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Flexible Systems Methodology[1]

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To facilitate the use of systems-based techniques and approaches more systematically, these have been related to each other by different schemes in the past. A review of the literature is presented to highlight the development of cohesive frameworks and use of a spectral and integrative paradigm. An outline of "flexible systems methodology" is provided to resolve the end of continuum paradoxes in the literature in a spectral and integrative manner. The methodology is presented in terms of its purpose, philosophy, paradigm, steps, strengths, and limitations. A case study of energy policy analysis is presented to demonstrate the application of Flexible Systems Methodology.

KEY WORDS: flexibility; integration; paradigm; systems continuum; systems methodology.

1. INTRODUCTION

Systems concepts and methodologies have been developed as a response to the ever-increasing complexity of sociotechnical and managerial systems. Many techniques and approaches based on systems philosophy have been developed which help in analyzing various problem situations in multiple ways. In the past, attempts have been made to judge the supremacy of one technique or approach over the others, but all such debates have not been able to lead to conclusions which are universal in nature. Different approaches have found favor in different situations and have their own strengths and limitations. The task of designing or selecting methodology for a particular problem situation is becoming more difficult with an ever-increasing choice of techniques.

It has been a constant endeavor in systems thinking to relate the developments in systems-based techniques and approaches to establish the trends and develop conceptual frameworks. Bertalanffy (1972) has reported extensive

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developments in the field of general systems theory and discussed the trends in systems science, mathematical systems theory, systems technology, and systems philosophy. General systems theory worked to structure sciences and systems (Boulding, 1956) and tried to embrace a variety of systems such as material systems, informational systems, and conceptual systems. It worked more as an umbrella under which the philosophical as well as the mathematical systems concepts developed.

Ackoff (1971) presented a system of systems concepts. He presented a behavioral classification of systems as state-maintaining, goal-seeking, multi-goal-seeking and purposive, and purposeful systems. Indirectly he gave a very important link between soft and hard systems thinking by relating learning to the achievement of goals.

Hall (1962) has described the framework of systems engineering which emerged as a discipline, under which a set of systems-based approaches and techniques is considered. In systems engineering a heavy emphasis were placed on structural modeling. Though it provided an overall framework, it proved to be comparatively too rigid to cater to all the requirements of managerial and social systems and is now seen as an example of hard systems thinking. Sutherland (1975) discussed various modalities of system structure such as structural dimension, evolutionary modalities, boundary modalities, organizational modalities, and modalities of system behavior in terms of deterministic and stochastic systems. These modalities help in clarifying the systems, which can then be better related to various systems analysis techniques.

The systems movement was reviewed by Checkland (1981), describing developments on different fronts and characterizing earlier developments as hard systems thinking and newer developments as soft systems thinking with a "learning" paradigm. Though he tried to rethink the systems approach, it resulted in a competitiveness between hard and soft systems thinking, which, in fact, are the two ends of the systems continuum and are more complementary paradigms rather than competitive.

Another important review of systems practice, by Stainton (1984), focused upon the distinction between systemic and systematic, and considered traditional operational research, systems analysis, and systems engineering, in contrast to the works on the softer side by Beer, Ackoff, and Checkland, and talked of "applicable systems thinking". This also divided systems thinking into two extremes, i.e., hard and soft, rather than bringing them closer to each other.

Organizational implications of systems thinking were reviewed by Gharajedaghi (1984), and a multidimensional modular design was recommended which can provide the required level of interaction and flexibility. This deals primarily with organizational design considerations; the application of systems thinking to organizational problems can be seen in many more applications.

A significant related development was in the area of cybernetics and its application in management thinking. Robb (1984) reviewed management theories and the relationship of cybernetics to them, along with new cybernetic contributions to management theory. These cybernetic concepts are used in many systems-based approaches and techniques and a cohesive framework is needed to utilize them effectively. Flood and Jackson (1991) provided a cohesive framework as a system of systems methodologies.

In order to use the available techniques more systematically, there is an increasing trend to develop schemes that relate these techniques in a meaningful manner. A thought-provoking review by Troncale (1988) put the developments in systems sciences together. It defines the domains of systems science as general theory of systems, systems theory, systems analysis, and systems applications. It provides a morphology of different fields of knowledge related to systems science and, also, linkage propositions between systems concepts (isomorphies). Further, it outlines various systems techniques or methods including both "hard" and "soft" types. It discusses the unified spectrum of systems approaches and the opportunities that could be derived from information transfer between operational research and systems science, such as (i) a rigorous taxonomy of systems, (ii) a rigorous taxonomy of isomorphies, (iii) a rigorous taxonomy of general systems functions, and so on. This paper derives inspiration from such a relational approach and further proposes a cohesive methodological framework that captures the essence of spectral (covering the whole range or spectrum) and relational thinking and provides a flexible approach to using the isomorphies and systems techniques and methods.

A set of consensus methodologies is being developed by Warfield (1990) as part of a science of generic design. The set of consensus methodologies is composed of primarily qualitative techniques. The concept is expanded in this paper to involve the whole range of techniques from quantitative to qualitative. Another recent development is the concept of "total systems intervention", as proposed by Flood and Jackson (1991). The concept of total systems intervention talks of six clusters of systems-based techniques in view of the relevant systems being simple or complex and the relationship between the people being unitary, pluralistic, or coercive in different problem situations. Here the concept is further generalized to integrate the clusters so as to form a continuum of systems-based techniques which can be used flexibly by suitably interfacing techniques as per the requirements of the problem situations.

The value of combining various systems modeling approaches can be effectively seen in the area of decision support systems (DSS) and artificial intelligence (AI), which are based on cohesive and symbiotic frameworks of quantitative as well as qualitative approaches. These have been called by different names such as expert support systems, intelligent decision support systems, knowledge-based decision support systems, etc.

An AI approach to model management in DSS was described by Dutta and

Basu (1984), which addresses the key issues in model management system design. Sal (1985) suggested that DSS research be directed to the concept of DSS generators, or more generally DSS design environments, and takes up the process of problem solving in a knowledge-based framework. Lehner *et al.* (1985) have outlined a practical approach to decision aid development that systematically exploits both the problem-structuring techniques of decision analysis and the incrementally modifiable software architectures found in AI.

Luconi *et al.* (1986) discussed the importance of expert systems and saw that the next logical progression in computer system development, i.e., data processing, DSS, AI, and expert systems, would give way to expert support systems. A new approach for assisting problem solving in ill-structured management domains through a knowledge-based human and computer cooperative system is presented by Niwa (1986).

Kerckhoffs and Vansteenkiste (1986) described the impact of AI techniques in modeling and simulation and briefly reviewed knowledge-based simulation, AI-supported model synthesis, and some additional topics with respect to integrating AI and the systems analysis approach. O'Keefe (1986) suggested that the most fruitful areas of cross-fertilization of expert systems and simulation are advice-giving expert systems that assist the simulation scientist and simulation user, new simulation tools built from knowledge-based tools, and intelligent front ends for simulation packages. Moser (1986) emphasized the need for user-friendly DSS and suggested that integration of AI and simulation could serve a great deal toward providing such systems.

Cooper (1986) contended that the gap between managers and the analytic/computer competence existing in present-day DSS software could be bridged with expert systems. Similarly a combination of data management and AI technologies is pointed out by Kellogg (1986).

Zeleny (1987) concluded that "integration" is now rapidly becoming a byword of the newly emerging high-technology and knowledge-based management systems and management support systems. These are more integrated versions of electronic data processing, MIS, DSS, expert systems, and AI and are now capable of creating, storing, maintaining, and expanding knowledge as well as supporting the knowledge process of humans. Most of the research efforts in the past have focused on physical integration of DSS and ES, but logical integration of DSS and ES, and organizational strategies for integration have received less attention. An organization-based DSS/ES architecture has been proposed by Chen (1989) to remove these shortcomings. Turban and Trippi (1989) point out that there is now a clearly recognizable evolution of operations research into DSS, which is in turn rapidly incorporating expert systems technologies. Such systems have greater capabilities and are more applicable to a much wider range of applications, can handle more steps in the decision-making process, and can fit more diversified and complex decision situations.

Thus, it can be seen that the philosophy of integration of quantitative and qualitative tools is emerging very rapidly to cater to the diverse requirements of the decision-making and managerial processes. Deriving inspiration from the developments in systems methodology in terms of schemes of systems techniques, and the wide applicability of integrated systems in computer-based management, the philosophy of integration of techniques is generalized over the whole spectrum of system techniques. It is presented in the form of an evolving methodology, in subsequent sections, which can take care of the varied requirements of problem situations in a flexible manner. The methodology presented here has evolved through the research work carried out over nearly a decade, and has been developed and applied in about 50 projects at the M.Tech., Ph.D., and industrial consultancy level.

2. PARADOXES

There are quite a few end-of-the continuum paradoxes in the literature which have created separate schools of thought. Some dominant ones are outlined below.

2.1. Hard vs Soft Systems Thinking

Hard systems thinking is based on an "optimizing" paradigm, whereas soft system thinking is based on a "learning" paradigm. Both paradigms have been criticized by each other. These paradigms are not in competition, however, and should be used in a complementary and integrative manner according to the requirements of the problem situation.

2.2. Quantitative vs Qualitative Analysis

There has been development in the past in quantitative techniques of analysis and qualitative techniques of analysis separately, and the proponents of either of the approaches form separate schools of thought. According to the quantitative school of thought, it provides a tangible and objective analysis of the problem situation, whereas qualitative analysis involves subjectivity and bias. On the other hand, according to the qualitative school of thought, it provides a fuller perspective of the problem situation more creatively by considering both the tangible and the intangible variables involved, whereas quantitative techniques try to see the complex situations very simplistically, involving only a partial set of variables involved and, thus, may mislead the user. Again, the qualitative as well as the quantitative techniques should be used in conjunction with each other to complement their strengths and weaknesses.

2.3. Individual vs System Structure

What should be the focus of attention, the individual or the system structure? This has been a persistent question in the management of different systems. Both the individual elements and the system structure are important for the performance of any system and should be given due weight in managing the system. However, depending upon the problem situation, the primary emphasis may be placed either on the individual components, or subsystems, or on the whole system. It should be treated as a continuum from the individual components to the whole system. Depending upon the situation under consideration, the emphasis should be placed on the appropriate portion of this continuum.

3. FLEXIBLE SYSTEMS METHODOLOGY: AN OVERVIEW

An overview of the proposed flexible systems methodology is provided in terms of its purpose, philosophy, and paradigm.

3.1. Purpose

The purpose is to formulate a problem-solving approach based on systems philosophy and using systems techniques flexibly for problem situations lying on the whole continuum, e.g., ranging from unstructured to well structured.

3.2. Philosophy

Problem situations can be handled with two possible philosophies at the extreme, e.g., isolationist and situational.

According to isolationist philosophy, a "best" approach is to be developed which will be useful in all possible problem situations. Traditionally, a lot of work in this direction has been done in different disciplines. For example, attempts have been made in scientific management (Taylor, 1947) to find one best way of doing the job, and in administrative management (Fayol, 1949) to develop general principles of management. In the systems literature work was done on development of a theoretical base to suit all classes of problems, e.g., general system theory (GST) (Klir, 1969).

On the other hand, the situational philosophy believes in developing a unique approach for each problem situation. It is built on the belief that every problem situation is unique in its own right and, thus, needs a unique way of handling it, for example, situational management and developing heuristics to solve typical problems.

Both these philosophies have worked but have encountered failures also. The isolationist view is bogged down with the development of a grand paradigm, which is an ideal and difficult to achieve, and thus, to encompass every possible variation in a single approach is almost self-defeating. Similarly, developing a unique approach for each problem situation is very time- and resource-consuming and, thus, is not a practical proposition.

The philosophy which lies in between these two extremes is of "flexibility," and is the basis of the proposed methodology. According to it, there are multiple ways of reaching the same end, and the suitability of the way or a combination of ways will depend upon the nature and attributes of the problem situation at hand. It does not advocate the invention of a new approach for each problem situation but, rather, selects an approach out of the existing well-researched ones, or a suitable combination or innovation of them, so as to match the requirements of the problem situation. It thus integrates all systems approaches and techniques into a family in which every one either individually or collectively contributes meaningfully. A similar spirit is in evidence in other disciplines also, e.g., to a limited extent in contingency theory of management (Luthans and Steward, 1977), and more prominently in flexible systems management (Sushil, 1994).

3.3. Paradigm

Flexible systems methodology is built on a "spectral and integrative" paradigm. It tries to resolve the end of continuum paradoxes, as it is based on a spectral paradigm, treating all the systems-based methodologies and techniques as lying on a continuum ranging from hard to soft, and all the problem situations also on a continuum ranging from well structured to unstructured, as shown in Fig. 1. Though apparently the different paradigms seem to be incommensurate, in reality there are overlaps and common points in different paradigms which will serve as linkage points.

As can be seen by the basic nature of various systems-based methodologies and techniques, they may be at different points on the continuum from hard to

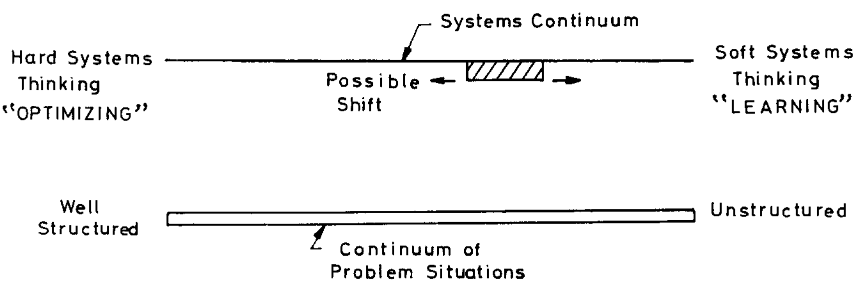

Fig. 1. Systems continuum: a spectral paradigm.

soft. There is a heavy clustering of methodologies and techniques toward the ends of the continuum, leaving a gap in between as shown in Fig. 2, as the two governing paradigms were ''optimizing'' or hard systems thinking and ''learning'' or soft systems thinking.

For example, techniques such as linear programming, goal programming, search methods, physical system theory, etc., are hard in their design, whereas approaches such as soft systems methodology, interpretive structural modeling, Delphi, scenario building, group problem-solving techniques, etc., are clustered on the soft side. There are very few approaches which lie on the middle part of the continuum in between the hard and the soft, e.g., system dynamics (Forrester, 1961). Wolstenholme (1990) has clearly emphasized qualitative system dynamics, and flexibility in using system dynamics methodology has been brought out by Sushil (1993).

It can be seen that the problem situations in real life are not clustered on the ends of the continuum, i.e., well structured or unstructured. The problem situations in real life lie on the whole continuum; rather, practically more in the middle part than the ends, with some parts structured and some ill structured.

Thus, in order to apply the existing systems-based methodologies, which are clustered primarily at the ends of the continuum, to the problem situations which lie more in the middle part of the continuum, assumptions must be made to match the two, so that either the harder or the softer approaches are adopted. There is a need to bridge the gap on the continuum of systems-based methodologies as shown in Fig. 2. This gap can be bridged by creating new techniques and methodologies which can cater to the problem situations lying in the middle part, i.e., some portions well structured and some ill structured at different levels of structuring, which is going to take its own time. Moreover, it will further add to the existing set of techniques and will demand more from the user in selection of the appropriate approach.

The alternate, and a more pragmatic, way of bridging this gap is to follow

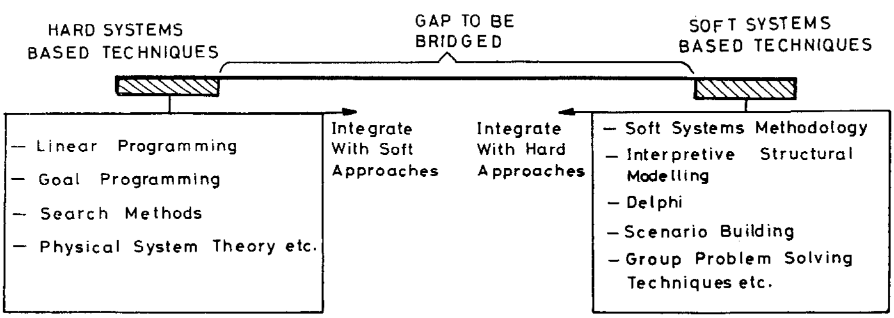

Fig. 2. Bridging the gap in the systems continuum.

an "integrative" paradigm, i.e., integrate and innovate different existing techniques and methodologies suitably to bridge the gap. The hard approaches are to be made comparatively softer by interfacing with softer approaches, and softer approaches are to be made harder by interfacing with harder approaches to make them effectively handle comparatively harder problem situations. This will make a movement from the ends toward the middle and the gap will be filled by suitable integration. However, ample care should be taken when integrating two or more systems-based techniques that the integration should not be superficial; it should be done by matching the philosophical and theoretical foundations of the techniques to be integrated so that deep linkages can be established.

The integration can be of different types, e.g., one-way integration, both-ways integration, submerging of one into another with identity, and full mixing of two techniques, as shown in Fig. 3. Flexible systems methodology proposes working with different types of integration of well-researched systems-based

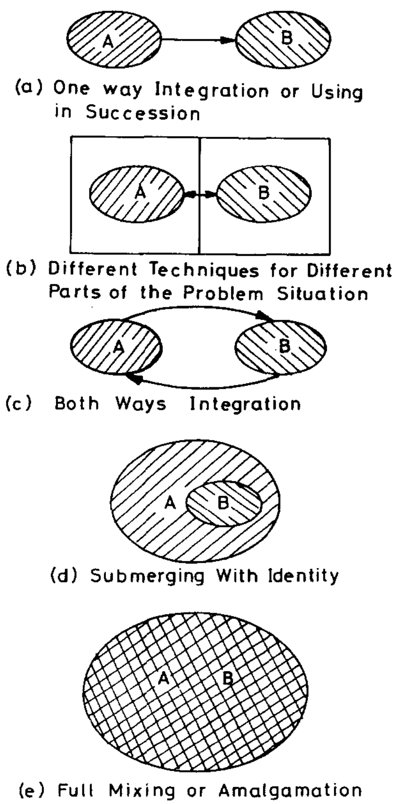

Fig. 3. Possible schemes of integration of techniques.

methodologies to complement their strengths and weaknesses suitably as the situations warrant.

Some examples of well-tried integrations are physical system theory (Koenig *et al.*, 1967) with system dynamics (Forrester, 1961) by Vij *et al.* (1988b) and Kumar and Satsangi (1993), linear programming and goal programming with physical system theory by Singh and Sushil (1990), system dynamics with fuzzy sets (Zadeh, 1961) by Pankaj *et al.* (1992), system dynamics with Monte Carlo simulation by Pankaj (1992), system dynamics with interpretive structural modeling (Warfield, 1990) by Pankaj (1992) and Vizaykumar, (1990), Delphi with system dynamics by Bora (1981), interpretive structural modeling with MIC-MAC (Godet, 1987) by Saxena *et al.* (1990), Delphi and analytic hierarchy process (Saaty, 1984) with fuzzy set methodology by Saxena *et al.* (1990), nominal group technique with interpretive structural modeling by Warfield (1990), expert systems with decision support systems by Luconi *et al.* (1986), and many others as discussed in Section 1.

4. STEPS

The steps in the implementation of the proposed flexible systems methodology are as follows.

4.1. Conceptualization

The problem situation is to be conceptualized in terms of the nature of systems and people involved and its attributes of structure, nature of outcome desired, level in the organization, clarity, uncertainty, data availability, functional area, situation specific characteristics, etc.

4.2. Fuzzy Clustering

In terms of the nature of systems and people involved in the problem situations and in view of their attributes, the problem situations as well as the systems-based techniques need to be clustered in a fuzzy manner. That is, a problem situation as well as a technique will have a membership function in different possible clusters. Different alternative clustering approaches can be used. One useful way described in the literature is total systems intervention (Flood and Jackson, 1991). This can be converted into "fuzzy total systems intervention," as in real life it is difficult to say that a problem situation involves systems which are either simple or complex, and the relationships between people are unitary or pluralistic. More dimensions of the problem situation can be considered in flexible systems management (Sushil, 1994) using different situation, actor and process continua. These can be treated as fuzzy sets and fuzzy clustering of problem situations and techniques can be done. Thus, by knowing the characteristics of the problem situation, the possibility of the usefulness of a set of techniques can be assessed. An expert system for this can be prepared or this can be done in a more creative manner.

4.3. Matching Attributes

The specific attributes of the problem situation in terms of structure, clarity, uncertainty, etc., can be matched with those of the systems-based techniques which have been identified with a comparatively high possibility of success.

4.4. Selection

Based on the matching of the attributes, either one or a set of systems-based techniques can be selected for analyzing the problem situation that can be used either in succession or in combination for different components of the problem situation. The selection can be facilitated through the use of expert systems or can be practiced in a creative environment.

4.5. Integration and Innovation

Different schemes of integration and innovation of techniques can be adopted. Some possible ones are shown in Fig. 3.

- Using techniques in succession.
- Using different techniques for different components in the problem situation.
- Using a both-way integration of techniques.
- Using one technique as a subset of the other.
- Using an amalgamation of techniques leading to a new technique.

4.6. Implementation

Once a suitable approach is designed in terms of proper selection and/or integration of the systems-based techniques, this should be implemented to model and analyze the problem situation at hand. The nature of implementation will depend upon the type of techniques finally selected.

4.7. Dynamic Shift

As the problem situations are analyzed using a particular set of systems-based techniques, and interventions are made, there takes place a dynamic shift in the attributes of the problem situation and so in the use of techniques required for analysis.

The application of the proposed methodology can be done flexibly on the continuum of fully creative to fully computer assisted, depending upon the nature of the problem situation, the cognitive burden, and expertise available. The above-mentioned steps are only suggestive guidelines to design an appropriate approach. The process of selection and integration of techniques is to be adopted flexibly in the practical situations.

5. STRENGTHS AND LIMITATIONS

The major strengths and limitations of the proposed flexible systems methodology are as follows.

5.1. Strengths

(i) It puts together all the systems-based techniques in a cohesive framework.
(ii) It complements the strengths and weaknesses of different techniques so as to use them effectively in a problem situation.
(iii) It provides a conceptual framework for the selection of appropriate methodology to analyze a problem situation in its totality.
(iv) It bridges the gap between qualitative and quantitative techniques by their suitable integration.
(v) The methodology designed to analyze a problem situation is more realistic and the assumptions in modeling are minimized.
(vi) It is flexible and can be adapted to suit any problem situation according to its requirements.
(vii) It facilitates more learning of the user about the nature of the problem situation and its conceptualization.
(viii) It resolves the paradoxes in the literature about hard vs soft systems thinking, quantitative vs qualitative analysis, etc.
(ix) It inbuilds more creativity in the analysis of problem situations.
(x) It brings different schools of thought closer to each other.

5.2. Limitations

(i) It requires the user to have knowledge of the whole spectrum of systems-based techniques, thus calling for higher level of expertise.
(ii) It demands time and resources for the selection of appropriate techniques and design of the methodology.
(iii) It needs more research to be conducted to interface different modeling methodologies suitably.

(iv) It requires more software resources to support complementary methodologies.

The above limitations, to a great extent, can be overcome by developing a suitable "expert system" for this purpose. A research project in this area is in progress under the supervision of the author.

6. CASE STUDY—ENERGY POLICY ANALYSIS

A significant application of physical system theory and system dynamics is being made by Vij *et al.* (1988a,b, 1990) and Vij (1990) in the flexible systems methodological framework for energy policy analysis. An overview of the integrated implementation is presented here.

6.1. Model Overview

The inherently complex and multifaceted nature of energy issues clearly implies that no single modeling methodology can describe and interrelate all the variables of interest in the energy policy area. In this study an attempt has been made to develop a multilevel hierarchical system dynamics model by using a sectorial approach for demand management and energy conservation, and a macrolevel approach for energy–economy interaction and transition dynamics.

A generalized multisector model which combines the input–output economics with waste management [input–output–waste (I-O-W) energy model] has first been developed in the physical system theory framework. This is a static model and is integrated with the system dynamics model to capture the dynamics at the macro economic level.

Integration of the physical system (PS) and system dynamics (SD) models is shown in Fig. 4, which is based on the submerging of the PS model in the SD model as shown in Fig. 5. A comparison of the PS, SD, and integrated models is given in Table I, which clarifies the significance of integration.

The main inputs to the PS model are sectorwise final demands, technological coefficients, waste recycling ratios, cost of waste recycling, natural inputs, and waste disposal. Initial values of these parameters and variables for a base year are fed exogenously.

The SD model needs initializing inputs on population, national income, national investment, sectorial capital, sectorial demand, sectorial labor, sectorial productivity, cost structure, and profitability data on new technologies. In addition to other outputs, it generates the sectorwise final demands and the technological coefficients. These data are fed to the PS model to get the values of sectorwise aggregate demands and other outputs at each time interval.

The integrated model generates yearwise projected values of the following:

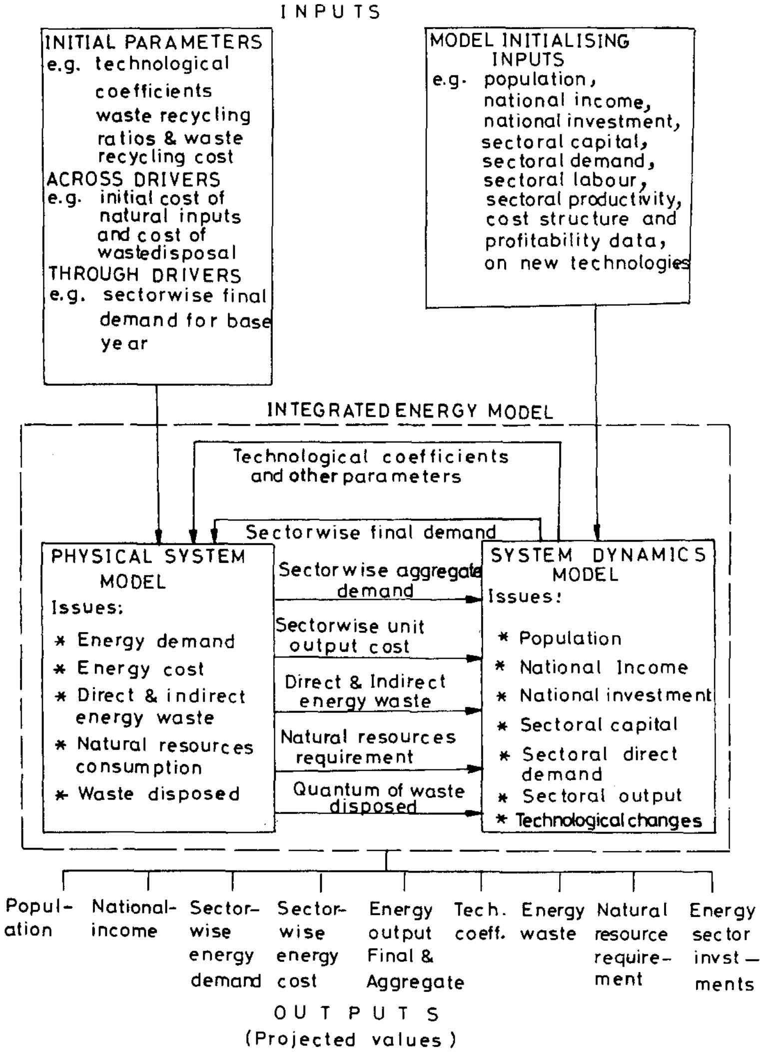

Fig. 4. Schematic diagram showing integration of the PS and SD models.

population, national income, sectorwise final and aggregate energy demands, energy cost, energy investments, technological coefficients, direct and indirect energy wastes, and natural resources requirement.

6.2. Policy Implications

The integrated energy model developed and tested in this study may be used for policy analysis and planning in the following areas.

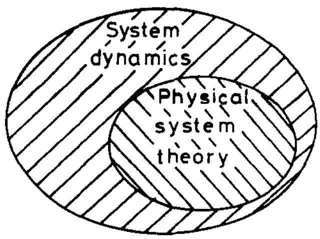

Fig. 5. Integration of techniques for case study on energy policy analysis

6.2.1. Energy Demand and Supply Balance.

Sensitivity analysis runs of the integrated energy model (Vij *et al.*, 1990) show that macroeconomic parameters such as national income are more sensitive to demand management policies in the energy-consuming sectors than the policies aimed only at increasing energy supply. In cases where the effect of energy constraints can be restricted to the final flow, i.e., supply to households, the national income is relatively unaffected. Demand management through improved material productivity in the energy-consuming sectors, coupled with increased labor and capital productivity of the energy supply sectors, may have a significant impact on the overall growth of the economy.

6.2.2. Resource Allocation

Model results show that higher priorities in investment to energy sectors do not lead to a significant increase in the national income. On the other hand, such sectorial priorities may be at the cost of investment in other production sectors. This could mean a deceleration in the growth of those production sectors where lower priorities are assigned. It is imperative to link the sectorial priorities to the basic needs of the people.

6.2.3. Energy Conservation

Sensitivity analysis shows that energy conservation has a significant relevance for developing economies. The impact of waste on natural resource requirements warrants serious consideration and should be an important policy parameter in national energy planning.

6.2.4. Construction Delays and Lead Times

Sensitivity runs show that the reduction of construction and lead times of energy projects leads to faster capital formation in the energy sectors and, consequently, an increased energy output. However, the increased energy supply should be accompanied by a productivity increase in other production sectors where energy is one of the inputs.

Table I. Critical Comparison of PS, SD, and Integrated Models

	PS model	SD model	Integrated model
1. Purpose	To study the issues related to energy demand, energy conservation, natural input requirements, energy waste disposal to nature, and cost of energy output in the context of sectoral interlinkages in the economy and their resulting cascading effect	To study energy issues in relation to other economic variables and their causality, e.g., population, national income, capital formation rate, sectoral demand, waste management, technology, natural resources, etc., in a dynamic environment	To study the following interrelated energy issues is a dynamic, multisectoral environment: sectorwise energy demand, energy output, direct and indirect energy waste, effect of energy waste on unit cost of energy available to the consumer, consumption of natural resources, population growth, and technological changes and their impact on the energy sector
2. Modeling methodology	Input–output economics combined with waste management, using graph-theoretic approach of physical system theory (IOW model)	System dynamics	Input–output economics and waste management in PS framework integrated with system dynamics.
3. Significance	(a) IOW model is a multisector energy model with waste parameter incorporated explicitly. (b) Energy conservation has been defined in a broader perspective covering direct as well as indirect energy waste. (c) Impact of waste generation and recycling in energy-consuming sectors on aggregate energy demand, energy pricing, ecological and environmental issues, and national accounting policies, clearly demonstrated	(a) System dynamics methodology provides an ideal framework for studying complex, dynamic, and nonlinear interactions in socioeconomic systems such as energy. (b) Long-term view of the energy problems (c) Feedback effects are considered. (d) Nonlinear relationships, which are typical in real-life systems are incorporated. (e) Emphasis is on microstructures of causal relationships, which generates macrobehavior.	(a) Integrated model is a multisectoral dynamic energy model incorporating the advantages of both input–output economics and system dynamics. (b) Two-level approach, i.e., sectoral approach for IOW modeling and macroeconomic approach for SD modeling. These are interlinked with each other. (c) Main features of SD models like feedback, nonlinearity, flexibility, and use of mental database for policy analysis and design have been incorporated.

		(f) Provides the much needed flexibility in the dynamic analysis of energy systems. (g) The model emphasizes policy analysis rather than mathematical sophistication. (h) Data limitations are not a serious problem in SD models.	(d) Computational effort is a compromise between the typical input–output modeling approach and SD. (e) Will be more acceptable than a pure SD model, as it builds on the already existing input–output tables used by planning purposes.
4. Limitations	(a) Static model, gives only a snapshot view of the energy problem. (b) Rigid structure. (c) Computational effort is more due to matrix inversions. (d) Data limitations, especially those related to sectorwise waste generation and recycling, because waste is not incorporated as an explicit parameter in national accounting.	(a) Multisectoral features and the multiplier effects due to interrelatedness of sectors are more difficult in SD models. (b) SD models have been criticized for lack of mathematical sophistication; many external assumptions are made based on too few and ill-documented data. (c) The concept of "one world one model" has been thought misleading. The real world shows some serious structural differences with respect to different "regions" which constitute the "world." (d) SD methodology is difficult for the uninitiated and makes a higher demand on professionalism than other methodologies.	(a) The integrated model combines two scientific paradigms which have traditionally opposed each other. Their "marriage" needs the sanction and approval of these professional communities. (b) The model is relatively "open" compared to the typical SD models, i.e., it incorporates many exogenous variables. (c) The present model is based on simple neoclassical structure. More sophistication can be incorporated by adding a monetary sector and foreign trade sector. (d) Policy design based on an optimum selection of policy options will be a natural extension to the model.

6.2.5 Energy Cost

Energy cost shows a higher sensitivity to material productivity changes than natural resources prices. Waste in the energy-consuming sectors has a more crucial effect on the cost of energy output.

7. CONCLUDING REMARKS

Use of different systems-based techniques and methodologies should be made in a more integrative paradigm rather than with an isolationist view so as to bridge the gap between them. This will obviate the end of continuum paradoxes such as hard vs soft systems thinking, quantitative vs qualitative analysis, etc. This will result in a more realistic methodology, and more creativity will be applied in problem solving. The methodology either can be applied at a fully creative level or some support can be provided to reduce the burden on the user by designing suitable expert systems for this purpose. Here only a broad outline of the methodology is provided, which can be treated, at best, as a good beginning point for using the existing systems-based techniques in a more pragmatic manner.

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