Cybernetic thinking in economic planning

An exploratory study for India

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Introduction

The Society of Management Science and Applied Cybernetics (SOMAC) was commissioned by the Planning Commission, Government of India, to make an exploratory study on the cybernetic approach to future planning with special reference to India. The study was done by a team headed by the author. This article presents salient features of the concepts, methodology and empirical treatment involved in this study[1]. The principal focus of the study was to explore whether a cybernetic outlook helps us in comprehending problems in a mega-system in a vast country like India and, therefore, in building scenarios for the future under various assumptions. Planning, particularly for the macro-economic structure of a country, has to be based on the following:

- a knowledge regarding the pattern of change of various economic indictors over the past (here, over a period 1950-92 after independence);
- an analysis as to how policy decisions have changed the course of events;
- an assessment of the interactions of India with the outer world, without which viable strategic planning cannot be evolved;
- development of scenarios for the next 50 years under different premisses.

Finally, we have the realization that managerial economics must blend pure theory with a realistic appraisal of the way in which organizations (countries/ corporate sectors) behave, and make provisions for the blending of economic and non-economic considerations, because economic policy cannot exist by itself but only as a fact of an overall policy[2].

Cybernetics in economics

Though the term "cybernetics" is used sparsely in economic literature, the use of system sciences has been advocated by leading economists like Boulding[3]

The author is grateful to Dr Nitish Sengupta, former Member-Secretary, Planning Commission and President, SOMAC and Professor S.R. Hashim, Principal Advisor, Planning Commission for helpful suggestions; to the Planning Commision for sponsoring the project; to Messrs Rajeev Kumar, Syriac Sebastian and Parveen Saxeena for help in statistical and computing work. Finally, I thank Professor Brian H. Rudall, Editor of this journal, for inviting me to contribute to this Special Issue

Kybernetes, Vol. 24 No. 7, 1995, pp. 61-74. © MCB University Press, 0368-492X

and Simon[4]. The concept of feedback occurs in the theory of multipliers by Keynes[5], and in the theory of accelerators by Samuelson[6]. An overview of cybernetic modelling of economic systems occurs in Ghosal[7]. An economic policy of a country is based on the comprehension of large dynamic systems.

In the practical world cause-effect phenomena may not always be quantified or quantifiable; they may be recognized in the form of cognitive (or declarative) statements which can be expressed in natural languages only. In cybernetics and artificial intelligence such logic statements can be used in decision making. The statement by Lord Kelvin, more than a century ago, that a knowledge is not perfect unless it is quantified, is being contested by system scientists who view that a logic statement (even without quantification) also conveys a considerable amount of information.

There is scope for the injection of cybernetic ideas in problems in economics. Some are mentioned below.

Process of development

Particularly in Third World countries, this process is not understood adequately through classical economics. A total model of the development process can be made only through an understanding of the total process of development, which includes factors like ancient and complex cultures[3].

Employment vs inflation

A perennial problem faced by all countries is to attain a high employment level without inflation. Reality is, however, that a high employment level is always associated with inflation. The total system of price determination may be approached like a problem of communication networks; hardly any work is being done in this direction.

Problems of sub-optimization

Sometimes it so happens that the attainment of optimization of a part of the system prevents the attainment of the optimum in the total system. Welfare economics presents many problems of this type.

Visualizing the effects of future policies

The policy adopted today will be reflected in the achievement of the production system tomorrow. The growth process is never invariant of human decisions. The policy aspect is not only relevant for technological options, but is of some value while making choices for marketing policies, social policies, etc.

Projection of the future

In statistics or econometrics projection of the future is based on the premiss that the past is a guide for the future. Accordingly, many of the projections are done by extrapolating the trend obtained in the past on the assumption that the growth curve is continuous. In a dynamic system subject to intervention by changing policies and changing global conditions, the growth process is at best

continuous with sectors of short intervals. There is the possibility of peaks and discontinuities. The logical way for future projection is to build scenarios under a number of premisses. The challenging problem to economic cyberneticians is to develop models to predict the effects of new policies in the future.

Statement of the problem

A cybernetic approach to future planning for a large country like India encompasses a wide spectrum, covering aspects of both macro-planning and micro-planning and, at the same time, it may also address the problems of global modelling as studied by the Club of Rome of Forrester and Meadow in the 1970s (see[8] for an excellent review). The study deals with the following problems, and explores their use in the context of India:

- It presents methodological aspects of looking into a dynamic system, such as India presents.
- It studies the pattern of changes of key indicators like gross domestic product (GDP) in real term (price level of 1980-81), population factors, money supply, nutrition aspects, problems of growth of industry, agriculture and transport sectors during the past, and determines the time points of discrete changes (jumps or dips), periods of discontinuous growth, etc.
- From the study of growth patterns an attempt has been made to assess how policies have contributed to such changes.
- Since growth in the past for most of the variables is discontinuous, there is no reason why the same pattern should not continue in future.
- Making predictions for the future is an important aspect of cybernetic thinking. The predictions are made in terms of conditional forecasts: assessment of feed-forward and feedback effects of policy decisions have been made.
- Strategic planning is a cybernetic concept, because it depends on evaluation of the influence of the outer world in the future. For example, in the past most of the foreign trade of India has been with the developed countries of the West (the USA and Europe). The emergence of Middle East and Pacific Rim countries (including Japan) as economic powers would produce significant foreign trade of these countries with India.
- Changes in social and economic perspectives would also have to be taken into consideration. Thus, just after the independence of India in 1947, self-reliance had been the most important aspect of Nehruvian policy; in the 1990s the principal theme of economic policy is globalization and the assumption of open systems. Nehruvian economy focused primarily on the development of the public sector; in fact a strong industrial base of India could be developed because of public sector development of coal, steel, power, cement, fertilizer and other basic industries. Opening up in

the 1990s would induce more privatization and foreign enterprises in infrastructure sectors.

- Finally, on the basis of perspectives of the future, an overview would be undertaken of natural resources available in India and from outside countries for the development of industry and agriculture, and policy would be determined for the development of such resources (including human resources). On the basis of scenario building for the future, constraints in the production of goods and food would be perceived. The future production matrix or GDP in 2030 or 2050 would be the result of decision taken in the intervening period.

Varietal aspects

Taking a cue from Ashby's Law of Requisite Variety[9], we have the following varietal aspects in a planning exercise:

- *Policy planning (or indicative planning).* This comprises a statement of goals to be achieved for different sectors at different time points in the future.
- *Strategic planning.* This aspect is concerned with establishing strategies for reaching the stated goals at different points of time. Various alternative paths may be available to reach the stated goals; a choice of a path/paths would depend on social and political considerations (see also [10]).
- *Operational planning.* This comprises the detailed process of implementation of the goals stated in indicative planning and the paths prescribed in strategic planning.

When India started a planning economy in the 1950s all these aspects were controlled and implemented by the government. With the opening up of the economy in the 1990s the present outlook is to prescribe only policy planning, leaving strategic and operational planning to entrepreneurs both in the public and private sectors. The broad strategy is to effect a synergistic system in which resources (human and natural) and capital are deployed optimally.

An alternative varietal structure for agricultural and industrial development is as follows:

- *Resource-based production* in which an industry is developed in a region only if it has resources locally or in the vicinity (for example, a steel plant is started if iron ores, limestone, power, water, etc are available).
- *Inverse planning.* This concept implies that certain economic activities are initiated in a region primarily for its development even if basic raw materials are not available. This is a feed-forward process in which essential materials are imported into the region from other areas for producing a complex of industries and agricultural goods, provided some infrastructural facilities are available. To some extent,

development of the UK and Japan has been due to inverse planning. In India there are many examples: for example, the city of Calcutta was transformed into a metropolis from a conglomeration of three or four villages by the British rulers over two centuries.

Exploratory modelling

Exploratory modelling (EM) is a modelling device in which empirical data are examined for the purpose of choosing an appropriate model; it is very similar to the exploratory data analysis of Tukey[11]. For the purpose of macro-planning EM has been applied to understand the behaviour of growth patterns of important economic indicators of India, e.g. GDP (at 1980-81 prices), money supply, production of energy, steel and important crops like wheat, rice, etc. A brief account is given below.

Pattern of GDP

The growth pattern of GDP (in 1980-81 prices) for the period 1950-92 is given in Figure 1. It suggests a growth pattern of exponential nature over short time intervals: there has been a peak or dip every six or seven years corresponding to some changes in policies or natural catastrophes. If $\ln G$ is plotted against time (G = GDP) we have,

$$\ln G = a + bt \qquad (1)$$

where a and b change at intervals of six to seven years. The rate of growth $b = d \ln G/dt$ changes after such intervals. On this basis, projection of GDP has been made up to 2016 in Figure 2, under three assumptions:

(1) 6 per cent rate of growth over 1996-2002; 7 per cent rate of growth over 2001-2006; 6 per cent of growth over 2006-2016;

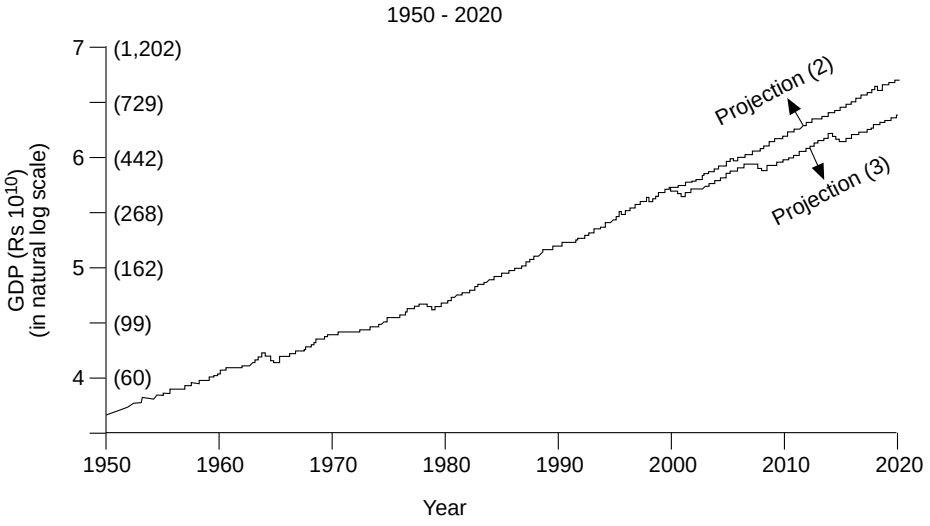
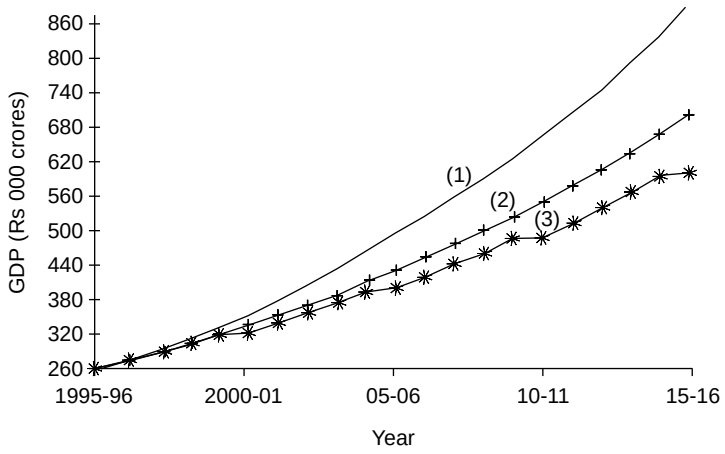


Figure 1.
Pattern of growth of GDP (1980-81 prices) in natural log scale



Note: 1 Crore = Rs 10,000 000

Figure 2.
Projection of GDP in 1980-81 prices

(2) 5 per cent of growth uniformly;

(3) 5 per cent of growth with depressions in 2000-1, 2010-11, 2015-16, etc.

It appears that there may be a number of trajectories of growth in the range obtained for (1) and (3) (Sterling £ = Rs 52 approximately; US$ = Rs 31.50 approximately).

Money supply

The pattern of growth in money supply is given in Figure 3, indicating exponential growth shown in (1) with changes in the values of (*a*) and (*b*). The annual rate of growth over 1950-92 varied between 15 and 18 per cent. The rates of growth of money supply and GDP are related in the following manner:

$$D \ln M/dt = d \ln G/dt + \mathrm{d} \ln W/dt \quad (2)$$

where *Wt* is the wholesale price index in year *t* so that *d*ln *W/dt* is a measure of inflation (*G* = GDP, *M* = money supply).

For a perspective of the future over the next 20 years, if the rate of inflation varies between 8 and 10 per cent, the targeted rate of growth of GDP (real) between 5 and 7 per cent, then the rate of money supply would range between 13 and 17 per cent over various short periods of 5/6 years in the future. On an assumption of 15 per cent growth rate money supply would increase from approximately 476 in 1995 to 4,285 in 2010 and 80,000 in 2030 (in 10^{10} Rupees) (see Figure 3).

A projection of the wholesale price index (*W*) (with base year 1981-82 = 100) would indicate a change from 275 in 1995 (January) to 869 by 2010 and 1875 by 2020 on the assumption of an inflation rate of 8 per cent.

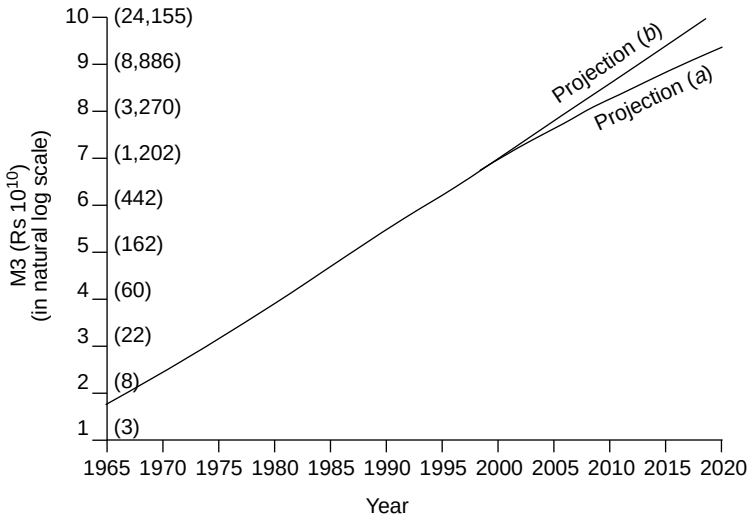


Figure 3.
Pattern of growth of money supply (M3) (in natural log) 1965-2020

The present poverty level of an Indian family has been estimated at Rs 1,000 (£20) per month in 1992-93; it would rise to Rs 4,700 or £90 per month by 2010[1].

Industrial production

The pattern of production of most of the industries over the whole country has been studied in[1]. An interesting aspect to note is that capacity restraint is reflected in most of the growth curves. For example, the pattern of production of steel (saleable steel or ingots) over 1950-92 shows sudden jumps corresponding to the starting of new steel plants or augmentation of production programmes (see Figure 4). After a certain time, a significant increase in production occurs only after increasing installed capacity. The pattern of growth appears to be a combination of a number of logistic curves given by

$$Y_t = K/\{1 + c \exp(-atK)\}\ K \qquad (3)$$

where K corresponds to the installed capacity; K increases when the installed capacity is augmented according to a policy decision by the government. Consequently, when installed capacity is increased, say, by starting new plants, there is a jump in production. Such an equation is particularly applicable to developing countries where capacity is less than the potential demand.

Quite a few industries (e.g. aluminium, petroleum crude, etc.) follow the growth pattern given by equation (3). Coal and energy show almost continuous exponential growth given by equation (1). From the normative planning approach, it appears that the energy production has to grow much faster than the rate of growth b of the exponential curve $Y_t = a \exp(bt)$ obtained now. The present value of b is between 0.11 and 0.12; to cope with a desirable industrial demand, b has to be increased to about 0.20 by the year 2000. The other alternative is to devise technology which is less energy intensive.

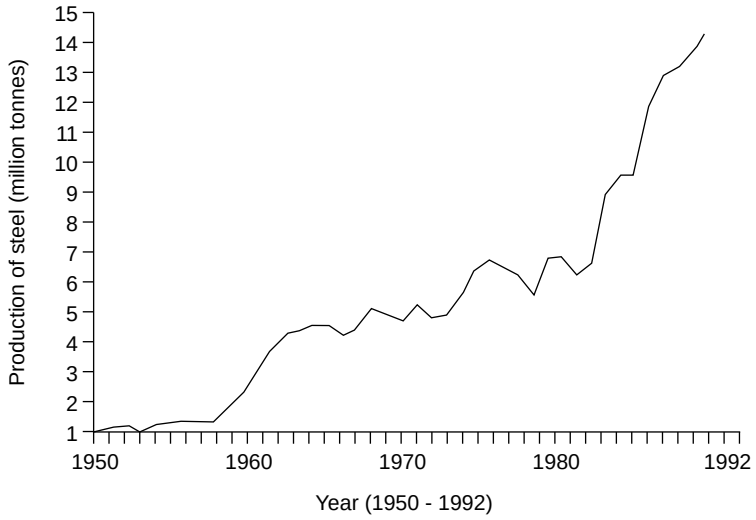


Figure 4.
Trend in production of steel, 1950-1992

Agricultural production

Principal crops like wheat, rice, maize, potato, etc. showed a dramatic rise in yields due to the green revolution in the 1960s. The production trend curve for wheat (Figure 5) shows the effect of the green revolution in the mid-1960s causing a sharp upward trend. The occasional dips or downward trends (early 1970s and early 1980s) were due to natural calamities like drought. The yield rate of wheat can be increased only through technological inputs like the intelligent use of high yielding varieties, fertilizers (combinations of *N, P* and *K*), etc.

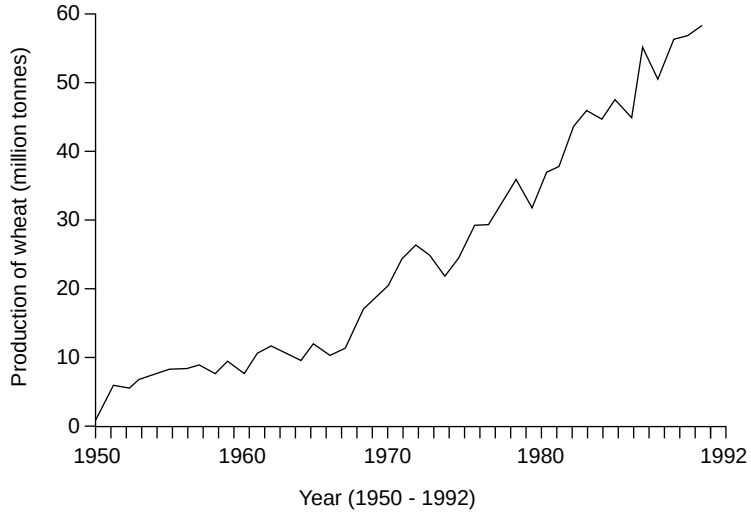


Figure 5.
Production of wheat, 1950-1992

Production of rice has shown greater fluctuation through the period 1950-92 (Figure 6); however there is an upward trend. The yield rate is increasing, but it fluctuates from state to state. It has a long way to go to reach the yield level of Japan and Italy.

A detailed future perspective for food production in India has been given in [1]. Challenges to cyberneticians, economics, agriculturists, etc. are to meet the food demand for a growing population which has been growing at a rate slightly above 2 per cent per annum. This aspect will also be discussed in the next section.

Transport

Transport is a crucial sector for development which calls for the increasing movement of men and materials. The mechanics of growth of the transportation network can be understood from a cybernetic viewpoint as follows: present traffic (y_t) either by rail, road or air is dependent on two aspects; first, potential demand (p_t) arising out of economic activities $E_1, E_2, \ldots, E_n$ in n sectors; second, capacity generation (K_t) through time. The complex relation structure between y, P and K cannot be explained through a multiple regression equation; on the other hand, there is scope to develop diffusion type equations. Before going into such mathematical structures, let us consider the empirical data for domestic air traffic, railways, etc.

Domestic air traffic. Until three years ago, Indian Airlines used to be the only domestic carrier, owned by the government. Its business used to be (and is still) monopolistic: price elasticity of demand is practically of no importance because most of the passengers (about 75 per cent) travel on official work of

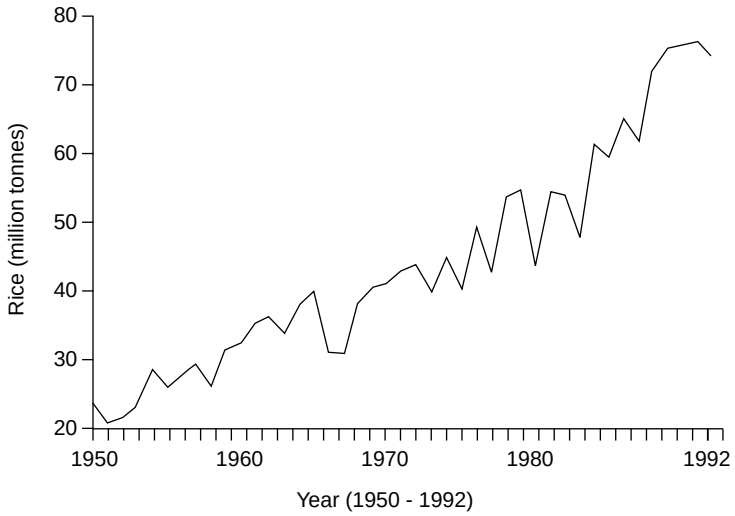


Figure 6.
Production of rice, 1950-1992

government/non-government organizations. Growth of passenger traffic against capacity provision (1984-1996) is shown in Figure 7. It shows that the actual traffic follows the capacity closely, because the load factor (actual traffic/capacity) is high, between 75 and 80 per cent over most of the trunk routes. Accordingly, a dynamic logistic model of growth as given below is appropriate:

$$d \ln y/dt = \lambda(K_t - y_t) \tag{4}$$

or

$$y_t = K_t/\{1 + c \exp(-\lambda_t K_t)\} \tag{5}$$

the same as equation (3). Because $K_t < P_t$ (potential traffic), y_t should increase to K_t immediately; however, given a capacity constraint, the traffic adjusts according to other logistic facilities, like airport capacity, development of technical expertise, etc.

In a developed country where $P_t > K_t$, we may express in y_t as follows:

$$\ln y_t = A + \sum B_i \ln E_t^i \ (i = 1, \ldots,) \tag{6}$$

where E_t^i is the production of the ith sector ($i = 1, \ldots, n$) in the tth year.

Rail transport. Here also the trend of growth of passengers originating cannot be expressed strictly as exponential; on the other hand, it can also be expressed in a dynamic logistic form (5) (see Figures 8 and 9).

A more detailed analysis has been made for rail and road transport in [1].

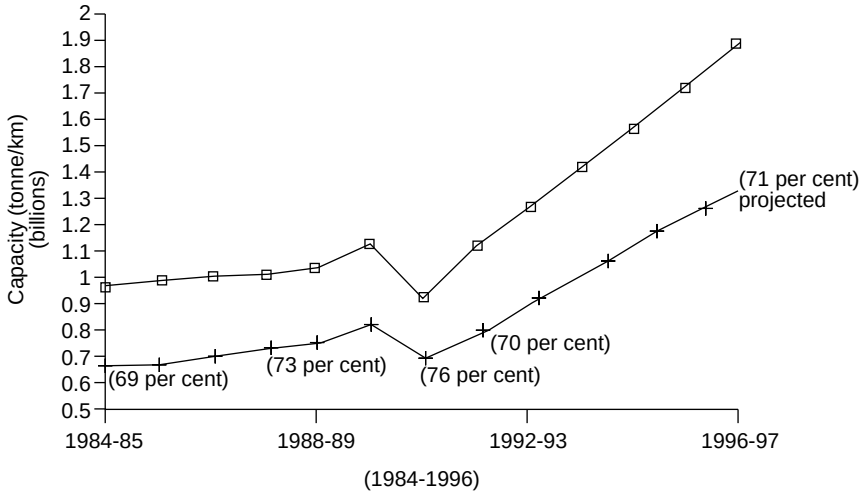


Figure 7.
Capacity available and utilized (Indian Airlines) estimated (tonne/km), 1984-1996

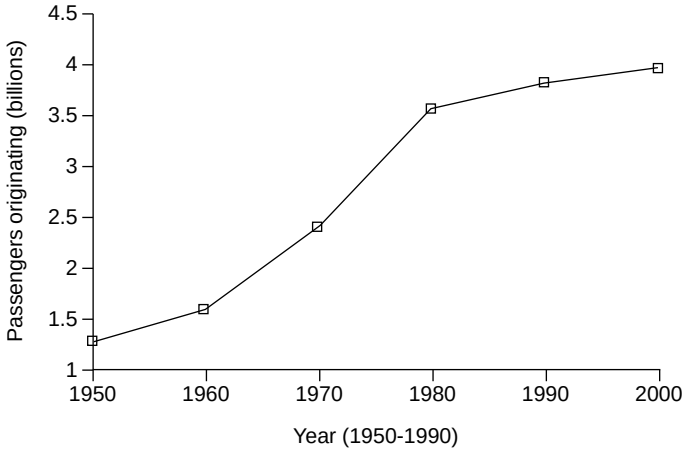


Figure 8.
Rail transport estimated passengers originating 1950-1990

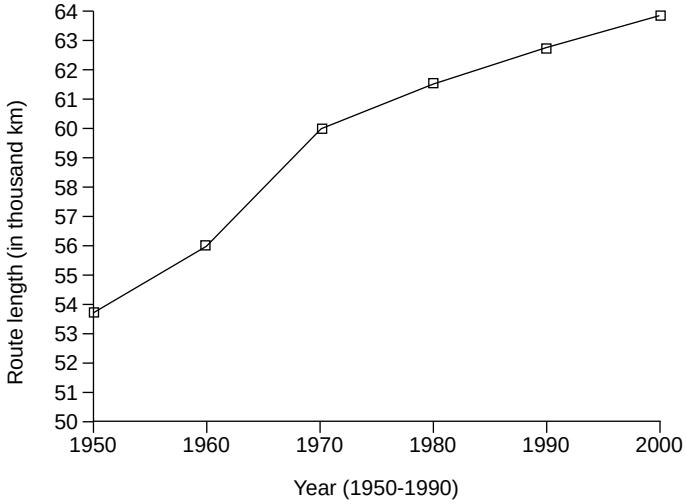


Figure 9.
Rail transport (route length) 1950-1990

Population dynamics and nutrition profile

The World Bank[12] classifies countries according to gross national product per capita (GNP per cap). Table I gives the basic indicators, e.g. GNP/cap, population, life expectancy at birth, adult illiteracy, etc.

The annual growth rate of population is 2.1 per cent for India as against 2.2 for Bangladesh, 3.1 for Pakistan, 0.2 for the UK, 0.9 for the USA and 0.5 for Japan. Most of the western European countries have attained a state of stationarity in population growth (61 million for the UK, 65 for Germany, 63 for France). According to[12], the hypothetical size of the stationary population for the USA is 348 million (by the middle of the twenty-first century), about 1,890 million both for India and China (by 2075). From these figures it appears that there is a strong correlation between female illiteracy and growth rate; even

Country	Population (millions) 1991	GNP per capita $US 1991	GNP per capita Annual growth rate 1980-91	Average annual rate of inflation 1980-91	Female illiteracy (%)	Life expectancy at birth
India	844	330	3.2	8.2	66	60
Bangladesh	110	220	1.9	9.3	78	51
Pakistan	116	400	3.2	7.0	79	59
Brazil	151	2,940	0.5	328	20	66
China	1,150	370	7.8	5.8	38	69
Indonesia	181	610	3.9	8.5	32	60
UK	53	16,550	2.6	5.8	0	75
USA	253	22,240	1.7	4.2	0	76
Japan	124	26,930	3.6	1.5	0	79
Australia	17.3	17,050	1.6	7.0	0	77

Table I.
Basic indicators

Source: [12]

within India a state like Kerala with a low female illiteracy (FI) rate of 13 per cent shows the lowest annual population growth rate (1.3 per cent over 1981-91); Rajasthan has a population growth rate of 2.5 per cent per annum and an FI rate of 79 per cent. It appears, therefore, that an explosion of population cannot be controlled only through family planning programmes but by a social transformation which would include augmentation of women's education programmes, increasing age at marriage of women, etc.

According to an estimate, about 27 per cent of the population (230 million in 1991) are below the poverty line, which presently is Rs 1,000 (US$32 or £20) per month. On the assumption of an inflation factor of 9 per cent per annum the poverty line would be Rs 2,000 per month by 2000 and Rs 4,700 per month by 2010.

A nutrition policy has been framed by the government by applying a systems approach. Income, knowledge, health facilities, productivity of soil, method of land and water management, level of technological expertise, etc., are all contributing factors. Sample surveys have been done throughout the country to ascertain protein-energy malnutrition (PEM), iron deficiency, iodine deficiency, vitamin A deficiency, low birth-weight children, seasonal dimensions of nutrition, etc. It appears that female literacy and better health awareness ensure better nutrition. Though there are variations among states, the state of development in Kerala proves the hypothesis that better female education is a positive factor in ensuring nutrition to children. An intervention programme for better nutrition, therefore, suggests nutrition education, micronutrient fortification, food supplementation, food price subsidies, and prevention of water-borne diseases like diarrhoea, dysentery, etc.

There are a few problems which need to be considered for future planning.

Age distribution of population

In 1991, out of a total population of 844 million, about 57 per cent belonged to the age-group 15-60; in other words, these 57 per cent contributed to the labour and workforce and supported older and younger people. By 2000 the total population would exceed 1,000 million, but the percentage of people in the age group 15-60 would be about 55. Employment would be a problem, because both agriculture and industry would be less labour-intensive.

Urbanization and environmental degradation

An alarming social-cum-economic problem is more and more congestion in cities, the emergence of more and more mega-cities and the flocking of the population from villages to cities. Most of the emerging mega-cities would not have infrastructural facilities to support a large population. The result would be environmental degradation, increase in crimes and chaos, unless the rate of rehabilitation of the growing population, through the facilities of education, employment, housing, etc. is high. There is scope for social cyberneticians to investigate problems in this area.

Availability of food vs poverty

On a country-wide average basis food availability per capita is 0.29 tonnes per annum, mostly in the form of cereals. However, about 27 per cent of the population cannot afford to purchase this amount and has to remain underfed. A system approach to the enhancing of the income of the rural workforce is necessary; to some extent the Gandhian approach to self-sufficiency of each household has to be combined with the development of large farms.

Cybernetic thinking for large complex systems also gives impetus to innovative models. For example, classical econometrics propagates the use of multiple regression equations, simultaneous equations, etc., to explain cause-effect behaviours in the growth of GDP, traffic, etc. It has been shown in the study that such textbook methods do not always explain discontinuities and peaks in growth. There is scope for explaining and predicting future growth through the dynamic logistic models given in equation (3). The use of logistic models also suggests that in developing countries, a policy for higher installed capacity (K) provides an impetus for growth. For example, in an airline, the introduction of more aircraft and port facilities may be the most significant factors for traffic growth. Also there is scope for the application of diffusion equations like:

$$\frac{\partial y}{\partial t} = a\frac{\partial y}{\partial x} + b\frac{\partial^2 y}{\partial x^2} \qquad (7)$$

in studying growth models.

Strategic planning calls for the study of the outer world and its dynamics for understanding the growth of foreign trade. There is scope for Markovian modelling in understanding trade behaviour among neighbouring countries.

It is intended to consider such modelling aspects in the future.

Concluding remarks

Some of the issues dealt with in[1] have been discussed in this article. The limitation of the exploratory study, however, is that scenario-building has been carried out with only a few macro-variables such as GDP (in real terms), money supply, population, food production, nature of inflationary pressure, etc. India is a vast country, however, within which various states show a good deal of variation; the fact that some states like Bihar, Orissa, Madhya Pradesh, etc. with good natural resources (including good soil conditions and mineral resources) are very undeveloped with a large population below the poverty line leaves scope for detailed systems studies. Problems of environmental degradation arising out of more industrialization, and more urbanization should also be studied. Taking a cue from Cairncross[2] that economic policy is only a facet out of an overall policy, we realize that social, technological and political factors are extremely important. In fact, the social impact of setting up a large industrial plant in a location which is primarily an agricultural area needs to be considered. Finally, present day technology, including availability of computerized systems, supports the development of small viable industrial units. In such a process of disaggregation there is a possibility of providing a high rate growth impetus to small states like Kerala, Goa, Harayana, etc., even though the entire country can at best have a growth rate of 5 to 6 per cent in terms of national product through the operation of the Law of Large Numbers.

The use of a cybernetic approach in problems of planning and development in Third World countries has been advocated by Sengupta[13]. There is scope for synergistic development between South-South and North-South countries.

References

1. Ghosal, A., *An Exploratory Study: Cybernetic Approach in Future Planning with Special Reference to India,* (Special Report to Planning Commission) Society of Management Science Applied Cybernetics, New Delhi, 1995.
2. Cairncross, A., "The managed economy", *The Advancement of Science,* Vol. 26 No. 127, 1969.
3. Boulding, K.E., "Economics and general systems", *International Journal of General Systems,* Vol. 1, 1974, pp. 67-73.
4. Simon, H., *Models of Man*, John Wiley, New York, NY, 1957.
5. Keynes, J.M., *The General Theory of Employment, Interest and Money,* Harcourt, Brace and World, New York, NY, 1936.
6. Samuelson, P.A., *Foundation of Economic Analysis,* Harvard University Press, Boston, MA, 1948.
7. Ghosal, A., *Applied Cybernetics: Its Relevance to OR,* Gordon and Breach, London, 1978, Chap. 3.
8. Meadows, D., Richardson, J. and Bruckman, G., *Groping in the Dark*, John Wiley, New York, NY, 1982.
9. Ashby, W.R., *An Introduction to Cybernetics,* John Wiley, New York, NY, 1956.
10. Ansoff, I., *Corporate Strategy,* McGraw-Hill, New York, NY, 1965.
11. Tukey, J., *Exploratory Data Analysis,* Addison-Wesley, Reading, PA, 1977.
12. World Bank, *World Development Report,* Oxford University Press, New York, NY, 1993.
13. Sengupta, N., "Cybernetics in problems of development of the Third World", in Ghosal, A. and Murthy, P.N. (Eds), *Recent Advance in Cybernetics and Systems,* Tata-McGraw-Hill, New Delhi, 1993, pp. 3-6.