Defining a problem or constructing a reference mode*

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Abstract

This paper attempts to describe the process of defining a problem – called a reference mode in Jargon - for building a system dynamics model. System dynamics models represent problems not systems, hence a model cannot exist without first defining a problem. The characteristics of a reference mode and how these might differ from a historical record are defined. A learning model is used to the delineate steps entailed in constructing a reference mode, which would often subsume past history as well as inferred future and which might also represent only a slice of a complex historical pattern. It is proposed that a small number of archetypical patterns might be developed to represent a large cross-section of problems encountered in experience. A methodological task ahead is to crystallize these patterns.

Key Words: System Dynamics, reference mode, experiential learning, problem definition, pattern recognition

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Introduction

System dynamics models represent problems not systems *per se*. Therefore, the first step in the modeling process is to define the problem the model will represent. This problem definition is named the reference mode in Jargon. A reference mode is based on historical information and is often described in a graphical form, although there are many misconceptions about what a reference mode is. More often than not, a reference mode is perceived to consist of historical data, whereas, historical data may only be a starting point for constructing a reference mode, which is an abstract concept that must be developed very carefully from the historical data and the inferred future trends it points toward. In fact, a reference mode is a fabric of trends representing a complex pattern rather than a collection of historical time series. It may contain concrete variables actually existing in historical data as well as abstract variables summarizing qualitative information. I shall attempt in this paper to describe the process of constructing a reference mode from historical data and illustrate this process with examples.

Reference mode represents a pattern of change

A problem is often perceived in a conventional sense as an existing condition which must be alleviated. For example, in the economic development context, poverty, unequal income distribution, high illiteracy rate, low infrastructure inventory and corruption are often defined as problems. In a business context, low market share, overstaffing, poor quality, low productivity, non-profitability, etc., are viewed as problems. In all such cases, the starting point for a policy search is the acceptance of the existing condition defined as the problem. In system dynamics, a problem is defined as an internal behavioral tendency found in a system. It may represent a set of patterns, a series of trends or a set of existing conditions that appear resilient to policy intervention. In other words, an end condition by itself is not deemed adequate as a problem definition. The complex pattern of change implicit in the time paths preceding this end condition would, on the other hand, represent the problem. Often, an end condition has not been reached when a problem is being defined. In such cases, the future must be inferred through an intelligent projection of the past patterns. Last, but not least, any time history may incorporate multiple patterns experienced over a single time path, over different geographic locations or over different periods of history. A penetrating problem description should collect these patterns so that a simple model that contains the policy space for a pattern change can be developed to represent the problem. Such a collection of patterns would constitute a good reference mode for building a model.

Reference mode is an abstract concept

Even when treated as a historical pattern, a reference mode is often represented as a complex time path, which can be a misleading way to start a modeling exercise. A complex time path can often lead to a complex model that might track a history and project a future, but which may not create any insights into the dynamics of the system under study since its behavior cannot be understood. Any policy recommendations arising out of an examination of the projections made by such a model are often disconnected from the microstructure of the model and constitute a common sense grocery list of instruments, rather than an operational process that can be implemented to modify existing decision rules. A reference mode, in fact, is not historical data, it is an abstract concept that must be arrived at through a careful analysis of the historical data and the future that can be inferred from it. Table 1 illustrates the differences between a reference mode and its related historical evidence. While historical evidence can consist of time series data or anecdotes, a reference mode is a pattern of behavior conceptualized from such evidence, and the two may have quite different characteristics.

Table 1: Characteristics of historical evidence and reference mode

Historical Evidence	**Reference Mode**
Quantitative	Qualitative
Descriptive	Intuitive
Complex	Organized
Events	Pattern
Past	Past and inferred future
Isolated time series	Integrated fabric
Noisy	Noise-free
Snapshots	Tendencies
System behavior	Problem behavior

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 past 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 it will represent a problem behavior rather than the system behavior. A reference mode is an abstract concept far different from the historical data and the qualitative descriptions concerning a problem. Let me illustrate this with an example.

Say we are investigating the change in worker productivity in a firm undergoing a re-engineering effort that would, in the first instance, increase profitability by decreasing the firm's workforce and cutting down on worker cost. Part A in Figure 1 illustrates what might appear to be the historical trends concerning profitability, worker productivity, and worker morale following the re-engineering effort. Profitability rises due to reduction of workforce, but worker productivity and worker morale do not. Part B of Figure 1 extends further these trends subsuming an extended experience of the process. After all, if worker productivity and worker morale are stagnant, the profitability increase will have to taper off after worker costs have been cut down as far as possible. Also, a declining rate of profitability growth, together with the worker attrition resulting from re-engineering, would affect the internal environment of the organization, which would lead to an erosion of morale and consequently also of productivity.

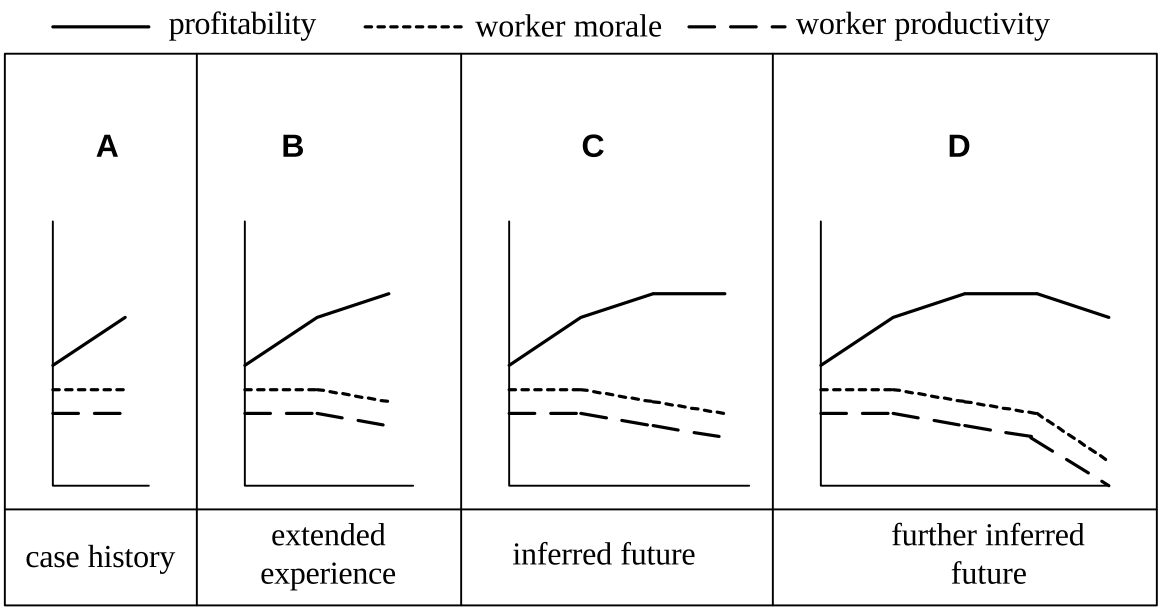


Figure 1 Constructing a reference mode from past and inferred future

Extending the trends further, one would expect that the eroding morale and decaying productivity would eventually create a stagnation in profitability and precipitate an inevitable decline as the feedback between profitability, productivity and worker morale continues to work. This is illustrated in parts C and D of Figure 1. Finally, the three trends in part D must be visualized together as facets of a whole fabric to get an intuitive appreciation of the problem. Viewed as disjoint trends, they will not tell the whole story. The conceptualization of the reference mode as a fabric, therefore, leads to an abstract concept that goes beyond what can 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 [Abbot 1987].

Learning process as a framework for constructing a reference mode

As I have pointed out in Saeed (1997), the conceptualization of a reference mode requires the same learning process as the development of a dynamic hypotheses, the construction of a model, the creation of the model understanding and the design of a policy for system improvement. I have also proposed that these steps could be built around Kolb's model of experiential learning illustrated in Figure 2 [Kolb 1984, Hunsacker and Alessandra 1980, Kolb, et. al. 1979, Kolb 1974, 1998].

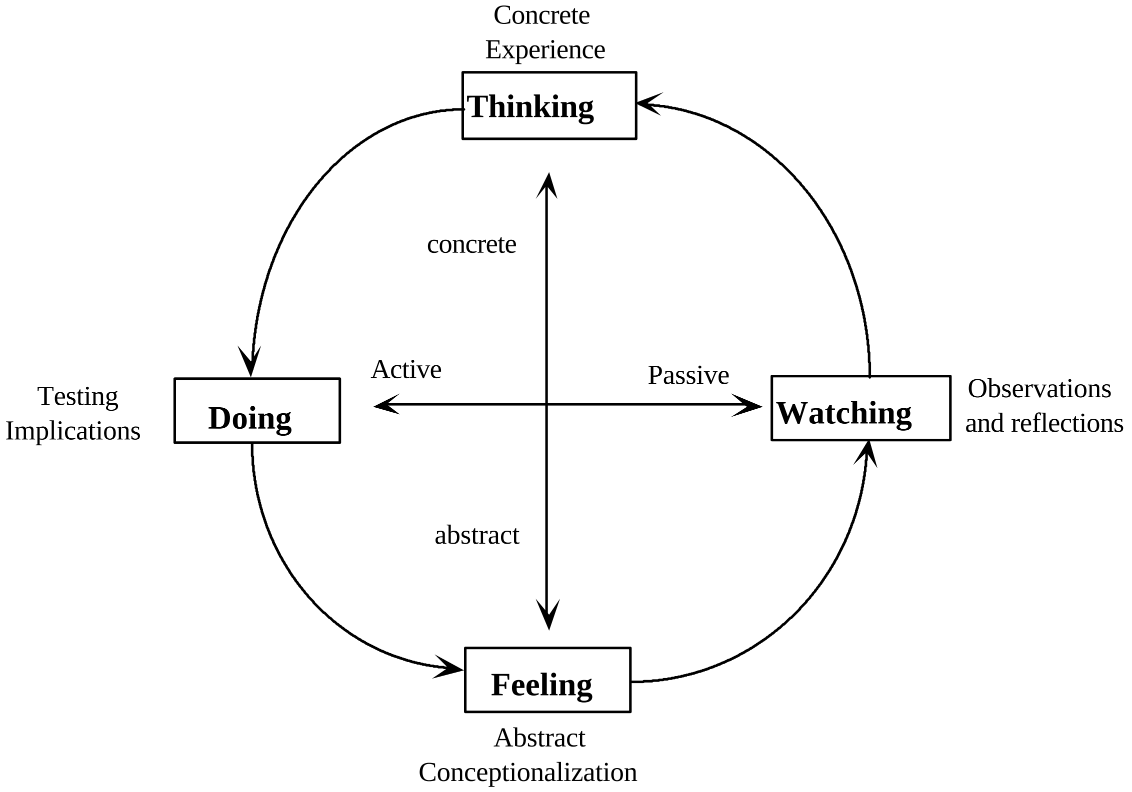


Figure 2 Kolb's model of experiential learning

Four basic faculties – watching, thinking, doing and feeling drive Kolb's experiential learning cycle. For the learning process to be effective, watching must result in the careful observation of facts, leading to identifiable organized patterns. These patterns, then, must drive thinking, which should generate 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 an enhanced framework 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 2. The first dimension, concerning the physical functions is passive – active. The second, concerning the cognitive functions is concrete – abstract. Thus, 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 physical and cognitive domains to create opportunities for refuting the anomalies arising between the two and thus reconciling mental images with the physical reality.

Figure 3 interprets Kolb's learning model in the context of constructing a reference mode. One must begin by carefully examining historical information, both quantitative and qualitative, in the passive physical domain to discern patterns that it incorporates. This process is followed by system identification in the concrete cognitive domain, which returns 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 by more abstract concepts, depending on the problem focus, the time horizon of interest and the policy space considered. 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.

Next, an experimentation process carried out in the active physical domain calls for drawing the trends and intelligently extrapolating them into the future on the basis of the knowledge about the system as illustrated in Figure 1. Finally, the drawn trends must be conceptualized as a multi-dimensional fabric - an abstract concept that represents the reference mode, which can be readily related to the information in the micro-structure domain for formulating a dynamic hypothesis.

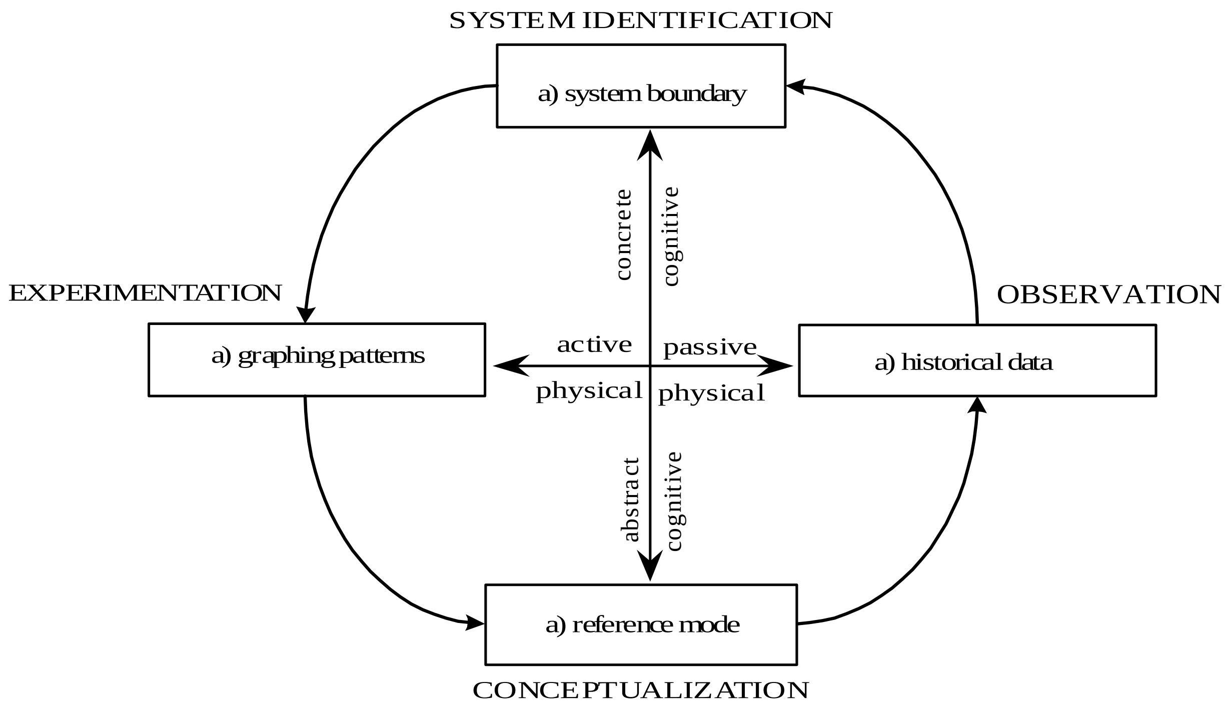


Figure 3: Learning process underlying the construction of a reference mode

An illustration

Some time ago, I prepared a background paper for the United Nations Economic and Social Commission for Asia and Pacific (UN-ESCAP) on environmental trends and their future projection [Saeed 1994]. Since projections were required for an extended period of time and could not possibly be based on a simple trend extrapolation, I adopted the process of constructing a reference mode to create intelligent projections. I'll illustrate here how the historical data was used to determine the food production pattern in the region covering past as well as inferred future behavior.

The first task seemed to be to organize the available numerical data so it could give information about the whole region. A complementary effort was also launched to review the related qualitative information. Some 300 time series, covering fourteen selected countries representing the Asia and Pacific region over the past three decades, were constructed from published UN sources to serve as a data-base for the analysis. In view of the many missing cells, differences in units and definitions of data categories, the variability in the national policies across countries and the possibility of the data from one country dominating an aggregate trend, it was decided not to aggregate country data into any regional categories but to examine closely the selected set of countries as a sample for comparable resource- and environment- related trends.

The selected countries were divided into three categories based on per capita income. Australia, Japan, Korea and Singapore were placed in category (A) representing relatively high levels of income; Malaysia, Thailand, Philippines, and Indonesia were placed in category (B) representing middle levels of income; while China, India, Nepal, Pakistan, Sri Lanka, and Vietnam were placed in category (C) representing relatively low levels of income. This classification was incidentally consistent with the one proposed by the Asian Development Bank [Okita 1989]. It also covered the variety of the countries in the Asia and Pacific region well, in terms of geographic location, form of government and economic conditions. The presence of a particular trend in the selected countries over all three categories provided the basis for the deduction that the trend is pervasive in the region covered by the sample.

Although, above data format was partly necessitated by the quality of the data available, it greatly facilitated making general inferences concerning the whole of the Asia and the Pacific region. The individual differences between the data elements, in this case the country-specific time series, allowed the data to be viewed as a sample representing the region it was drawn from. The countries in the various categories of the sample were not viewed as special cases, but as many outcomes (or multiple behavior modes) of the agricultural system of the region.

Time series plots for the various categories of countries were prepared for population, GDP and GDP per capita to examine growth in the consumption base. The use of agricultural resources was examined through a per capita food production index, fertilizer and pesticide application, cultivable land and area under forests. The following observations were made with respect to the growth of the consumption base and the condition of renewable agricultural resources.

Growth of the Consumption Base

Figures 4: a, b and c show population and GDP growth in the three categories of countries selected for the analysis. Considerable population growth is shown over the three decades covered by the data in all categories, although growth is much higher in the low-income countries. GDP growth is the highest in the middle-income countries, while growth rates in the high- and low- income countries are comparable. Consequently, as shown in Figures 5: a, b and c, GDP per capita has grown at comparable rates in the high- and medium- income countries due to moderate population growth in the former and high economic growth in the later. However, high population growth rates and moderate economic growth have led to stagnation in GDP per capita in the low-income countries.

According to the projections of UNCHS, shown in Figures 6: a, b and c, tremendous growth has also occurred in urban populations across the board and the high growth rate is expected to continue, although these rates are projected to taper off in the high-income countries. On the other hand, rural populations have shown stagnating or declining trends in the higher income countries and may be expected to decline further in the future. However, due to the overall momentum of population growth, rural population has risen significantly in the medium- and low- income countries, but is expected to taper off and begin to decline over the second decade of the twenty-first century. As also shown in Figures 6: a, b and c, the total population is expected to continue to rise in all countries well into the twenty-first century, although the rates of projected population growth are negatively correlated with the levels of income - lower income countries experiencing higher and continued rates of total population growth and urbanization [UNHS 1987].

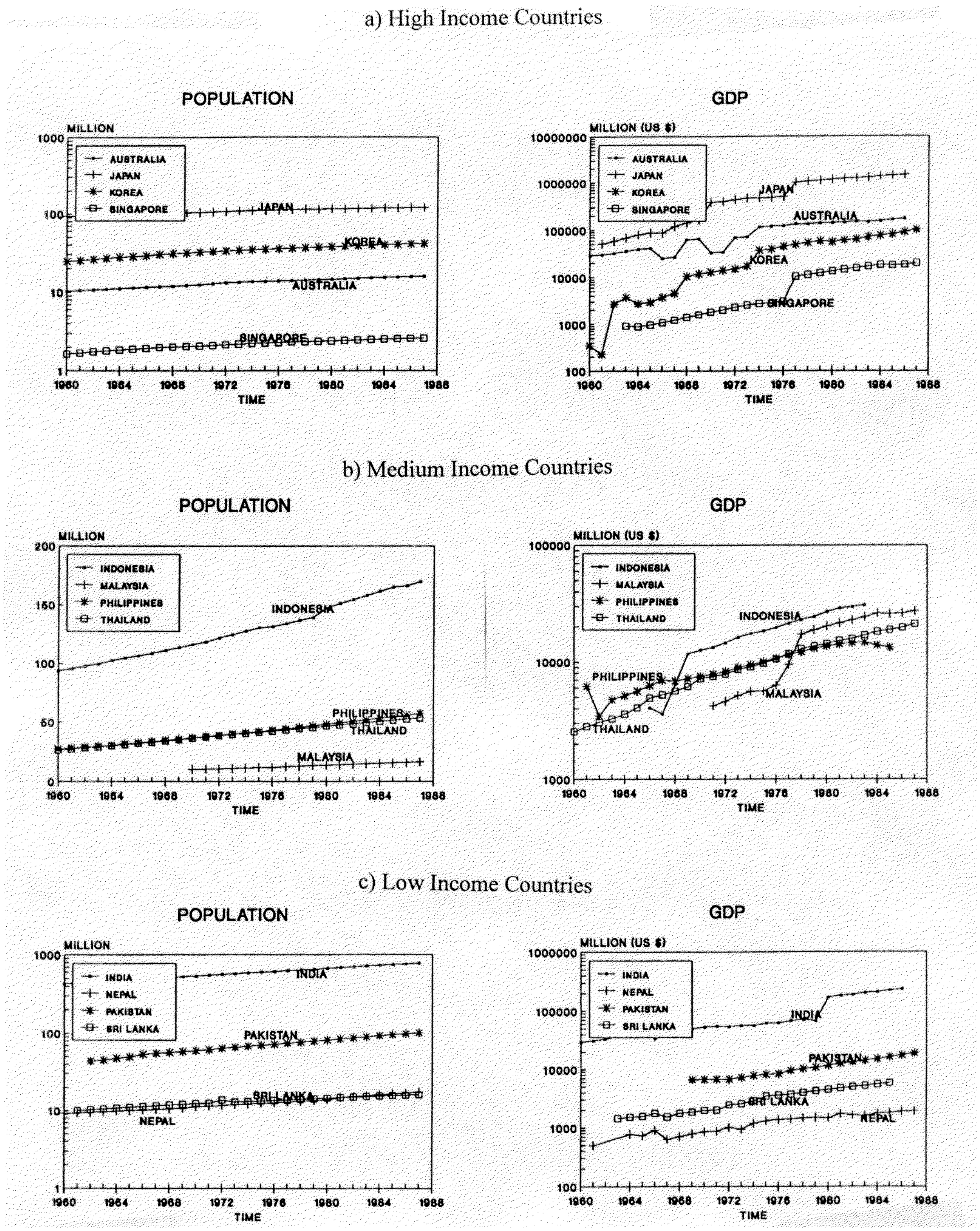


Figure 4 Population and GDP growth

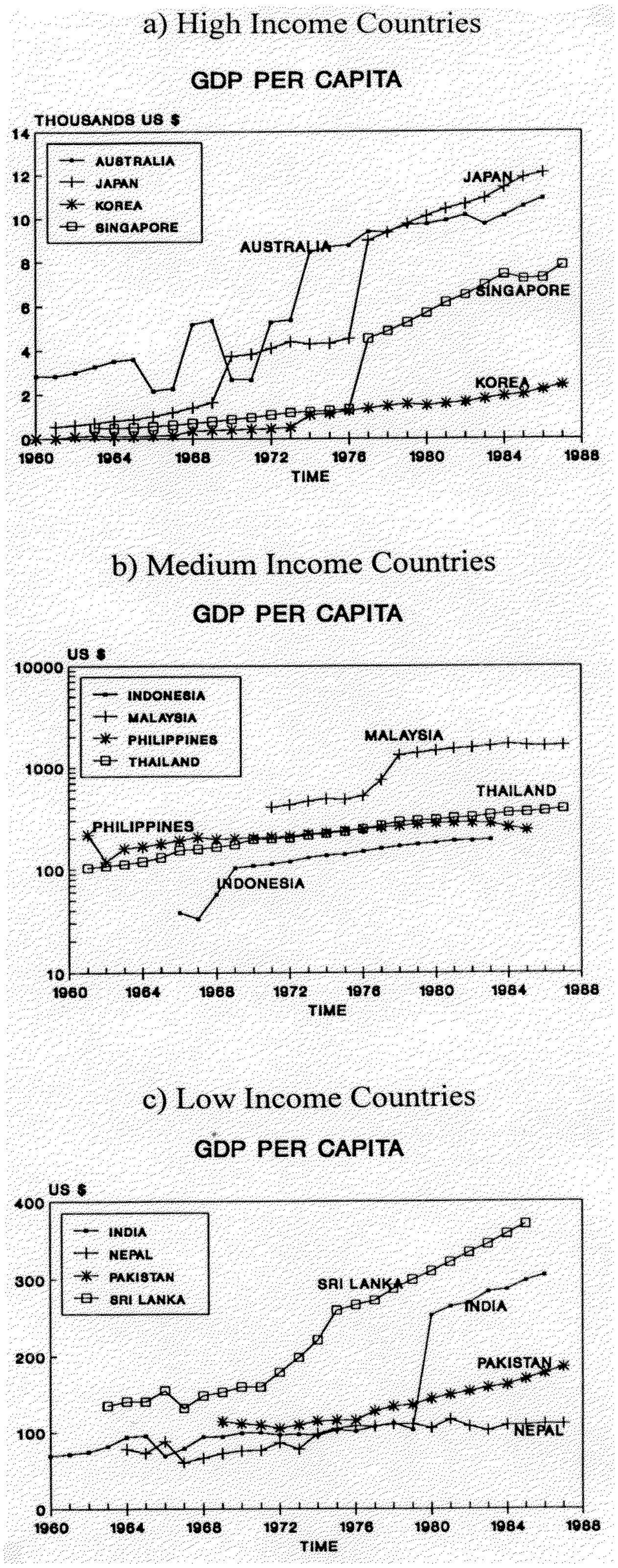


Figure 5 GDP per capita growth

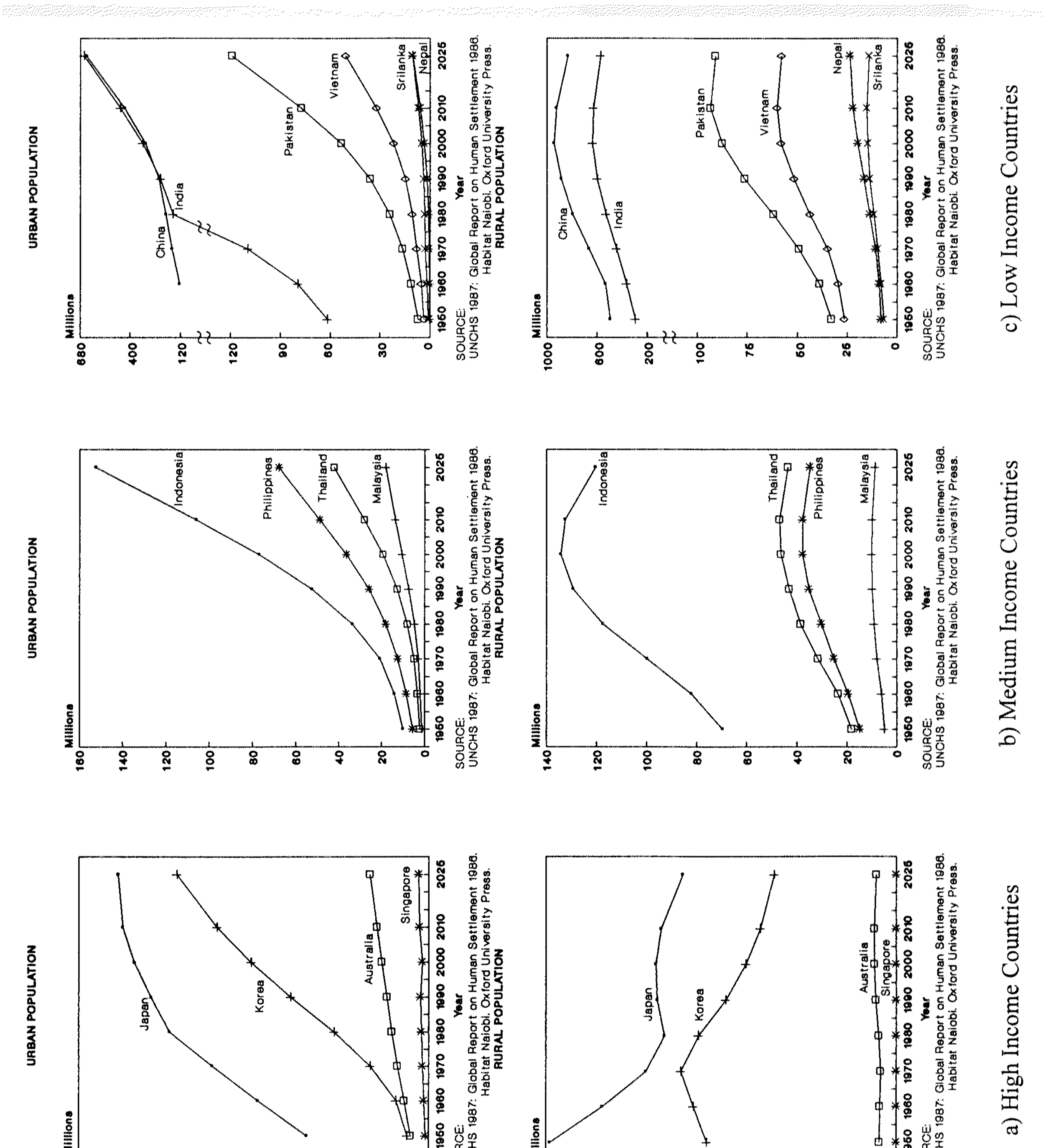


Figure 6 Projections for urban and rural population

In all cases, there is growth in the consumption base originating from two sources, growth in population and expansion in economic activity. It remains to be seen how far the growth in the consumption base can be sustained by the natural resource base and the environmental capacity.

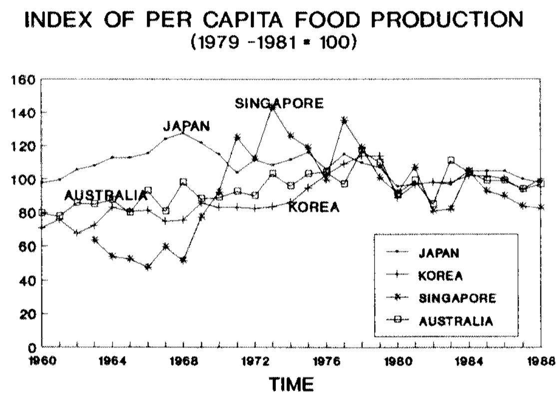
A significant side effect of the expansion of economic base is the growth in urbanization, which is necessitated by the technological choices requiring concentration of production activity to achieve economies of scale. The concentration of human activity, however, may also create concentrated doses of pollution which the environment is unable to assimilate. The results of this are manifest in a lowering of the water table, pollution of groundwater aquifers and acid rain, all of which adversely effect agriculture. Urbanization also often encroaches on prime agricultural land, which reduces production potential, especially in Asia where only marginal lands remain uncultivated.

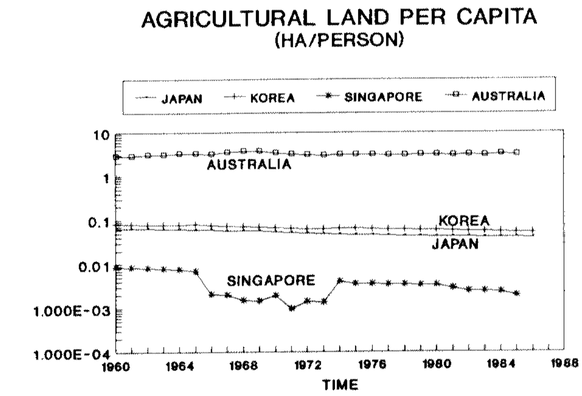
Condition of Renewable Agricultural Resources

Renewable resources considered include agricultural land and forests, which have traditionally met the food, fuel and timber needs of society. Figures 7: a, b and c show past trends in food production per capita and agricultural land per capita in the countries of the three designated categories of the sample.

The food production index is not comparable across selected countries due to differences in the criteria used for calculating the base figures, but represents only an internal measure of the changes in food availability in each country. Some autonomous jumps also appear in the data since it has been constructed from many sources which, although mostly published by the UN, contains some inconsistencies in the definitions used to represent the various categories of data. For the purpose of constructing a reference mode, however, long-term patterns of trends rather than numerical values of the time series are to be compared across the countries of the sample. Hence, the above problems can be tolerated.

a) High Income Countries

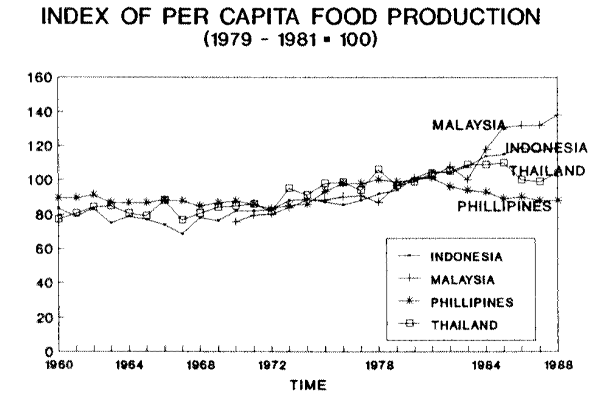


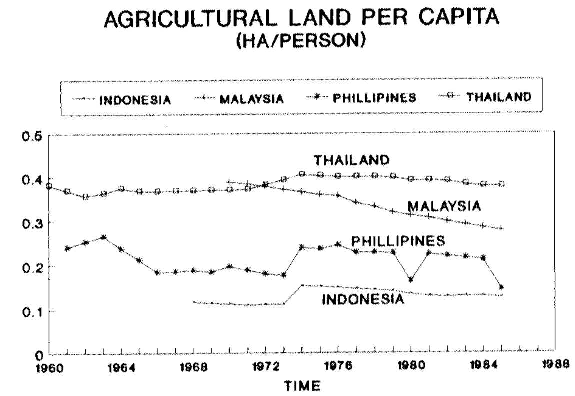


Source:
FAO 1989: FAO Quartely Bulletin of Statistics 1989. Vol.2. New York.
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.

Source:
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.
UN 1979: Demographic Yearbook 1978. NY.

b) Medium Income Countries





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UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.

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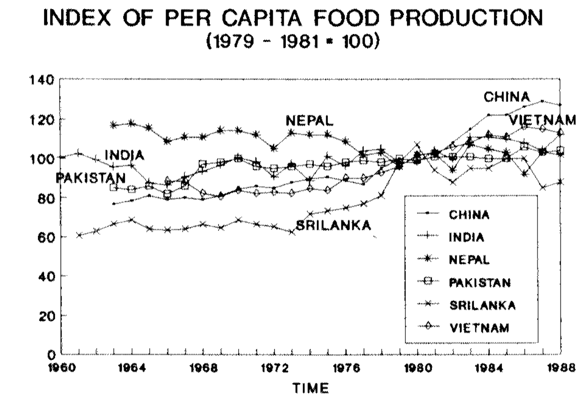
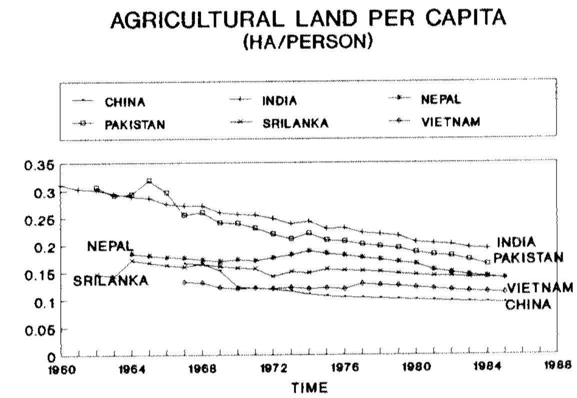
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.

c) Low Income Countries





Source:
FAO 1989: FAO Quartely Bulletin of Statistics 1989. Vol.2. New York.
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988).NY

Source:
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.

Figure 7 Food Production per capita and agricultural land per capita

It is observed that food production per capita exhibits a rising trend in all cases in spite of considerable population growth, while agricultural land per capita shows a declining trend, except in Australia, where it has been possible to maintain it at a steady level. This indicates that increases in food production have been obtained largely through increasing the intensity of cultivation and application of chemical fertilizers and pesticides. Indeed, as indicated in Figures 8: a, b, and c, fertilizer application has drastically increased in all countries of the sample over the past three decades. The application of pesticides also seems to have increased in the countries where data is available. The pesticides data, however, is inconsistent since in some cases it refers only to DDT while in others it covers all pesticides.

Irrespective of the increases in yield, the absolute quantity of cultivable land has not increased much in most of the countries of the sample, except in Australia, where it has been possible to commission large tracts of unused land. This is shown in Figures 9: a, b, and c. It is observed that, in general, where cultivable land did increase, it was at the cost of the forest area, which is already very small in the countries with a stagnant level of land under agriculture. Some jumps again appear in the plotted data, due to the changes in the definitions of the forest area and agricultural land categories used.

Unfortunately, deforestation not only reduces valuable timber and fuel wood resources, it is also known to cause soil erosion, water loss, flooding or drought, desertification and silting of irrigation reservoirs, depending on the particular function of a forest in the complex organic relationships existing in the ecological system [Bowonder 1986]. In spite of this knowledge, about half of the area under forests in the developing countries was cleared between 1900 and 1965. At current rates of deforestation, the rest is likely to disappear in 50 years [UN-ESCAP 1986].

Excessive use of land resources has also been known to depreciate soil quality. Soil degradation has occurred in the countries of the sample and elsewhere because of erosion, chemical deterioration, loss of texture, water logging and salinity, all resulting from efforts to intensify agricultural activity [Bowonder 1981]. Given the over-taxing of land resources, the per capita food production index may be expected to decline in the future across the board. Declining trends have already appeared in Nepal and Bangladesh, as shown in Figure 10.

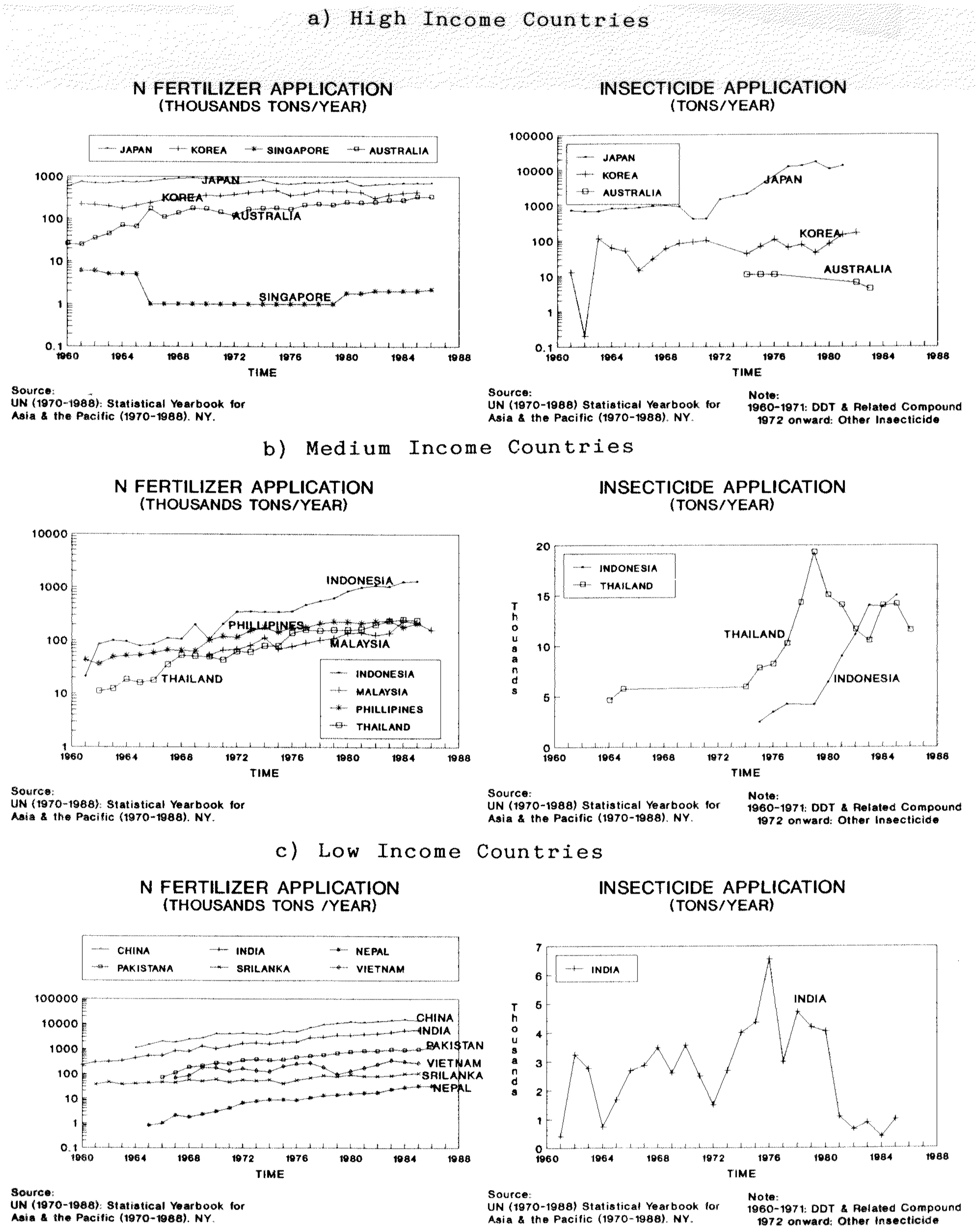


Figure 8 Fertilizer and Pesticide application

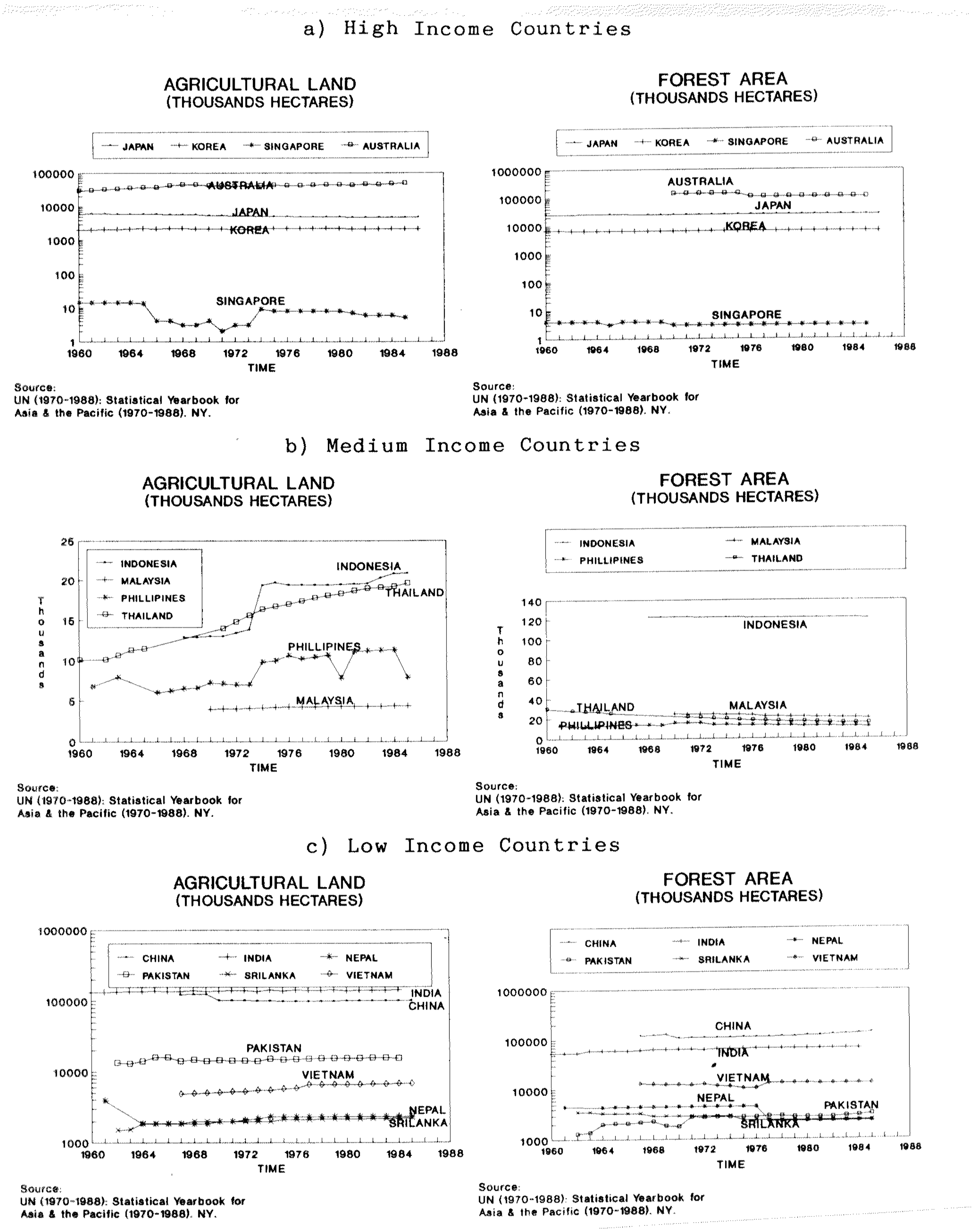


Figure 9 **The competition between cultivable and forest land**

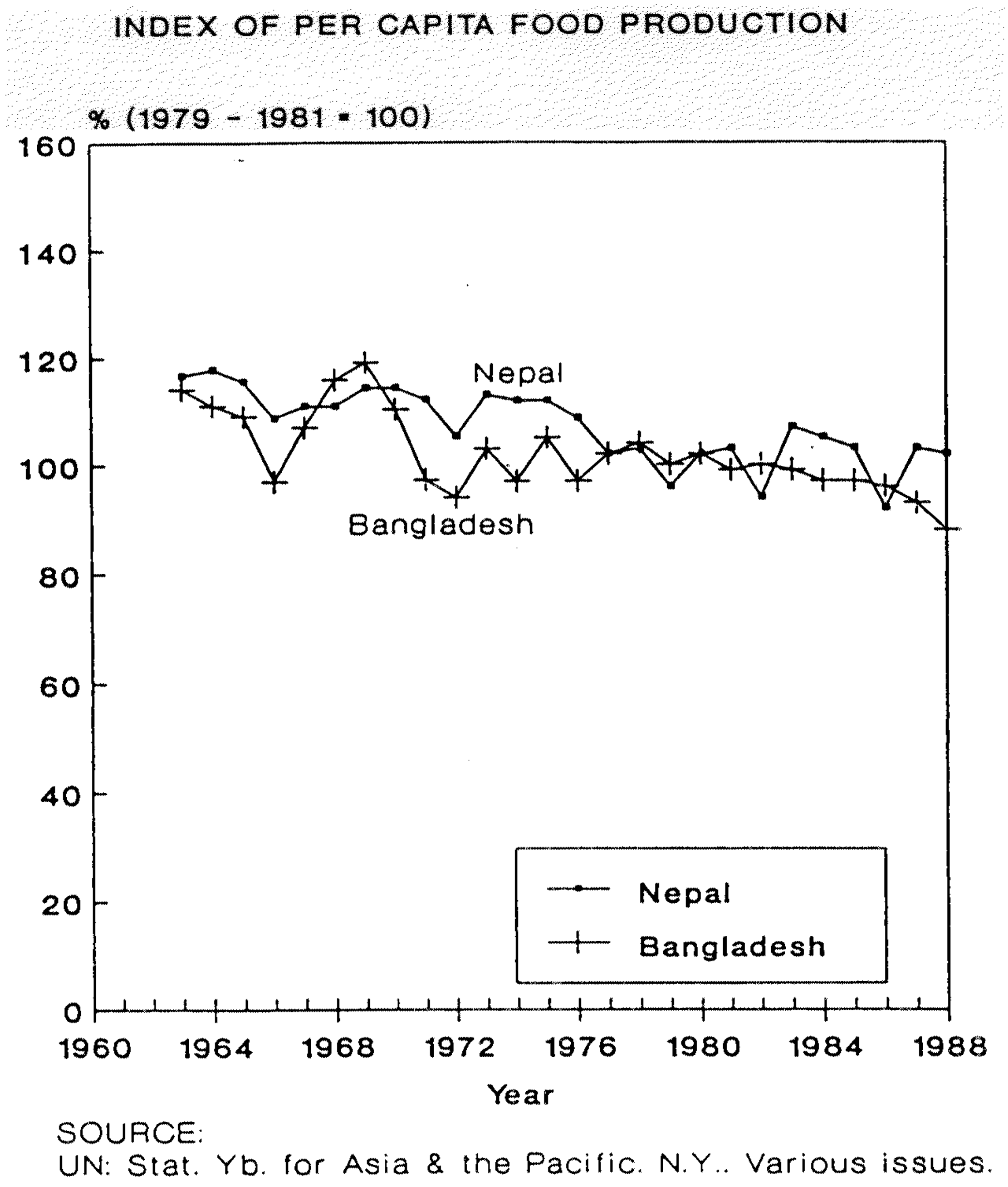


Figure 10 **Declining food per capita trends in Nepal and Bangladesh**

Reference mode

The observed trends in the data taken from a geographically, economically and politically diverse set of countries show that in all cases, increases in agricultural production - clearly a private gain whether pursued by individuals or collectives - has been achieved in the first instance by making an intensive use of the land resources viewed as capital inputs rather than as an environmental system. It is also quite evident that expansion in agricultural land has been achieved by consuming forests - another environmental system which is important to the maintenance of agricultural land as a sustainable resource, but which is viewed by individuals and collectives involved with agriculture as an unused endowment. A variable implicit in the above description is soil fertility, which is partly dependent on the volume of standing forests and partly on the intensity of cultivation. Soil fertility can be propped up by fertilizer application, but would eventually decay if the pressure on soil and deforestation continues.

The projections obtained from digesting the above information indicate a tragedy of the commons in making, which is analogous to a reference mode that might be constructed from the assimilating above information in a learning framework described earlier. In this reference mode, inferred future of food production per capita will show an overshoot and decline behavior which would be followed by a similar trend in population. Land under forests and soil fertility would decline to a low stagnant level and land under cultivation would rise to a high stagnant level. Figure 11 illustrates the pattern arrived at.

It should be noted that the reference mode constructed in Figure 11 is a pattern encompassing the past and future, rather than merely being a historical record and is based on both past history and inferred future. It contains both concrete variables appearing in the historical record and abstract concepts like soil fertility that sum up several pieces of quantitative and qualitative information. The time horizon of a reference mode may depend on the purpose for which a model is constructed, but it will invariably be longer than the historical record. In this case, it must be much longer than the historical record if the purpose is to search for a sustainable future as the time constants of the processes being considered are long.

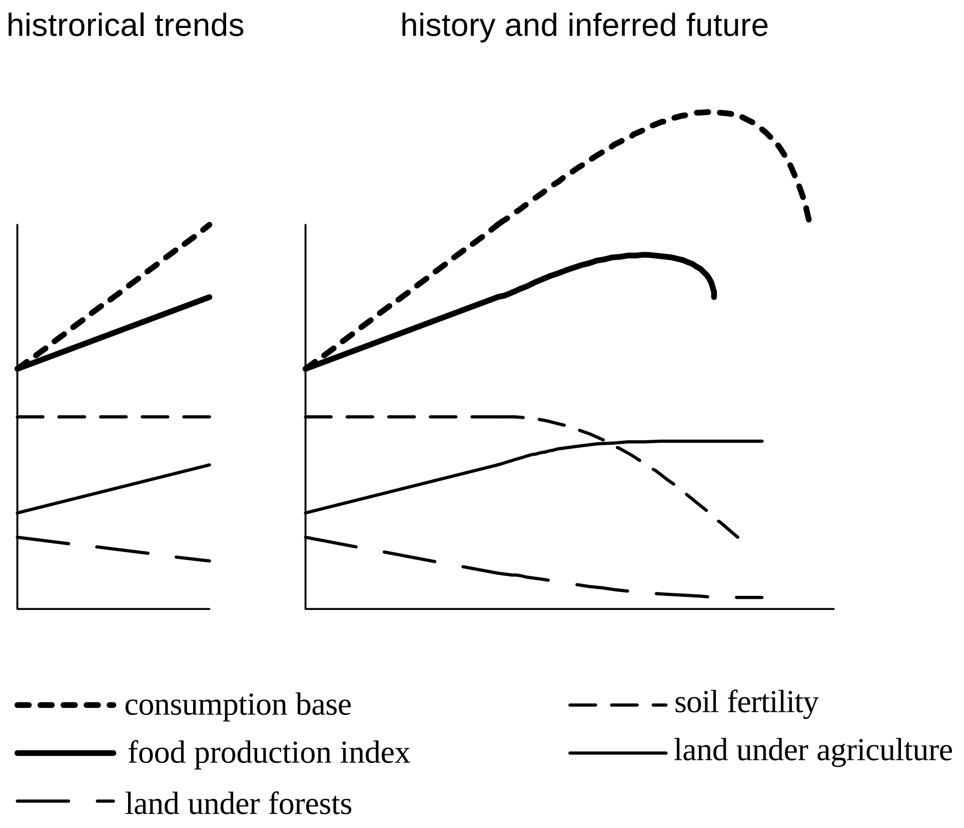


Figure 11 **Reference mode describing food production patterns constructed from numerical and qualitative historical data**

A reference mode is best visualized as a fabric subsuming the trends drawn on paper and would often fall into recognizable categories of patterns, in this case - the overshoot and decline pattern describing a tragedy of the commons. This raises an important issue: why have we not attempted to recognize widely occurring patterns of behavior as reference mode archetypes? A related problem is that in a messy world, problems may not present themselves as neat archetypes, but as complex time histories. How should such complex time histories be partitioned to arrive at problem archetypes? Let me address the second question first.

Dealing with complex time histories

I have discussed the process of partitioning a complex problem in Saeed (1992) and Richardson (1997). Since models cannot be made overly complex if they are to remain understandable, complex problems must be sliced into smaller parts so that the parts meet the requirements of the intended policy design. This calls for separating the *multiple modes* contained in a complex historical pattern in a rather special way.

The term *multiple modes* is not new to system dynamics, although it is used a bit loosely. Not all classes of behavior implied by *multiple modes* may be relevant to creating a model for an effective policy design. In fact, many intuitively sensible schemes of partitioning a system may create models that do not incorporate policy space for investigating the possibilities of change. The *multiple modes* relevant to a problem may refer to the simultaneously existing components of a complex pattern of behavior that is exhibited by a system over a given period; they may represent patterns experienced over different periods of time in a system of relationships; or even patterns experienced in similar organizations that are separated by geographic space. The conceptual space in which *multiple modes* can be found is, therefore, three dimensional as shown in Figure 12.

When multiple modes contained in a complex historical series are the focus of a modeling effort, the complex modal space will be sliced as shown in Figure 13. The simultaneous modes constituting the complex historical pattern will be subsumed in a selected partition while the variety of patterns in the temporal and geographic dimensions are ignored. Such a problem slicing process will create situational theories and forecasting models that may explain a unique and complex pattern, and also extrapolate it into the future, but that do not shed any light on the possibility to change it.

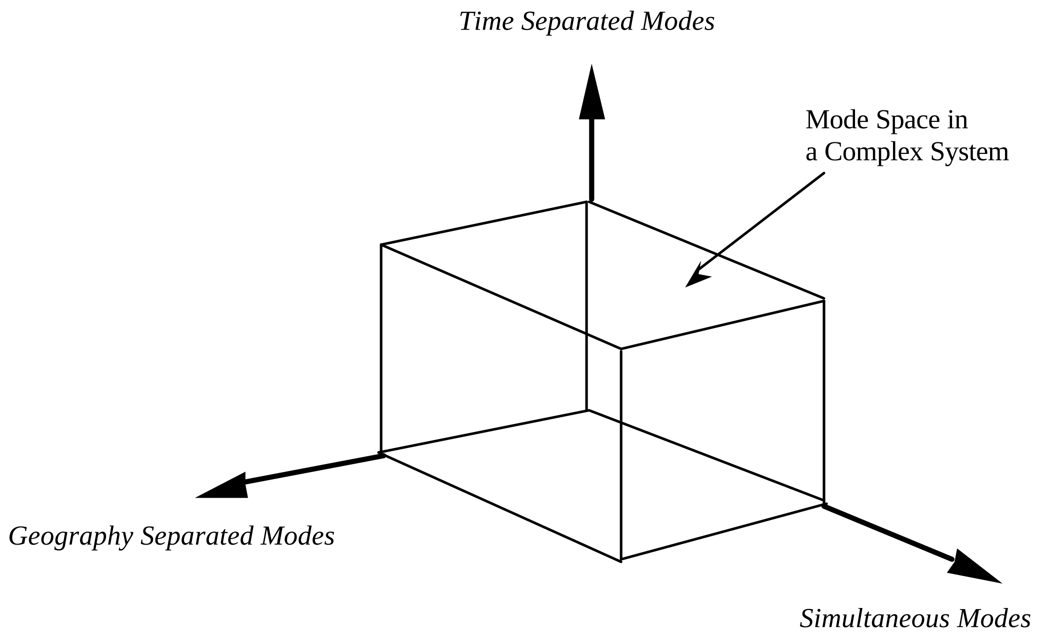


Figure 12 **Multiple mode space**
Source: Saeed (1996)

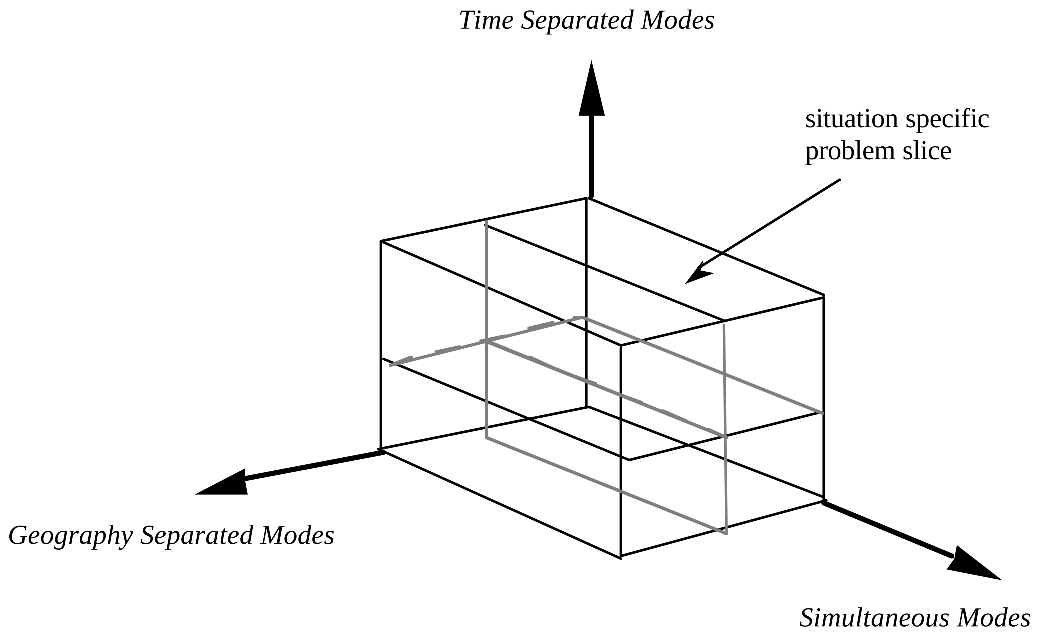


Figure 13 **Problem slices for developing forecasting models and situational theories**
Source: Saeed (1996)

On the other hand, when a model is intended for exploring policy options for system change, the complex modal space must be sliced as shown in Figure 14. The partition selected for modeling will subsume multiple modes that are separated by time and geography since only then its underlying structure would contain the mechanisms of modal change. It may not necessarily incorporate multiple modes that exist simultaneously in system behavior since interaction between the mechanisms creating these modes may not provide any additional policy space, although this may enhance a model's ability to track history accurately. When policy exploration rather than tracking history is the primary purpose of a modeling effort, simultaneously existing multiple modes and their underlying structure can be separated and addressed in different models for limiting complexity contained in a single model.

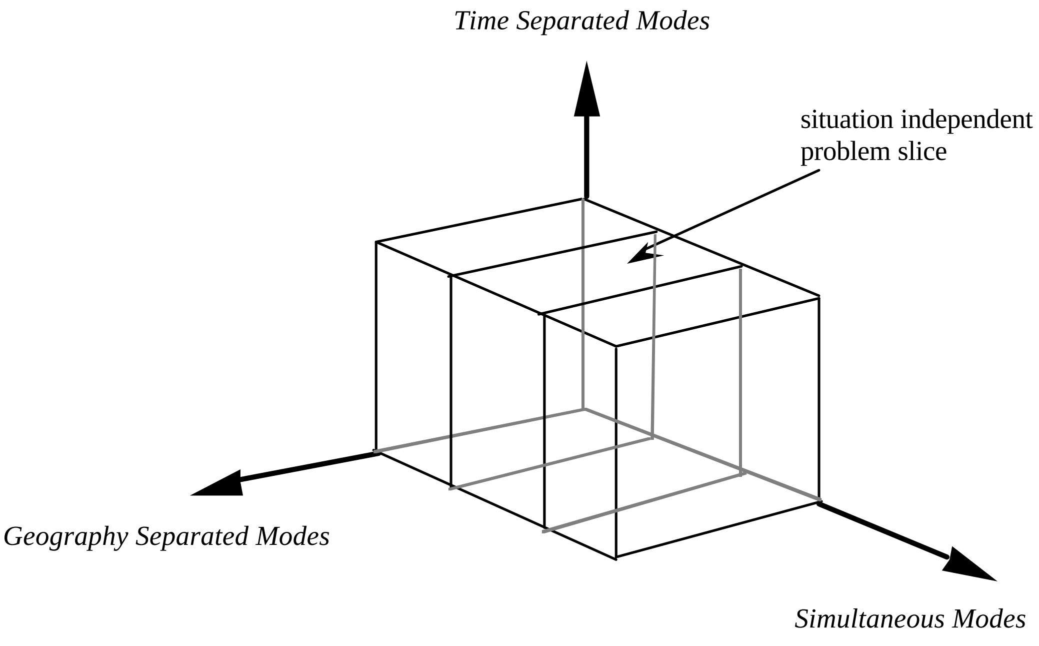


Figure 14 **Problem slices for exploring policy design**

Source: Saeed (1996)

Representing a complex system as a number of submodels that produce behavior different from what appears in the historical data will require defining thereference mode differently from historical behavior. For example, each of the two complex time histories shown in Figure 15 contains a trend simultaneously existing with a cyclical tendency. To be able to address the two issues concerning the cycles and the trends, this problem may be represented by two models: One subsuming the multiple modes existing in the two trends, the other subsuming the cyclical mode existing in both of them. The two models so created will keep together the symbiotic processes underlying the potential multiple patterns thus providing the policy space to attempt a design for change. Also, the two components of the design so created can be pursued quite independently.

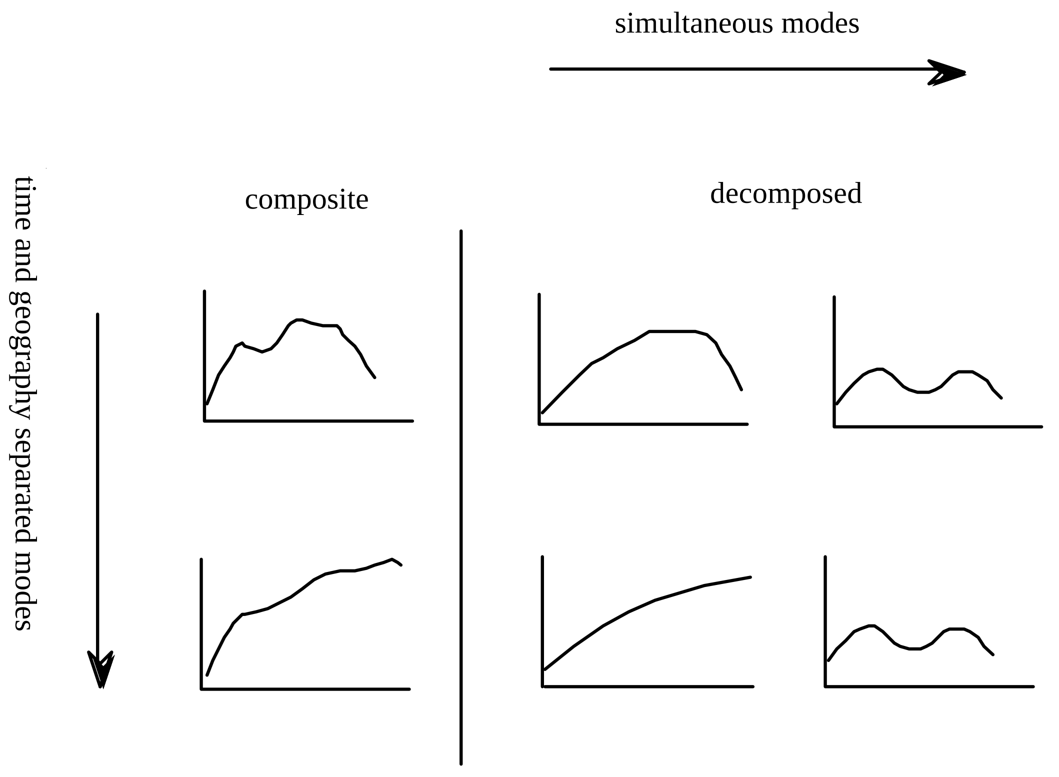


Figure 15 Decomposing multiple modes for slicing a complex problem

Source: Saeed (1996)

Reference mode archetypes – a task ahead

The concept of archetypes representing generic systems pervasively found in experience is quite old in system dynamics, but somehow, the starting point for the archetype seems to have been the system structure not a problem pattern it might represent. Even the nomenclature used to define system archetypes is inconsistent. Archetypes found in the literature have been named both with respect to structure and behavior and multiple archetypes may display the same behavior. These anomalies arise apparently from not using the reference mode as a starting point for defining archetypes.

Jay Forrester has often pointed out that a small number of systems can represent about 90% of the problems encountered in experience. It is only appropriate that we attempt to define these problems in their generic form, which has been the motive behind defining archetypes. Table 2 shows ten of the most commonly stated archetypes implicitly referring to a reference mode in system dynamics. Unfortunately, many of them represent truncated patterns not useful for modeling policy issues as they do not subsume inferred futures.

Table 2 commonly stated reference modes

Sluggish adjustment
Exponential growth
S-shaped growth
Overshoot and decline
Oscillation
Escalation
Erosion
Resource misallocation
Policy resilience
Multiple modes

Sluggish adjustment and inability to arrive at a designated goal is a pervasive problem both in physical and social systems with inadequate feedback tracking discrepancy, although this phenomenon occurs together with other patterns. Yet it represents an important basic pattern subsuming a widely occurring reference mode.

The exponential growth pattern is experienced widely in systems fueling their own reproduction, although exponential growth would almost never go on for ever. Thus, exponential growth is only a relatively short-term phenomenon, which invokes concerns about overshoot beyond sustainable levels followed by an inevitable decline. It might be uninteresting to investigate exponential growth *per se* from a policy perspective. Only when it is coupled with its inferred future, a possible smooth transition to equilibrium in the form of an S-shaped growth, or a dysfunctional overshoot and decline, does there appear to be an interesting reference mode.

Oscillation is another widely experienced pattern, which might appear together with other patterns, but sliced from the rest would have a unique policy implication of creating a damping process. Hence, oscillation cannot be divorced from the extent of damping present in it. Escalation implies increasing commitment to a failing cause, both in the physical and metaphorical sense. Escalation, like exponential growth may not represent a complete reference mode category, since any escalation trend must end into a catastrophe.

Erosion is another inadequately defined pattern as an eroding trend must culminate with the turning around or demise of an organization. Resource misallocation on the other hand represents a tendency towards a misallocation goal, and even though it may appear to be a static pattern, the past tendency precipitating it has significant policy implications. Policy resilience and multiple modes can manifest in a variety of patterns and hence cannot be views as specific patterns.

At the outset, there seem to be three broad categories of problem behavior modes possible:

1) tendency towards a single and unique equilibrium
2) tendency towards multiple equilibria
3) patterns of growth and instability.

Within the first category, the system would tend to come to an equilibrium characterized by problems like low productivity, poor efficiency, unequal income distribution, low market share, etc. Such modes might give the appearance of a static rather than a dynamic problem, however, the points of interest in them are the end conditions *per se* but how they are reached, irrespective of the initial conditions. The second category of problems concern processes that may not lead to a single and unique equilibrium, but might display multiple equilibria depending on the inputs and the environmental conditions. Activating growth mechanisms in such systems might also transform a functional equilibrium into a dysfunctional one. The last category of problems concern growth, overshoot and instability. Often a smooth transition to a sustainable state is desirable, overshoot and instability are to be avoided.

Further work is needed to identify specific patterns within each category that should fit pervasive problem patterns. Once the reference mode archetypes are evident, generic systems underlying them, both in terms of feedback loops and simple stock and flow structures should be delineated.

Conclusion

I have attempted in this paper to define the characteristics of a reference mode and how it is distinguished from historical data, both qualitative and quantitative. A reference mode is an abstract concept subsuming past as well as inferred future behavior. It can best be visualized as a fabric collecting several patterns as well as the phase relationships existing between them. It may contain concrete as well as abstract variables that are different from the data it is based on. It may also represent only a slice of the complex time history it emulates and may thus look very different from the history itself. A reference mode is an end product of a learning process that is similar to the process involved with building a model and analyzing it. There seems promise for constructing generic forms of problem patterns which might fit a large cross-section of the dynamic problems encountered in the world. Constructing these generic forms is not attempted in this paper but is seen as an important part of the methodological progression expected.

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