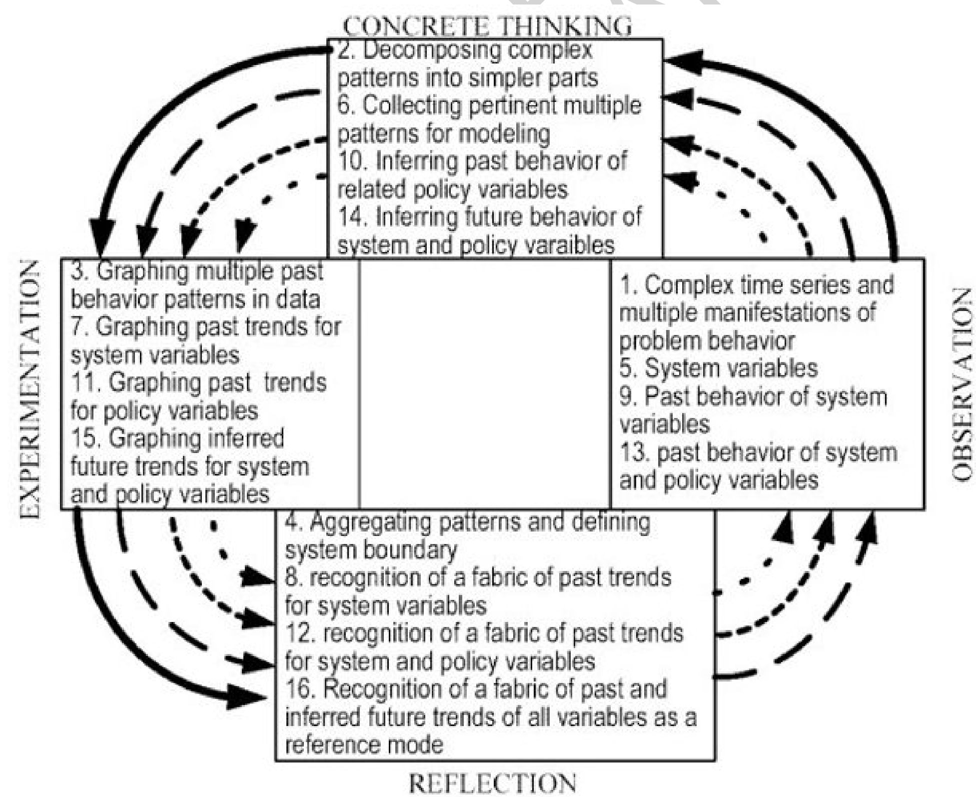

Figure 2. Sixteen steps involved in the construction of reference mode.

4.1 First Learning Cycle: Delineation of a System Boundary

One must begin by: 1) Carefully examining historical information both quantitative and qualitative residing in the complex time series and event descriptions as well as in the multiple manifestations of the problem behavior in different periods and in different places. 2) This is followed by decomposition of observed complex patterns into simpler parts. 3) Next, a round of experimental graphing creates simple multiple patterns representing slices of the complex behavior one has set out to model. 4) A careful examination of the decomposed graphs helps delineate the system boundary in terms of the variables that must be considered to describe the discerned patterns. These variables may or may not be the same as in the historical data. Some of the variables in the data can be aggregated while others substituted with abstract concepts, depending on the problem focus and the time horizon of interest.

4.2 Second Learning Cycle: Recognition of a Fabric of Past Trends Within the Defined System Boundary

The second learning cycle begins with: 1) A careful examination of the variables discerned within the system boundary. 2) The multiple patterns related to these variables are then collected into groups representing multiple modes of behavior experienced in different times and in different organizations. 3) A second round of graphing past trends addresses system variables and their multiple modes as differentiated from the first round that concerned historical data. 4) Finally, the drawn trends are recognized as a multi-dimensional fabric representing past problem history.

4.3 Third Learning Cycle: Constructing a System of Past Trends for Policy Variables Missing from Historical Data

While a model that replicates history can be constructed without building an adequate policy space in it, such a model is often not useful in terms of exploring an operational means for system improvement. Experimentation with such a model would often lead to normative statements about what should be done, not what can be done, to improve system behavior. To create an adequate policy space in the model, structure representing policy decisions must be included although information about the behavior of policy-related variables may not exist in the historical data. For example, if potential policies concern resource management, policy space representing choice of resources and technology should be included. If they concern delivery of certain services, the role of institutions delivering those services and how such institutions are to be supported should be included. If taxation and expenditure by government are possible policy instruments, the process of their determination, and how they would impact the behavior of the responding actors in the system should be included.

Construction of past patterns of behavior for the policy variables would often require going through an additional learning cycle that begins with: 1) A careful examination of the past behavior of the delineated system variables; this is followed by: 2) inferring behavior of related policy variables for which one might often have to delve into the empirical or the theoretical premises of the various policy threads. 3) An attempt is made to graph the past patterns of behavior for the policy variables; which, when 4) combined with the already drawn past trends for the system variables create an integrated fabric of past trends.

4.4 Fourth Learning Cycle: Projecting Past Trends into Future to Create a Reference Mode

The fourth cycle begins by 1) carefully examining the past behavior of system variables paying special attention to their phase relationships and relative positions; 2) next, these trends are intelligently projected into the future keeping in view the progression of the whole fabric instead of concentrating on one trend at a time. This process might often bring to fore any turning points in system behavior that would appear if current policies continue to be practiced. 3) A third round of experimental graphing extrapolated trends creates essential components of a reference mode; and 4) the graphed trends representing past behavior of the system variables, policy variables and their inferred future viewed as a fabric finally define the reference mode representing a succinct description of a developmental problem. This process is illustrated with an extensive treatment of the food shortage problem in the next section.

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Biographical Sketch

Khalid Saeed heads the Social Science and Policy Studies department at the Worcester Polytechnic Institute in USA. Trained at MIT in system dynamics and economic development, Dr. Saeed is widely recognized for his work on computer modeling and experimental analysis of developmental, organizational and governance-related problems. He has written two books and numerous articles on sustainable development and system dynamics modeling. Dr. Saeed received Jay Wright Forrester Award for his work on sustainable development in 1995. He has served as President of System Dynamics Society and as an associate Editor of System Dynamics Review.