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MANAGEMENT OF TECHNOLOGICAL INNOVATIONS TOWARD SYSTEMS-INTEGRATED ORGANIZED TECHNOLOGY

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PREFACE

This paper, which was presented at the Third International Conference on Management of Research, Development and Education at the Technical University of Wroclaw in September 1978 extends the discussion of the Systems-Integrated Organized Technology (S-IOT) approach, first enunciated by G.M. Dobrov in a paper to the Academy of Management Annual Meeting at Orlando in 1977.

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INTRODUCTION

Recent work in systems analysis has introduced the importance of "orgware" (OW) as a component of organized technology (G.M. Dobrov, "A Strategy for Organized Technology" a paper delivered at the Academy of Management Annual Meeting, Orlando, 1977). The analysis of "orgware" along with the well-established technological components of hardware (HW) and software (SW) represents an important new addition for analysis of technological systems. This paper emphasizes the need to view technological systems in the framework of HW-SW-OW interactions. These interactions are seen as important aspects in the assessment and the management of technological systems.

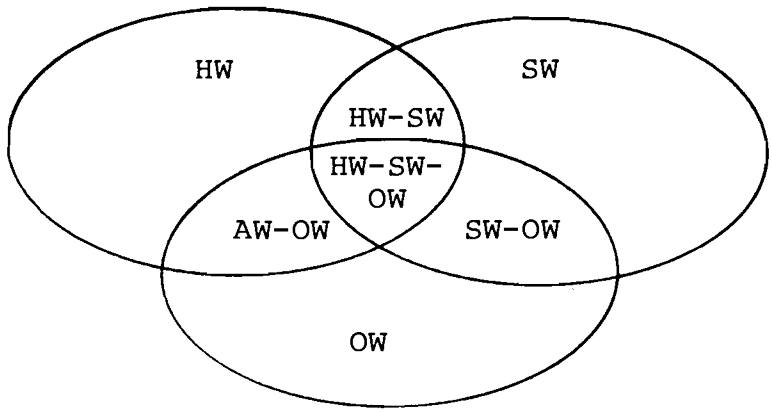
This view allows for the consideration of seven areas of systems analysis within the framework of technological systems (Figure 1).

THE CONCEPT OF ORGANIZED TECHNOLOGY

The increasing social mission of science as a potential and direct productive power is realized through the creation and correct adaptation of new technological systems.

Through the perception of individuals, teams and institutions dealing with the problems of technology creation and utilization, technological advance faces a broad scale of national and international needs, and it manages to overcome the greatest of social demands and constraints.

Applied systems analysis has come to be understood as efforts directed toward the managerial problems of creation, transfer, and mastering of new technologies which are urgently needed, and



SH - General purpose computer
HS - Microprocessor
OH - Office and communication managers
SO - Think tanks
OS - Operation research, system analyst, organization
SOH - Computer simulation, business games, M.I.S.
OS - Consulting companies

Figure 1. HW-SW-OW framework.

for the future process of mutual substitution of components. This is considered to be among the main factors for the further development of mankind. In this sense, organized technology can be viewed as a primary object of socially responsible management in various national, regional and institutional contexts.

ORGWARE AS A SYSTEM DIMENSION OF ORGANIZED TECHNOLOGY

It should be appropriate at this point to define the construct Orgware (OW)

O R G W A R E

(OW)

A SET OF ORGANIZATIONAL ARRANGEMENTS, SPECIALLY DESIGNED AND INTEGRATED USING HUMAN, INSTITUTIONAL, AND TECHNICAL FACTORS TO SUPPORT APPROPRIATE INTERACTION OF THE TECHNOLOGY AND EXTERNAL SYSTEMS.

Experience gained during the last decade has made it clear that as a rule it is not enough to have only a set of technical means or even skilled staff. It has to be supplemented by special organizational (in more general terms, socio-economic) innovations. To prove the point we can recall lessons learned in connection with many science and technological "shocks" or national and international difficulties in technology transfer.

For each modern technological system to achieve success it urgently needs a specially designed organization to provide the utilization of decision-makers' skills and the interaction of this system with other systems of different natures.

On the macro level Orgware seizes a set of special economic and legal regulations (a system of prices, taxes, stimuli and constraints). On the operative level Orgware includes organization-structural solutions, procedures for management, training of manpower, maintenance service and special ways of interacting with other systems.

THREE DIMENSIONALITY OF ORGANIZED TECHNOLOGY: COMPONENT INTERACTIONS

Figure 2 depicts differing conceptions of the relative roles of technology, science and organization. Stage I shows a more primitive view of science (S), technology (T) and organization (O) as separate realms of activity. Stage II suggests another view of technologically related developments and activity; hardware (HW) and software (SW) are somewhat integrated, yet together remain essentially unintegrated with knowledge of organization and management (OR/Man). Stage III shows the integration of HW-SW-OW as a model for understanding organized technological systems. In our studies of the computer industry, for example, this Stage III view has replaced earlier conceptions of computer systems with only HW-SW interaction. Many experts now view orgware aspects as something not outside the technology, but something intrinsic as well. This understanding produces a conception of a given technological system as an essentially three-dimensional technological entity (Figure 3).

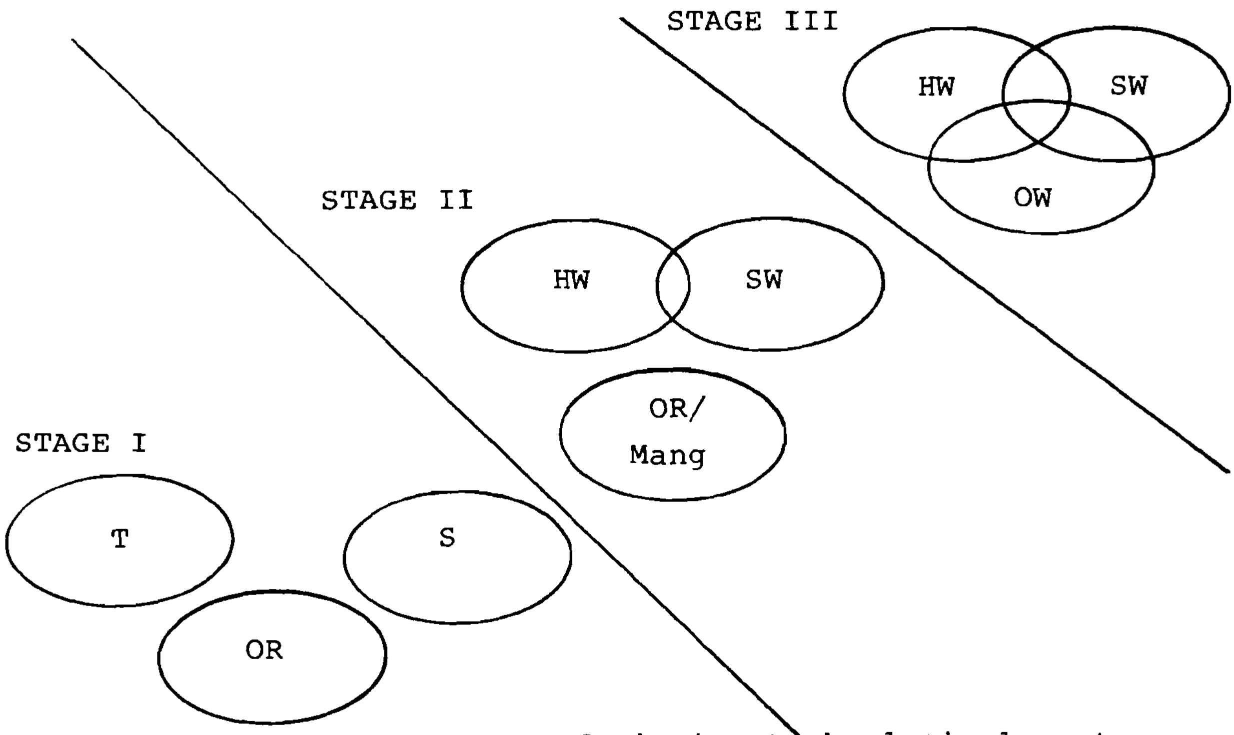


Figure 2. Differing stages of viewing technological systems.

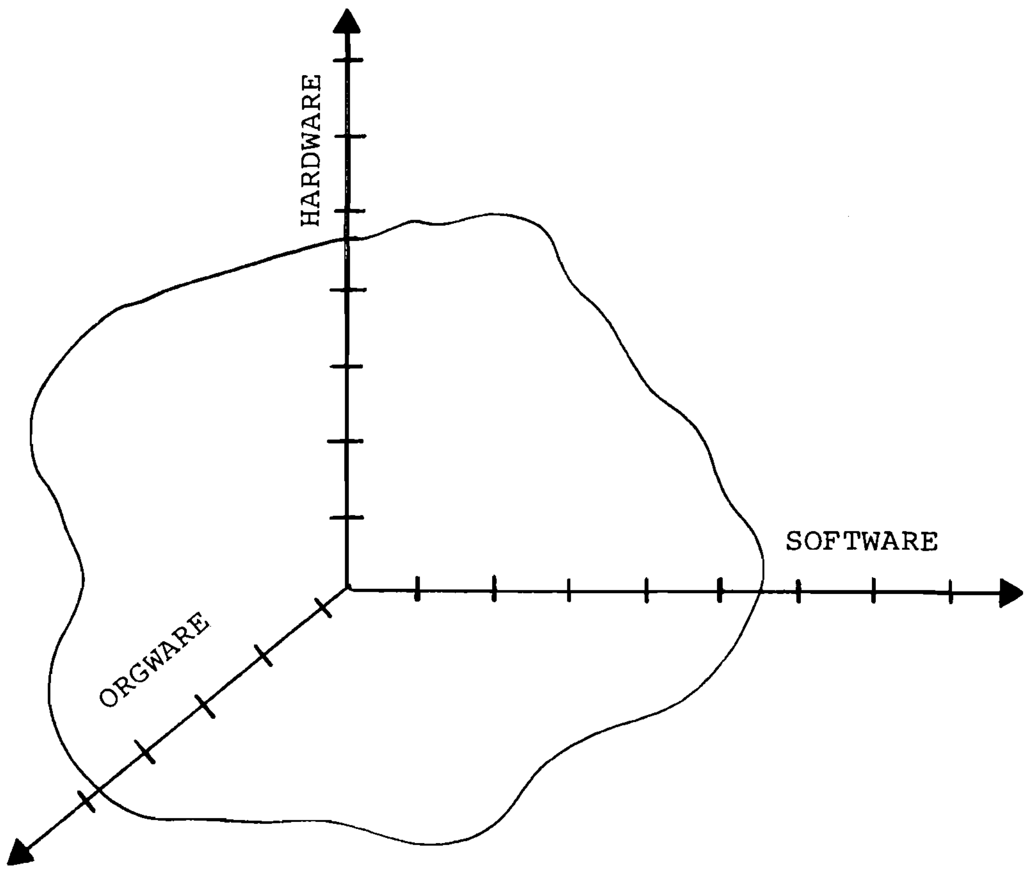


Figure 3. The space of a three-dimensional technological system.

The range of possible elements in a given technological system can be quite extensive. Figure 4 illustrates some of the various elements in a "structural tree of systems technology". Some classic examples of the hardware, software and internal structure of orgware are depicted. Of primary importance, however, is the question of element interaction. What is the internal structure of an organized technological system? And how might we formulate a framework for analysis of "advanced" technological systems?

Figure 5 depicts three components (HW, SW, OW) of a technological system with several specific elements in each component. An important element of the hardware component, for example, is "machinery and facilities". An element in this example for the hardware-orgware sector is "engineering support for monitoring". This element of interaction between the components of hardware and orgware is crucial to the system and, for a conventional type of an organized technological system, this element may be quite common.

Figure 6 shows the same system but with the addition of more elements from each HW, SW, OW component and elements which are combined HW-SW, HW-OW and SW-OW elements. These examples are

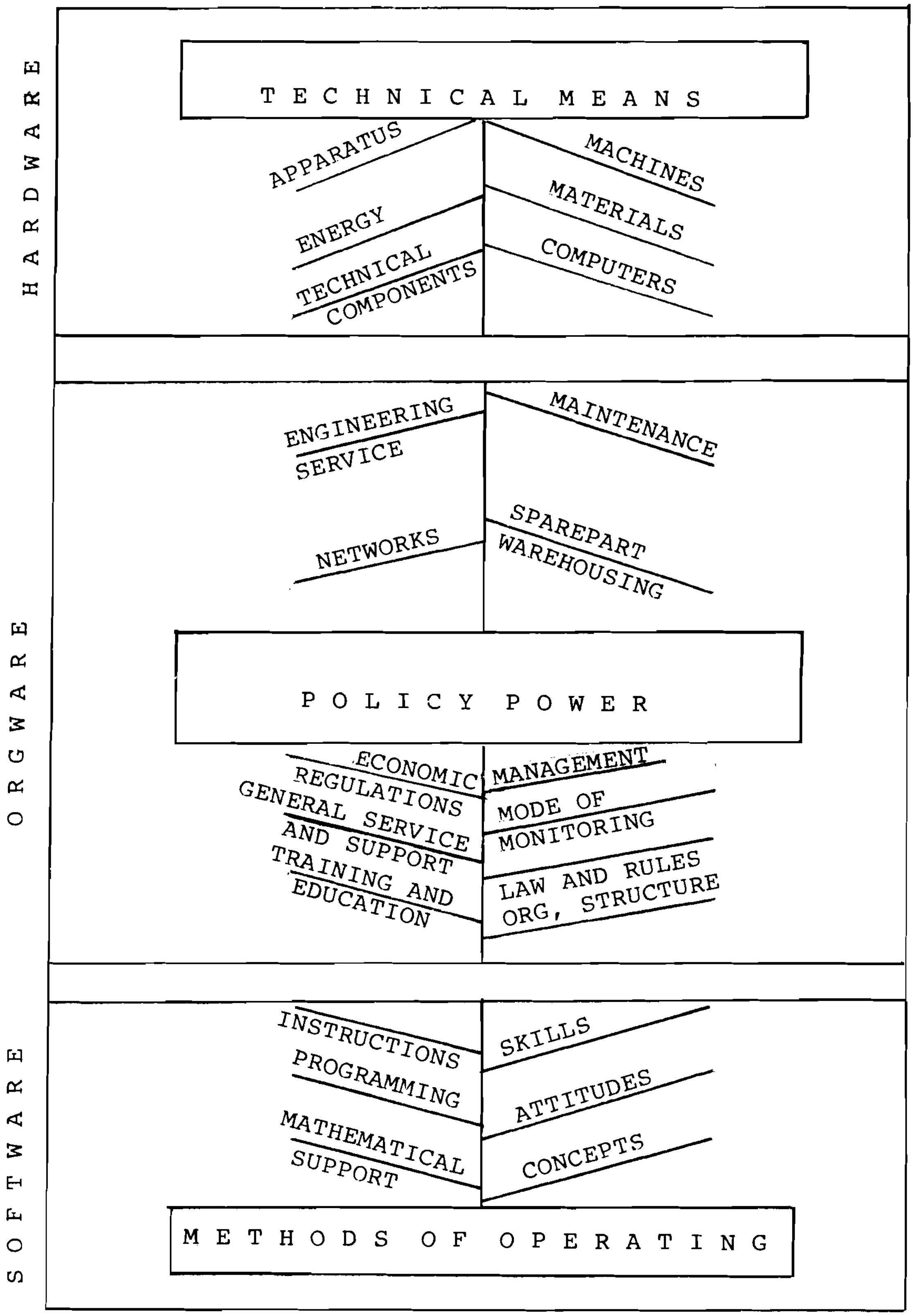
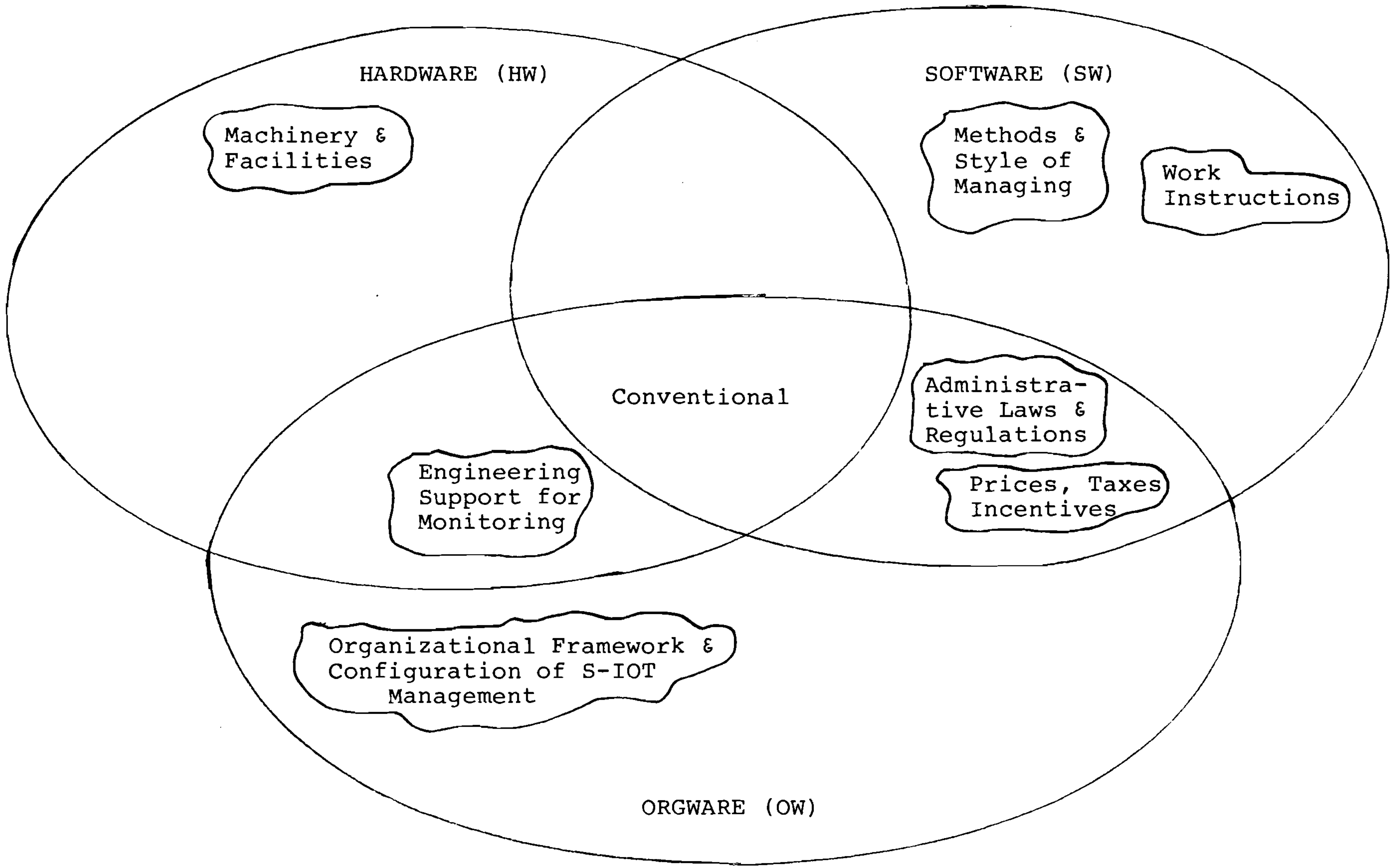
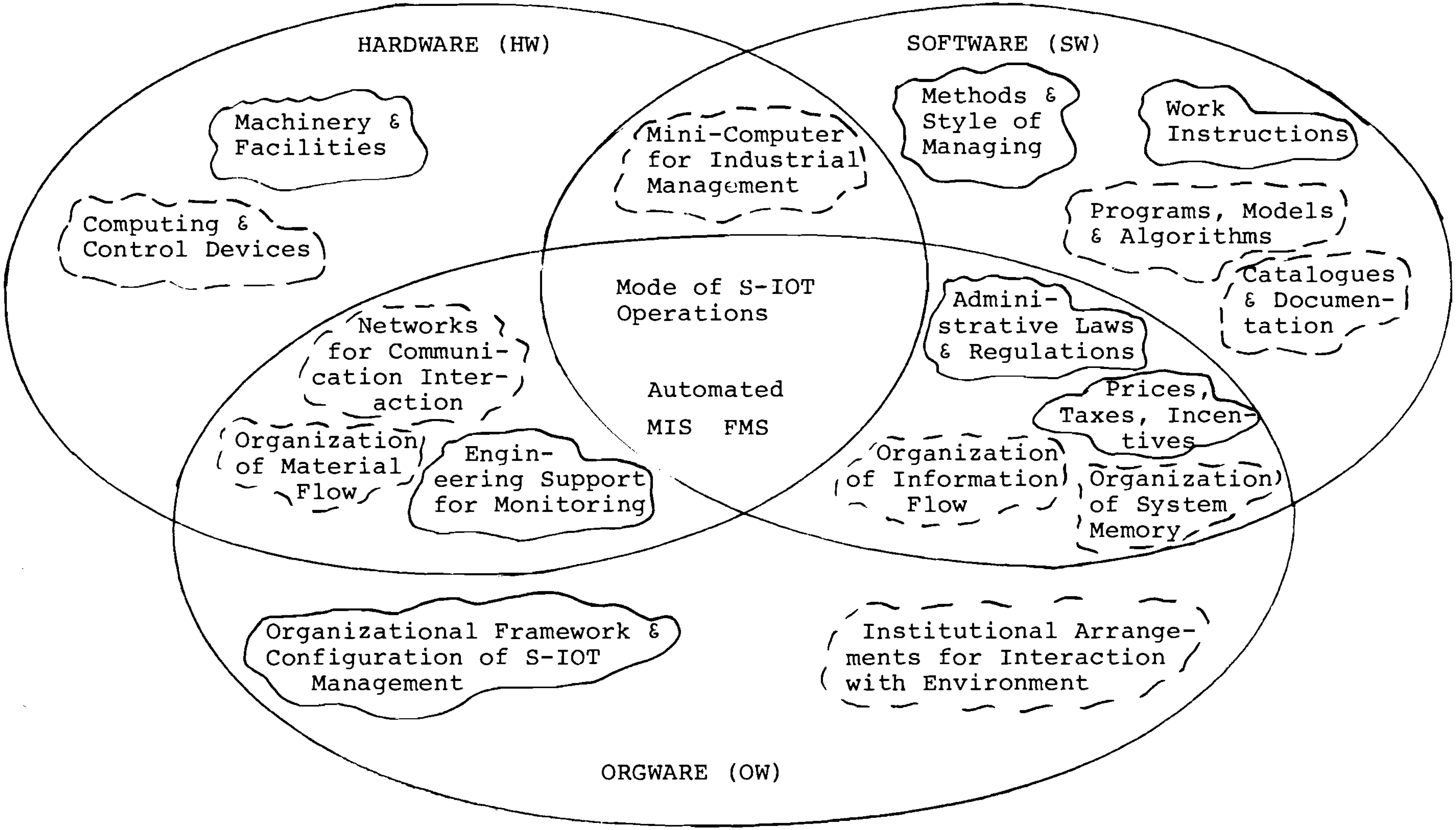


Figure 4. Structural tree of systems technology.



Hardware, Software, Orgware Interactions in Systems-Integrated Organization Technology. (S-IOT)

Figure 5. A conventional technological system.



Hardware, Software, Orgware Interactions in Systems-Integrated Organized Technology (S-IOT)

Figure 6. An advanced system.

ones which have been specially designed to interact in a mutually supporting manner. Unlike the simpler, conventional system (Figure 5), this system is more complex and has been more carefully designed with qualities of "systems integration". The construct of "Systems-Integrated Organized Technology" is thus appropriate for more advanced technological systems and is defined broadly as follows:

```
S - I O T
y   n r e
s   t g c
t   e a h
e   g n n
m   r i o
s   a z l
    t e o
    e d g
    d   y
```

> A technology option consisting of a comprehensive set of primary components (hardware, software, orgware) the model of operation of which is characterized by mutually supporting elements, interacting to achieve a defined purpose.

The creation of a S-IOT condition is not an easy task. The construct suggests immediately that we are dealing with advanced levels of system interaction. Figure 6 includes, for example, advanced hardware elements (computing devices), advanced software (programs, algorithms, etc.) and special orgware arrangements (organizational framework). Other elements include mini-computers, communication networks, flow design and even special arrangements relating to issues external to the system, i.e. prices, taxes, incentives. At the center of this diagram are the system elements (management information system and flexible manufacturing system) which ultimately involve the interaction of hardware, software, and orgware technological components. These elements, products of the three-way interaction, require an advanced level of design planning, decision making and coordination in the system and as such are the products and essential elements of a "S-IOT" system.

Not only are the elements comprehensive and advanced, but also they are carefully designed and put together so as to be mutually supportive to integrated system functioning and overall system cohesiveness. These system qualities are seen as facilitative to the overall accomplishment of a system's technological function or purpose.

S-IOT AND OTHER CURRENT APPROACHES: SYSTEM "INTEGRATION"

The concepts of system integration and three-dimensional technology (HW-SW-OW) are not completely novel approaches. Current work in this area is important for understanding the S-IOT formulation, and some similarities can be seen.

"System integration" has been discussed and researched by Lawrence and Lorsch in several industrial studies. Their emphasis has been primarily to view integration as an important quality and a process within organizations. Their conceptual and operational approach focuses on organizational structure, inter-group relations, task structure, individual psychological differences and several other aspects of what generally might be called a social-psychological-structural emphasis. Integration as an organizational quality is expressed in terms of cooperation, collaboration, consistency, "smooth interfacing" of organizational components, and is a positive feature of organizational system behavior. Although Lawrence and Lorsch have dealt with task issues, we see their work falling within the software-orgware realm of our framework. The work of Perrow also deals with software-orgware issues. His conception of technology derives from a task-information notion and relies on a psychological emphasis.

In contrast, the work of Hickson, Pugh and Pheysey (1969) relies on a predominantly hardware-orgware approach to the study of technological interactions. They have, for example, derived three technological subsystems quite close to the HW-SW-OW framework. In their comparative study of 77 industrial organizations they identified three separate technological areas: "operations", "materials", and "knowledge" technology. This approach centers on the central variable, "workflow integration" which includes various aspects of machine, method, and task structure. The well-known Tavistock emphasis on socio-technical systems also integrates two basic realms of systems--the social and the "technical" or task related aspects. Galbraith and others who have used the "information-processing" approach stress the notion of integrating task, structural and human-psychological aspects into system design. This work in the organizational design field suggests a strong precedence in orientation to system integration as an important concept for systems, and a strong reliance on two or three dimensional models of the technological systems which are integrated into cohesive work processes.

THE PLACE AND ROLE OF THE ORGWARE AND S-IOT CONCEPTS AMONG ORGANIZATIONAL THEORIES

What are the place and role of the orgware concept and S-IOT among existing theoretical approaches? Of course, many "organizational theories" and models exist in the literature, and we have included several of the major ones in Figure 7. This figure shows five areas of focus or "objects of analysis", the various organizational means used to deal with them and the respective branches of organizational theory to which they correspond. The orgware construct plays a special role within this broad array of general theoretical branches. Relating its place in this array to that of other branches, it could be said that it fills a sequential step. Decisions made, for example, which focus on operational technology in a manufacturing process have important impacts on other objects of analysis, i.e. manufacturing aspects, manpower issues, plant organization and even industrial sector planning. If decisions concerning the operational technology of a system

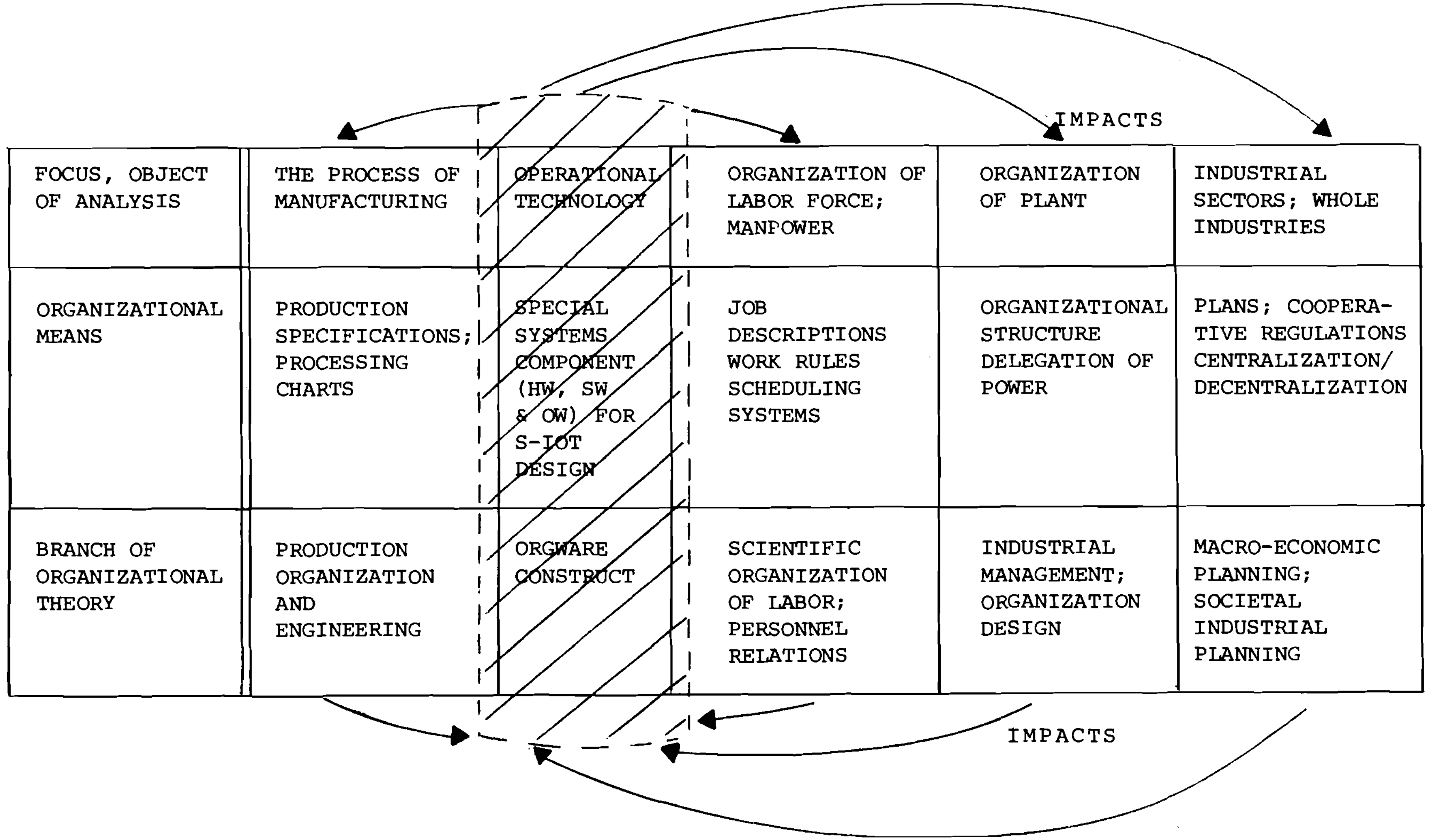


Figure 7. The place and role of OW-construct among organizational theories.

are omitted or if insufficient attention is given to appropriate integration of HW-SW-OW components, there will be likely adverse effects on manufacturing process, plant and industrial levels.

S-IOT DESIGN IN WELL-KNOWN HISTORICAL CASES

Some attention and review has been given to several well-known actual studies in which work processes were redesigned or special organizational arrangements were designed. These reviews have focused primarily in "socio-technical system" studies and have suggested the importance of the various operational factors of task and group structure, and other HW or SW factors (Cummings and Thomas 1978 and Miller 1975). The authors suggest that "orgware" is, in fact, an important primary component of technological systems in managerial experience, and that S-IOT can be illustrated in an historical perspective. Figure 8 presents several well-known historical examples in which:

1. Specially designed organizational arrangements or modifications were designed as part of

2. a wholly integrated technological system or subsystem with definitive hardware and software component interactions.

In each of these cases, the system design which led to positive outcomes was the change in the comprehensiveness of technological component (SW-SW-OW) interactions. In fact, one of the key factors was the purposeful inclusion and regard for special organizational arrangements facilitative to the technological change.

The FMS (flexible manufacturing system) which is a class of computer-aided manufacturing systems having multiple work stations, direct numeric control (DNC) automated material handling, and system control by computer with appropriate algorithms, is an example which particularly illustrates the essential experiential manifestation of an S-IOT design (Gerwin and Hutchinson, "FMS" working paper).

MANAGERIAL PERCEPTION AND CHOICE IN THE FRAMEWORK OF THE S-IOT TECHNOLOGICAL OPTION

Why does S-IOT not take place automatically? And what explains differences in managerial knowledge or intuition concerning choosing S-IOT design options for actual systems? In Gerwin and Hutchinson's study of comparative FMS applications in the USA, FRG and GDR, there is reference to this question

> It appears that the S-IOT concept is not an obvious choice option and that some managers and decision-makers might somehow perceive and operate with a knowledge of S-IOT and others might not. There certainly are many environmental factors involved in

CASE	NEED ARISING FROM	ORGANIZATIONAL MODIFICATIONS (S-IOT)	RESULTING OUTCOMES
ARKWIGHT COTTON MILLS (HAMPTON)	TEXTILE INDUSTRY GROWING AND OLDER METHODS CHANGING	- DIVISION OF LABOR - CENTRALIZATION OF TASKS - COORDINATION SYSTEMS	- CUT LENGTH OF WORK DAY - INCREASED EFFICIENCY - DEVELOPED LARGE SCALE ORGANIZATION STRUCTURE AND PROCESS
FORD MOTOR COMPANY ASSEMBLY LINES	NEED FOR IMPROVED PRODUCTIVITY WITH INCREASED PRODUCTION OF AUTOMOBILES	- SPECIALIZATION OF LABOR - TASK DESIGN: ASSEMBLY LINES	- INCREASED PRODUCTIVITY - INCREASED PROFIT
VOLVO AND SAAB (DOWLING)	NEED FOR IMPROVED SYSTEM FOR PRODUCTIVITY, EMPLOYEE RETENTION, AND EFFECTIVENESS	WORK ISLANDS DIVERSIFIED TEAM	- IMPROVED PRODUCTIVITY - IMPROVED QUALITY - IMPROVED MORALE
ELECTRONIC DATA PROCESSING (BURACK)	NEED FOR IMPROVED INTEGRATION OF EDP SYSTEM INTO ORGANIZA-TION	MODIFIED ORGANIZATIONAL STRUCTURE	- IMPROVED CONTROL OF NEW EDP SYSTEM - INTEGRATION OF EDP INTO TOTAL SYSTEM
TECHNOLOGI-CALLY ADVANCED HOSPITAL SYSTEM (McMANUS)	NEED FOR STREAMLINED INTERNAL "LIFE SAVING" SYSTEM WITH NEW ELECTRONIC EQUIPMENT	LIFE-SAVING TEAMS PLANS FOR EMERGENCY CONTINGENCIES	- IMPLEMENTED SYSTEM - LIVES SAVED
FMS (GERWIN & HUTCHINSON)	NEED FOR IMPROVED INDUSTRIAL PRODUCTIVITY	INTEGRATED AUTOMATED MANUFACTURING SYSTEM	- 75% REDUCTION IN MANUFACTURING COSTS

Figure 8. Several historical cases which illustrate S-IOT: changes in comprehensiveness of technological component interaction (HW-SW-OW).

relating to the differences observed by Gerwin and Hutchinson; however, looking from differing pyschological frameworks at FMS, may produce different choice behavior which could have important consequences in terms of technological system design or adoption of existing S-IOT technology.

We are suggesting that managerial perception of technological options, knowledge of S-IOT possibilities for design, and differing technological choice behaviors are likely interrelated factors in various situations and at various levels. This perspective may suggest a possible link between S-IOT design concepts and the reality of human decision-making in technological choice situations.

Policy makers should, for example, not neglect the importance of properly and appropriately designed technological systems.

Are some experts too influenced by HW-SW, or HW-SW interactions alone?

This may be an important problem in system design which other systems analysts have encountered as design "pitfalls". This problem can be stated in the rather oversimplified, but largely accurate statement that:

Hardware produces "sell" hardware
Software produces "sell" software
Orgware produces "sell" orgware

Who "sells" S-IOT as design?

One answer to the last question is that competent systems analysts should and already do operate in a S-IOT perspective in most cases. For some this is quite an accurate description of reality; for many, however, the S-IOT emphasis (and purposeful inclusion of OW) can be excluded.

S-IOT BENEFITS

We hypothesize that an advanced technological system, particularly large scale systems, e.g. large organizations, with "S-IOT qualities" are probably attained or reached through differing managerial emphases. Figure 9 depicts several paths leading to such a possible advanced system:

- a path in which priorities are chosen in favor of growth (vis a vis technological change)(e.g. "mass production industry")
- a path in which priorities are chosen in favor of technological change (vis a vis growth)(e.g. "science based industry")
- a general trend in which there are mixed orientations to growth and technological change.

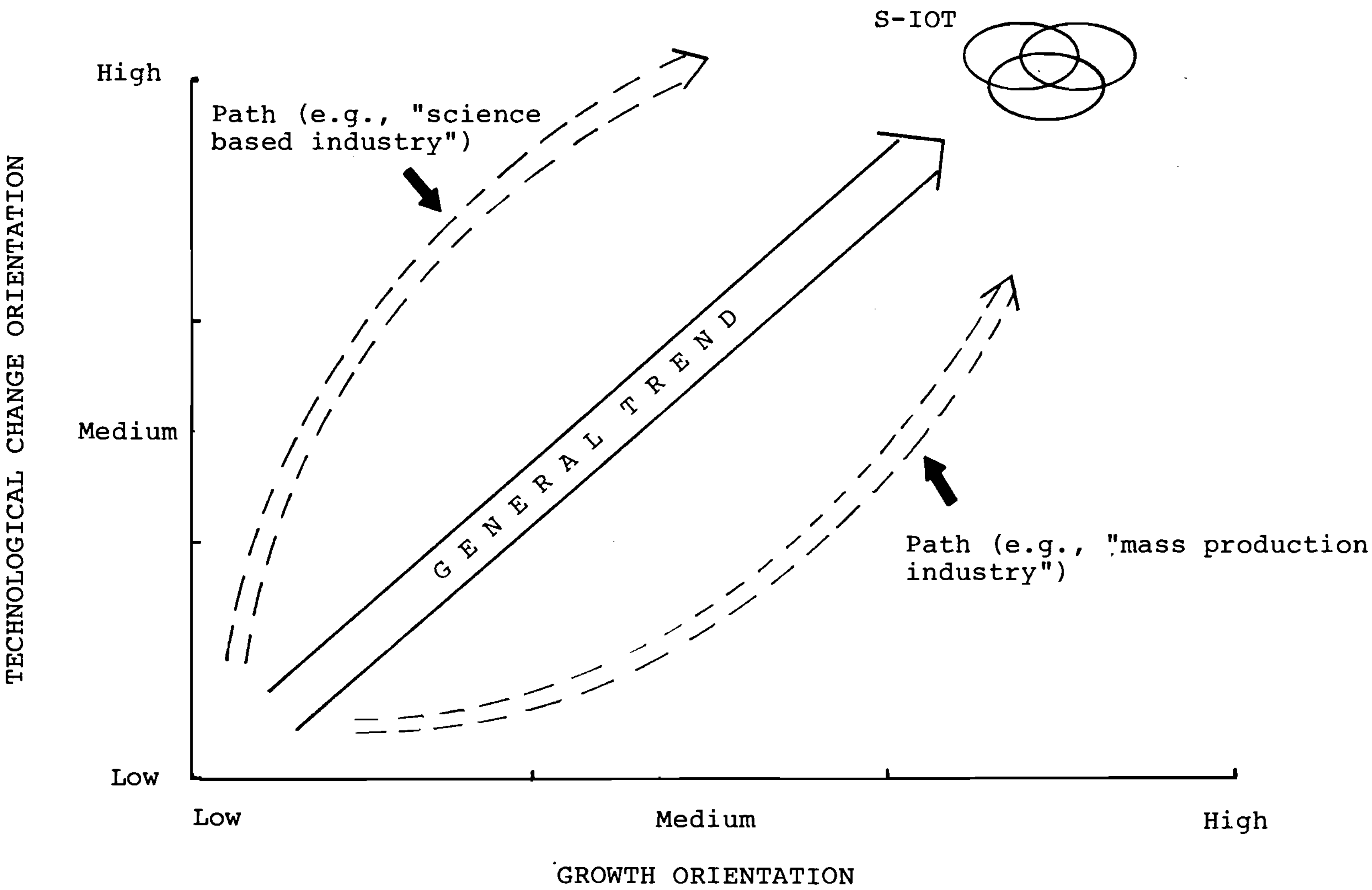


Figure 9. Paths to S-IOT.

From a technology transfer perspective, however, if a society or network of organizational systems attained a level of $S\text{-}IOT_1$ as in Figure 10 there may accrue reserve benefits in the system for an advanced pattern of transfer to less advanced systems, e.g. $S\text{-}IOT_2$. In this case, "Path 3" could be possible for technology transfer. "S-IOT understanding" in the overall system may, thus, have benefits beyond initial S-IOT applications.

One of the essential understandings about the S-IOT construct is that it requires a harmonizing or blending of HW-SW-OW components and component elements in "micro-design". However, this does not necessarily mean that we are always dealing with a complex system. The S-IOT emphasis is the integration or harmonization at a level appropriate to the level of inherent complexity, not the attempt to achieve complexity.

DESIGNING S-IOT AS A TECHNOLOGICAL OPTION A GENERAL FRAMEWORK

Thus far we have dealt at a general level with questions, "What is S-IOT?", "Where has it come from?", and now we must ask "Where is it going?" We might ask, how do we design S-IOT as a technological option into actual systems, e.g., organizational systems?

Much of the literature in organization design (Levinson 1971, Galbraith 1974 and 1977, Khandwalla 1977, Magnusen 1977, Burack 1975) suggests a two-component process--diagnosis (or analysis) and design--which comprise an iterative process over time as in Figure 11. This figure applies the general diagnosis--design process to a S-IOT system in an iterative mode.

DESIGNING SYSTEMS FOR "SUCCESS"

One cycle of the design could, for example, include specific sub-diagnostic, and sub-design issues, e.g. depicted in Figure 12. The length of the cycle, of course, will vary as a function of variables such as system complexity, analytic complexity, priorities, etc. The general diagnosis-design process may take place within or outside the actual system, by members or may be assisted by outside experts. In most cases, the crucial subprocesses will involve dealing with existing orientations to HW, SW or HW-SW combinations. Native managerial orientations in the system may, for example, be "hardware predominant" or "software predominant". Systems analysts who would be assisting such managers in an actual case of S-IOT diagnosis-design would have to assume not only a role as scientist, e.g., in simulation, experimentation, etc., but perhaps also as educator to native managers concerning new choice options. Such analysts might point out that what is needed in the next design cycle is not a HW-SW emphasis or a given "piece" of technology, but rather more of a HW-SW-OW integration through intangibles, i.e. new special methods, training, regulations. The S-IOT design process, thus, requires the combination of conventional systems analysis with emphasis on HW-SW-OW integration at an appropriate level of complexity in an iterative model of application.

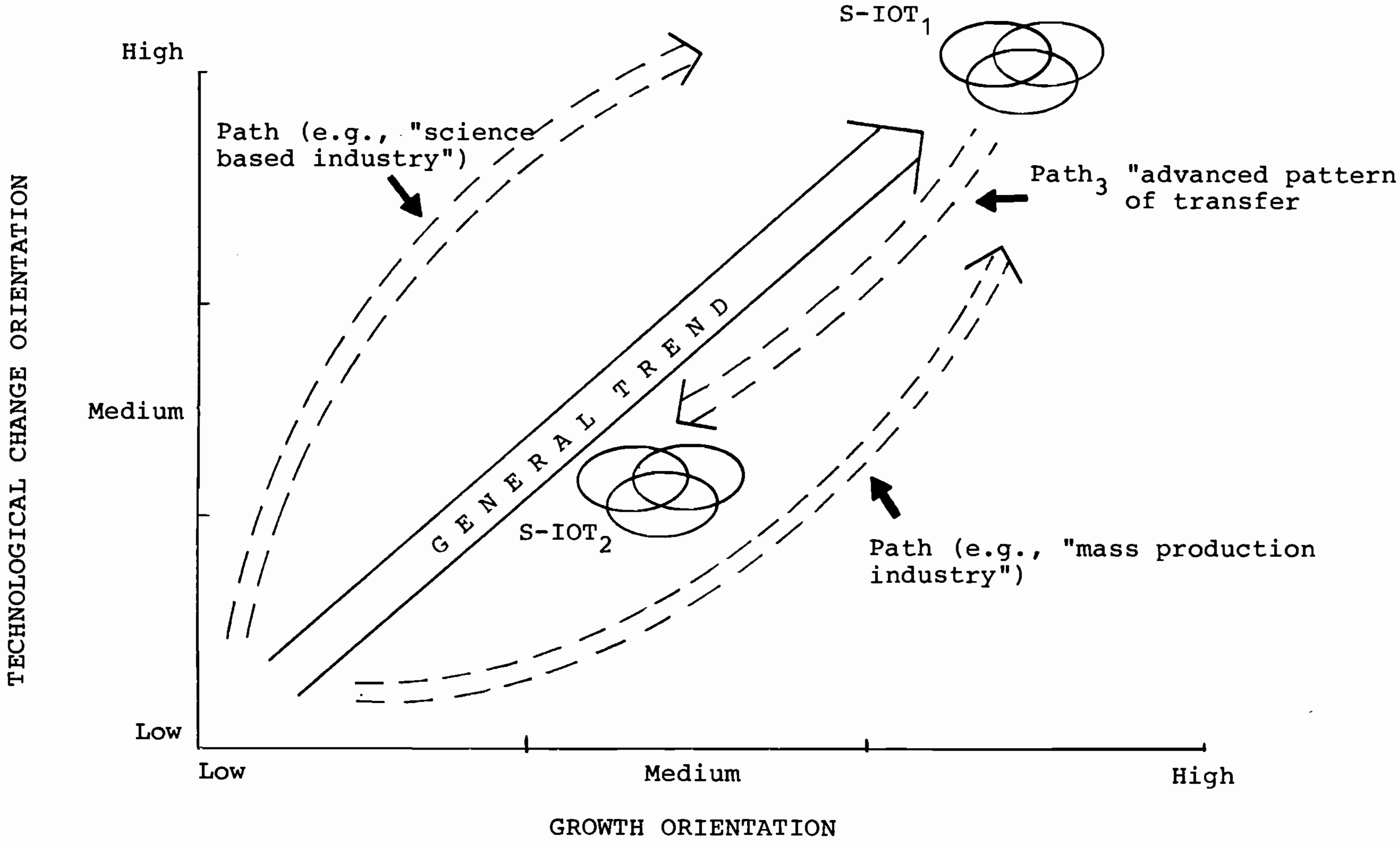


Figure 10. S-IOT benefits.

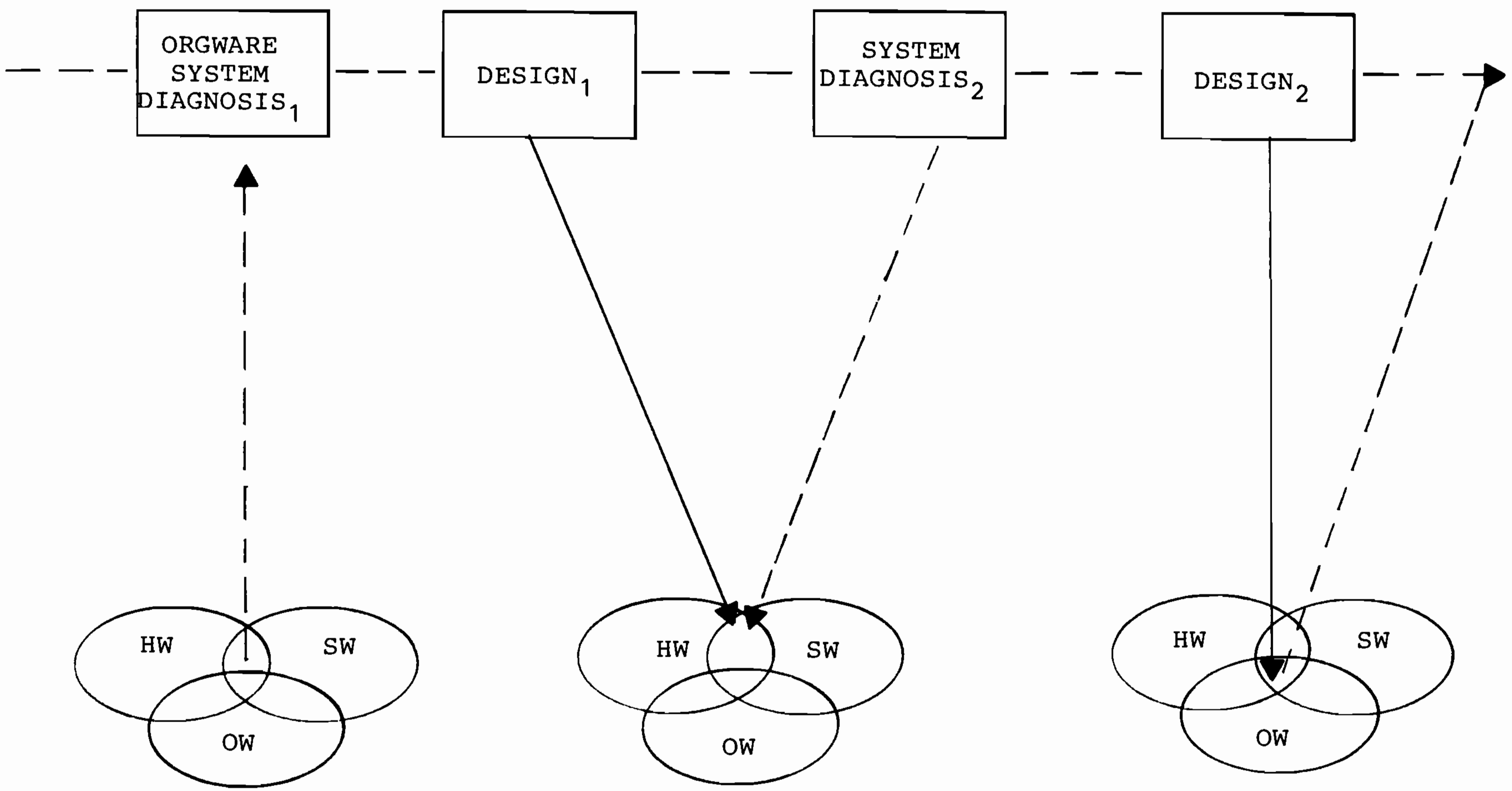


Figure 11. Example of iterative diagnosis-design process for S-IOT.

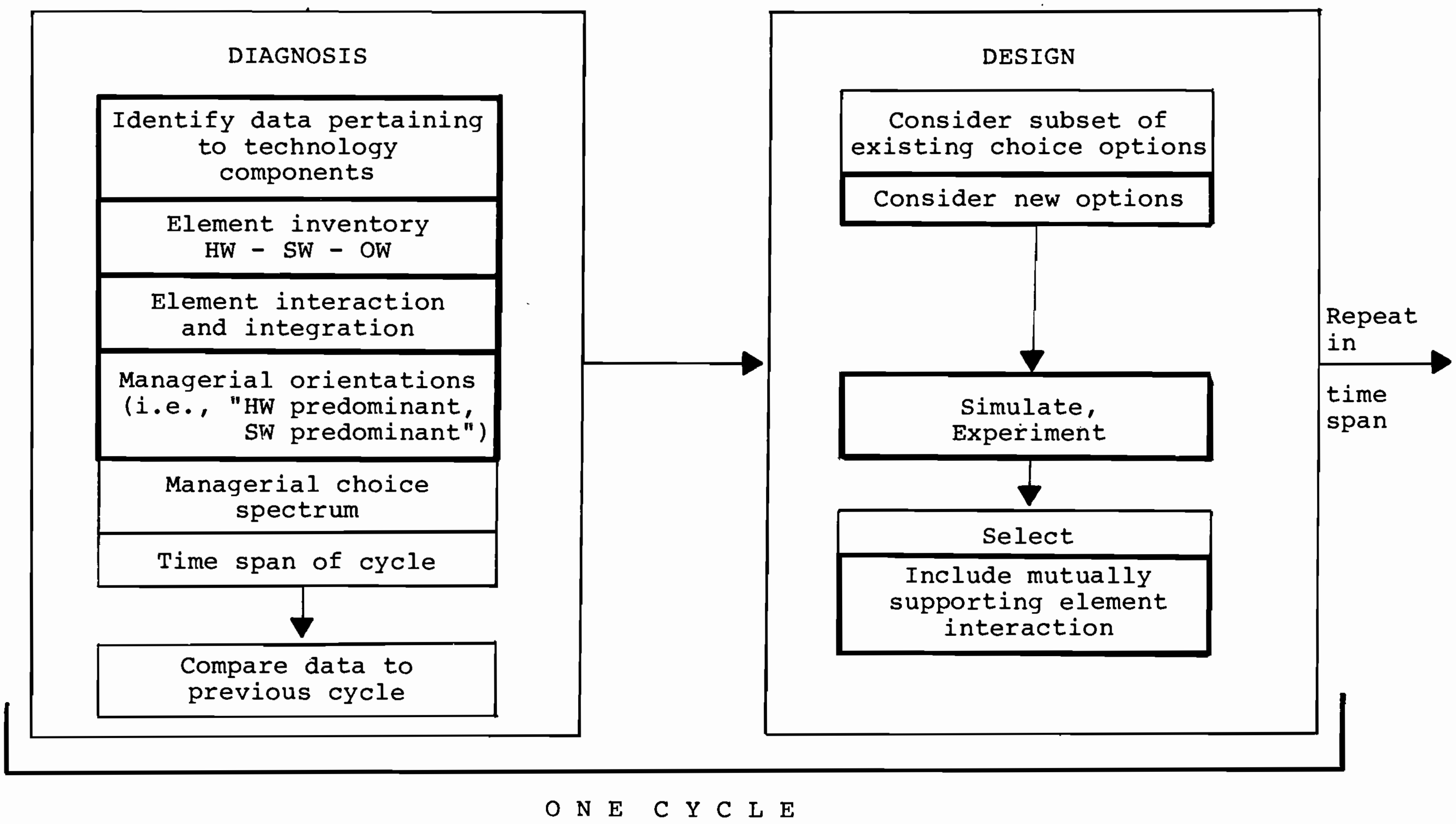


Figure 12. General flow of S-IOT process.

APPLICATION OF THE S-IOT FORMULATION TO THE SHINKANSEN CASE STUDY

It is important at this point to show the usefulness in using the S-IOT approach for analysis of "successful" and "unsuccessful" cases. Three large-scale case studies have been analyzed at IIASA. These included the Tennessee Valley Authority (TVA), Bratsk-Illimsk project in Siberia and the Japanese Shinkansen case study. The special region in the United States was Tennessee Valley and in the Soviet Union it was Siberia. The Shinkansen project was quite different from the first two. Shinkansen is really the study of the application of an advanced technology in a large scale organization; it also included the second aspect of attracting industry to a particular region in Japan.

We consider the Shinkansen experience as an interaction within an eco-techno-ecological system. In our analysis it appeared that there were certain key factors involved, and there were certain issues and various responses which were made. We tried to use a method of analysis which would enable a synthesis of these factors. The Shinkansen project involved not only railway analysis but also subsystem analysis in transport, environmental, regional, and technical areas. We tried to use systems analysis also for societal and social problems that were relevant since it became clear that these topics could not be omitted from our study. However, we had some difficulties in using systems analysis for the overall evaluation of the Shinkansen project. The question became: how can we best understand the overall "success" of Shinkansen? What were the system "roots of success" of Shinkansen? This question suggests the possible application of the S-IOT framework for the Shinkansen project as an advanced technological system.

What additional analytic benefits did this framework provide? In this approach, we compared hardware potential, software potential and orgware potential in the given system. We obtained an understanding of some issues of "system excellence", "obstacles" and issues of "obscurantism". An understanding was also included relating to existing dependency relationships in the system. These emphases led to an expanded overall evaluation (Figure 13).

SYSTEM EXCELLENCE

"Excellence in hardware" included high-speed vehicles, heavy ballast track lift, line and tunnel equipment, track security, facilities, and use of electronic equipment. There was also excellence in software systems due largely to a transfer of knowledge from the military industry to the rail industry.

And there were special OW arrangements, i.e. the establishment of a special Shinkansen task force, decision-making process, construction constraints and a special government decision-making process.

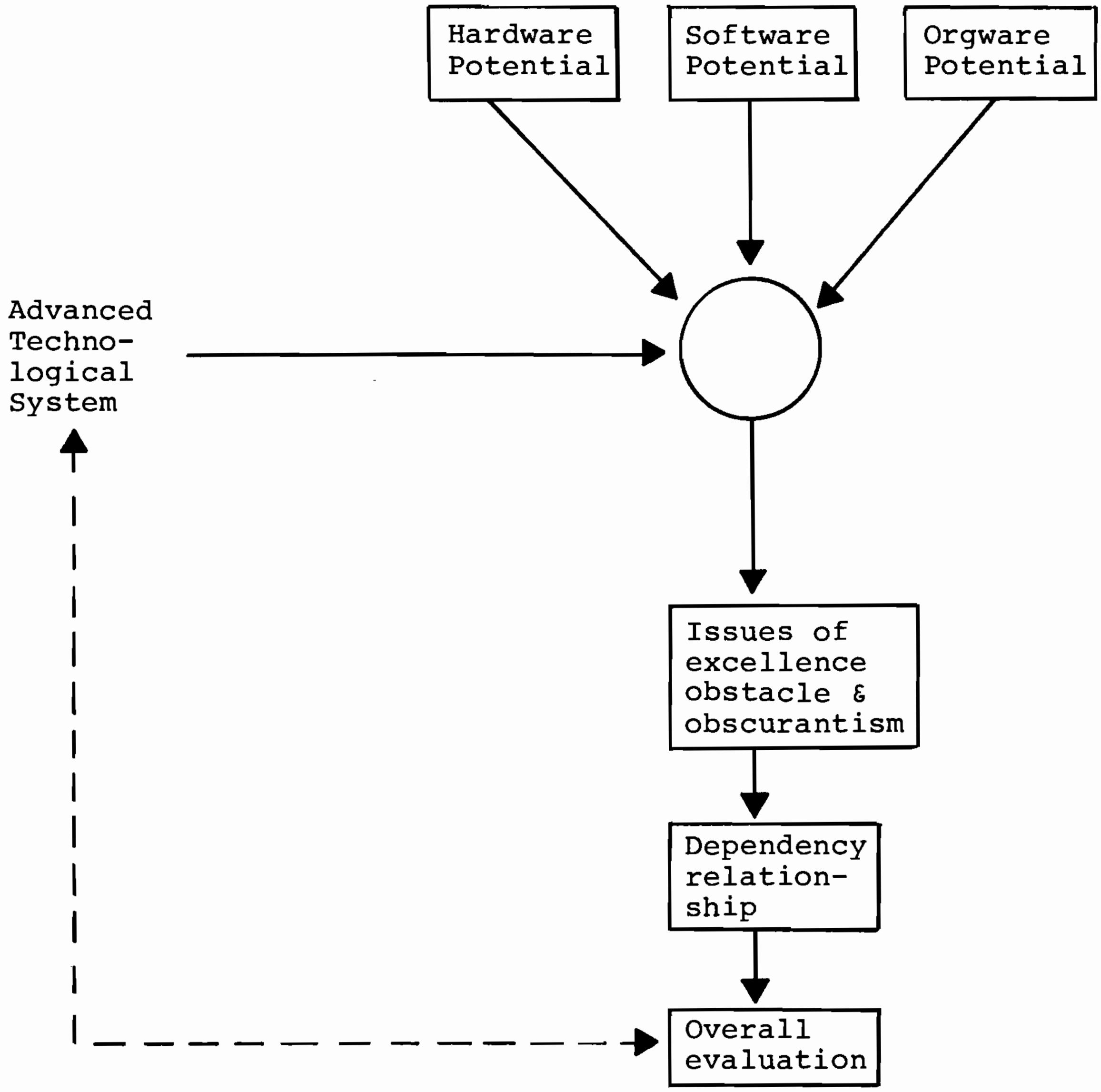


Figure 13. Framework of S-IOT analysis of advanced technological system.

All of these issues of excellence in specific hardware, software and orgware were, however, not sufficient without a successful blending and harmonization of the systems. In the final analysis the success of the system greatly depended on a centralized computer traffic control system, an example of one system element which is a combination of hardware, software and orgware components.

Issues of excellence in each of the hardware, software and orgware areas may exist in isolation in other countries. Without the particular combination of these factors, as we see in the Shinkansen case, other experiences have not shown the success we have seen with the Shinkansen combination of systems. France, for example, has a record of having possessed high speed vehicles for railway transportation. Other countries as well have possessed some of the excellent hardware or excellent software needed for an advanced railway transportation system on the lines of Shinkansen. Other than Shinkansen we have not found a case of such scale where the combination of all the necessary systems are present.

SYSTEM OBSTACLES

What kind of obstacles were encountered in the Shinkansen case? This aspect must be considered in a total S-IOT framework for analysis. The framework of our analysis and thinking is that of advanced technological systems, and in our consideration of the Shinkansen case some obstacles did exist. In the late 1950s there was a concern that the railway hardware was too noisy, and this suggested major problems for implementation of the system in the environment at that time. There were certain organizational limitations as well, i.e., limited decision-making power, and a price system not supportive to the development of a large scale railway system. As well, there were certain limitations of software e.g., lack of noise-reduction research. An understanding of obstacles of this sort helped us in the overall analysis of the system and its development.

UNSUCCESSFUL EXPERIENCES

If we turn, for example, to another project which was planned but never implemented, we can learn even more using the same framework. In 1962, the United States began two large scale programs, the Apollo program and the national railway development program. The Apollo program was a very good example of a S-IOT system on a large scale in which hardware, software and orgware elements were appropriate in combination. Many systems experts agree that the Apollo program was a successful large scale system. The national railway development program focused on the northeast corridor of the US and was in a sense, the American answer to the Shinkansen project. If we consider this program as another case for S-IOT analysis, we can apply the same general framework for understanding advanced systems. When we consider, for example, issues of excellence, we see the several elements of the combined

HW-SW-OW technological systems, i.e. high potential for hardware, high research potential for software information systems concerning railway transport, and the potential for application of program management. In this framework, the system possessed some necessary components for a combined technological system. Many advisors during this time urged the Kennedy administration to begin the program on the basis of "excellent potential". There was a perceived excellence in hardware, software and orgware potential.

From the S-IOT point of view, few of these advisors would have urged the immediate commencement of the program. This conclusion derives largely from a consideration of technological system obstacles as well as issues of obscurantism and ignorance.

There was a third set of issues for large scale systems as advanced systems--issues of obscurantism or ignorance. In software, for example, we found the perception of railroads as a dying technology. This perception was, according to many experts, a widespread and deeply rooted societal issue. Hardware was considered old-fashioned railroad hardware. This aspect included not only the trains themselves but stations and railroad facilities. The issues of obscurantism included an ailing passenger railroad organization and, according to some experts, a general public ambivalence concerning the development of a rail system of this size as a national priority.

S-IOT analysis would have suggested less optimism for the development of the project. An interesting end to the story for the American railway system occurred last year when a high level decision was made to purchase railroad technology including organizational knowhow from the Japanese.

The authors would like to suggest that this approach can provide potential benefits to the existing scientific methods of systems analysis.

POTENTIAL BENEFITS FROM THE S-IOT FORMULATION

Definition:	Helps to focus attention of systems analysts on OW problems.
Construct:	Helps managers to avoid practical omissions in their approach to technology.
OW as a New Dimension in Policy Studies:	Helps policy makers to be more comprehensive in technology transfer, organizational design and developing systems-integrated organized technology.

REFERENCES

Burack, E. (1975) Organization Analysis: Theory and Applications, Hinsdale, Dryden Press.

Cummings, T. (1978) Sociotechnical Experimentation: A Review of Sixteen Studies, in Pasmore and Sherwood (eds.) Sociotechnical Systems: A Sourcebook, La Jolla.

Galbraith, J. (1974) Designing Complex Organizations, Addison-Wesley, Reading, Mass.

Galbraith, J. (1977) Organizational Design, Addison-Wesley, Reading, Mass.

Gerwin, H. "FMS" working paper.

Hickson, Pugh, and Pheysey (1969) Operations Technology and Organization Structure: An Empirical Appraisal, Administrative Science Quarterly, 14(3).

Khandwalla, P. (1977) The Design of Organizations, Harcourt, Brace, Jovanovich, New York.

Levinson, H. (1971) Organizational Diagnosis, Cambridge: Harvard University Press.

Magnusen, K. (1977) Organization Design, Development and Behavior, Scott Foresman and Co., Glenview, Ill.

Miller, E.J. (1975) Sociotechnical Systems in Weaving, 1953-1970: A Follow-Up Study, Human Relations, 28:349-386.