WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

EVOLUTIONARY BEHAVIOR OF COMPLEX SOCIOTECHNICAL SYSTEMS

Z. Bonen

April 1979

#1056-79

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

EVOLUTIONARY BEHAVIOR OF COMPLEX SOCIOTECHNICAL SYSTEMS

Z. Bonen

April 1979

#1056-79

Evolutionary Behavior of Complex Sociotechnical Systems

Z. Bonen

Abstract

A complex sociotechnical system (STS) is composed of many people and many types of equipment interacting together to perform some tasks. A product/machine evolves by generations; a STS, on the other hand evolves gradually and incrementaly. Patterns of evolution are described for product, a single STS and tandem STS. A mature, inflexible STS acts as a filter blocking radical change proposals and accepting only incremental changes which cause minimum disruption to its present state. Hence, radical change is usually championed by newcomers penetrating via empty niches. Radical change is much more difficult in an area covered by tandem interlocking inflexible sociotechnical systems.

1. Introduction

A model of the process of evolution of a sociotechnical system (STS) was described in a previous paper (1). This model stressed the general impact of system properties on future evolution. It turns out that STSs act as filters, tending to accept changes congenial to their present state[1] and to reject radical changes threatening STS disruption. In this paper we shall classify various types of systems and describe the processes of evolution associated with them. This detailed discussion supports the conclusions of the above model.

2. Classification of Complex Sociotechnical Systems

Systems are usually described as small, medium or large with no precise definition. Here, we shall try to define and classify systems by categories convenient for the study of the process of evolution.

First of all, we shall differentiate between a inanimate system, i.e. a product or a piece of equipment, and a complex sociotechnical system (complex STS) which contains many people and inanimate systems interacting together to perform a set of functions/missions. A product has a finite life time and evolves by successive generations (car, airplane, typewriter, refrigerator). Though a current product generation may be improved by various modifications during its lifetime, sooner or later it becomes obsolete and is replaced in toto by a new generation distinguished by some novel features.

Complex sociotechnical systems, on the other hand, are not built in one piece. They evolve gradually, mostly through incremental changes

---

[1] STS state is defined by the following attributes: Values and objectives, structure: the set of roles and relationships among STS members, equipment and technological processes, personnel specific skills and training.

(addition/subtraction/ substitution/fusion) of equipment, personnel, organization and operating methods. Hence, at any point of time they may contain incongruous constituents of various ages and levels of development. Systems do not have a definite lifetime like products, indeed they may exist for a long time. There is a great variety of sociotechnical systems, for example: Production line in a factory, newspaper printing press, rail network, R&D group, an army tank company, ground to air missile battery. In general, a STS may be as small as a small workshop or as large as a big societal system.

The basic difference in evolution between a product and a complex STS, evolution through generation change versus gradual evolution, is pertinent to all stages of system work: analysis and problem definition, synthesis and design, development, testing and operations. Thus a real issue posed by complex sociotechnical systems to system theory is not how to design and optimize a large scale system from scratch, but rather how to understand, facilitate and perhaps optimize their process of evolution.

Products/inanimate systems may be divided into two categories:

1. Separate/stand alone products which can perform specified functions independently (digital watch, hand calculator, dishwasher[1]).

2. Embedded products which operate within a STS (traffic control equipment, communications transceiver, instrument landing system). Their performance is tied to the functioning of other system constituents. The evolution of an embedded product is obviously connected with the evolution of the system in which it is embedded.

---

[1] A dishwasher does require a supply of electricity and water. However, these are widely available with common standards and place little constraint on dishwasher evolution.

Complex sociotechnical systems may be classified by:

1. Equipment/Personnel relative weight.
2. Spatial dispersion.
3. Decision structure.

The relative weight of equipment versus personnel, ranges from social systems which contain no or little technology (schools) to (almost) fully automatic systems (power grid, telephone network). At one extreme, evolution means changing roles and relations between people, at the other end it means substitution of and changing interactions between pieces of equipment. Here we shall concentrate on labor intensive, medium to high technology complex sociotechnical systems where evolution unfolds through combined technological and social change.

Spatially, we can distinguish between a local compact STS and a dispersed STS. The constituents of a compact STS interact functionally to perform a combined task in a limited area (e.g production line, a tank company, local airport control). Decisions in a compact STS are concerned mostly with detailed functional coordination.

The constituents of a dispersed STS, usually many compact systems that are dispersed over a large area, interact mostly through transfer of material and data (e.g. airline reservation system, military command and control system, railway system). Compact systems are often small and dispersed systems are often large, but this is not always the case.

The evolution of a dispersed system includes the evolution of three distinct but interacting components:

1. Local compact systems.
2. Higher management structure.
3. Interconnecting network structure.

The management structure of a large dispersed STS may vary from strong central management to no management at all (e.g. an ecological system with no conscious direction). Here we shall deal mostly with systems which have at least some management. Hence, they are capable of purposive evolution.

The above classification is summarized in Figure 1

<table>
<tr><td colspan="2">System Level</td><td colspan="3">Relative weight</td></tr>
<tr><td>Unitary Systems</td><td></td><td>Men</td><td colspan="2">Machines</td></tr>
<tr><td rowspan="3">Complex Systems</td><td>Compact</td><td rowspan="3">Social Systems</td><td rowspan="3">Socio-technical Systems</td><td rowspan="3">Automatic Systems</td></tr>
<tr><td>Dispersed Managed</td></tr>
<tr><td>Dispersed Not Managed</td></tr>
</table>

Figure 1

Following section will deal with the evolution of a product (sec. 3.1), compact STS (sec. 3.2) and tandem STS (sec. 3.3). Specific problems connected with the evolution of dispersed systems will be dealt with in a later paper.

3. <u>Evolution of Various Systems</u>

3.1 <u>Product Evolution</u>

Our main interest is in complex sociotechnical system evolution. Hence, our discussion of product evolution will be brief and limited to some aspects relevant to STS evolution. In general, product evolution is connected with the evolution of the two sociotechnical systems involved in its production and its use and should be discussed in that context (Figure 2).

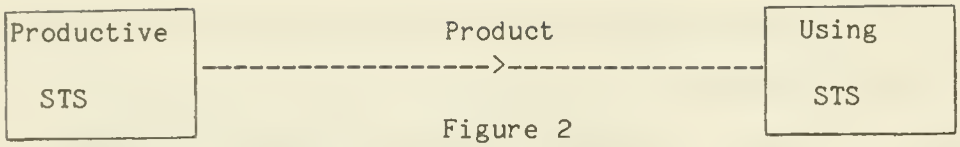


Figure 2

In this section we shall deal with the separable case of a stand alone product. Thus, there is no using STS, only independent users. As for the productive STS, it is easy for it to accomodate and introduce apparently promising new stand alone products[1] matched with its existing structure and technologies. Here, there is no threat of disruptive structure change (1) and few problems with well known technologies.

On the other hand, new stand alone products based on new technologies are usually introduced by fluid flexible productive STSs (2) which are receptive to radical technical innovations. These new products serve as a vehicle for transfering the latest technology from the laboratory into the market.

As mentioned above a product evolves through successive generations. The first generation is concerned mostly with feasibility proof and initial market acceptance. If the product survives this test, the direction of evolution of later generations depends strongly on user demands[2]. These ranging from mostly cost oriented demands (most consumer goods) to mostly performance oriented demands (military weapons, technical instruments). The first case is described by Abernathy and Utterback (2). Here, once a dominant design is established, product innovation and improvement declines, production process innovations become dominant, volume increases rapidly and unit cost decreases.[3]

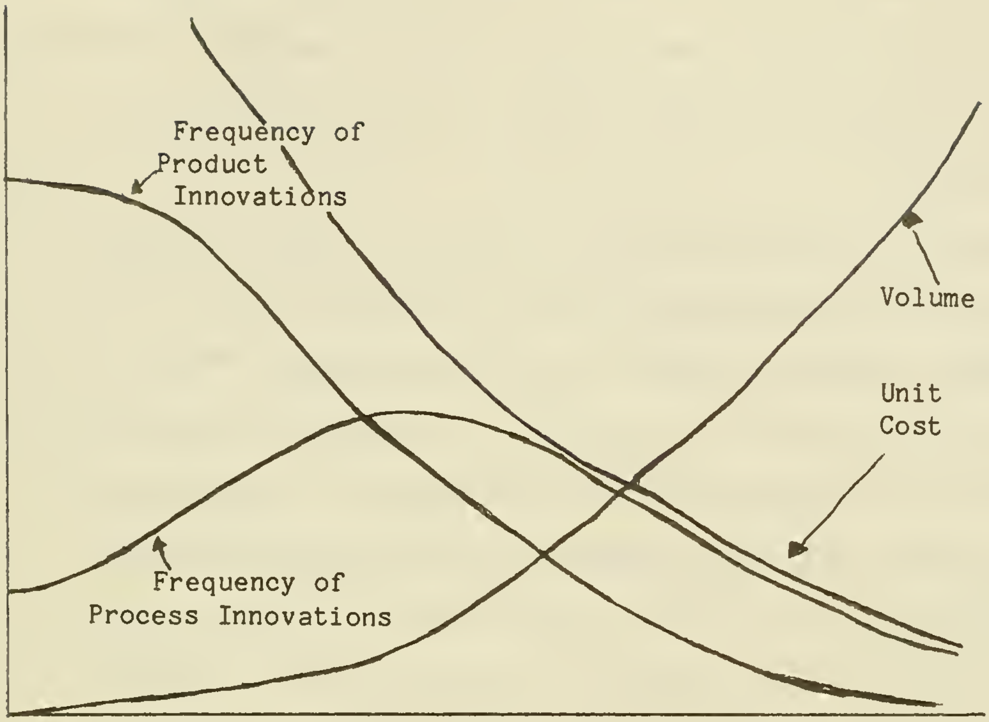
---

1 Products for which the benefit-cost estimates appear to be promising.

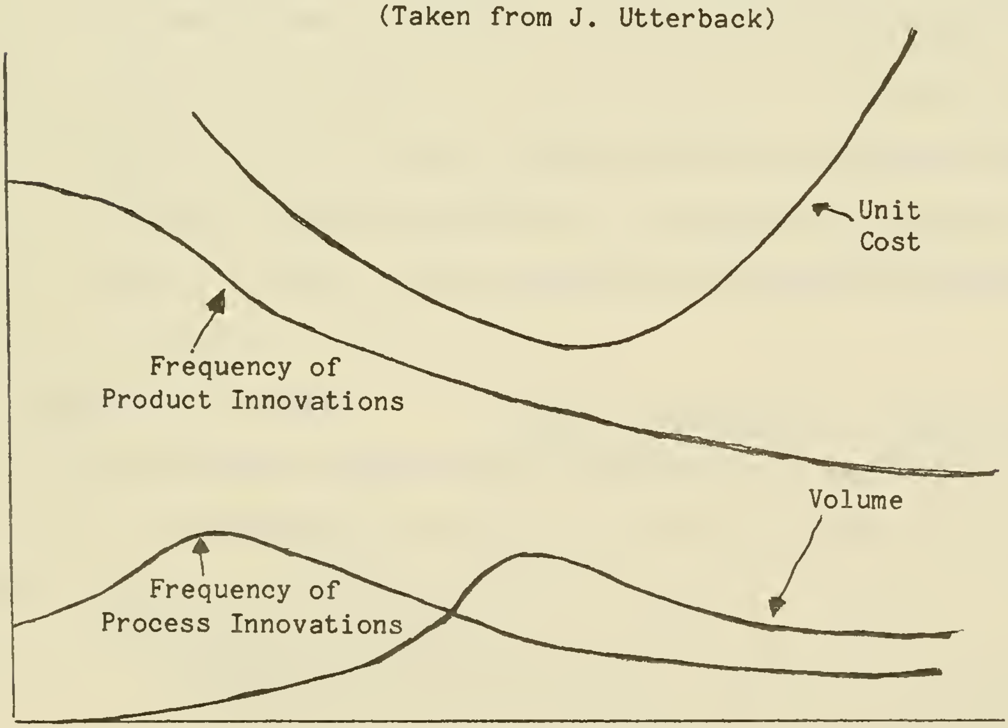
2 Indeed, as shown by von Hippel (3), users may even create the first generation of the product, especially in industrial equipment.

3 This is a typical case of adaptive specialization (1) which may lead the productive unit to a dead end if the product becomes rapidly obsolete for some reason.

Evolution of Product Characteristics



time ------->
Consumer Goods Pattern
(Taken from J. Utterback)



time ------->
Military Systems Pattern

Figure 3

In the performance oriented case, provided there are technological opportunities for product improvement, considerable performance changes occur between generations. Volume remains small or medium and cost increases from one generation to the next. This is a typical situation in military weapon systems.[1]

These two different patterns are shown in Figure 3. These processes may cause in the long run large changes in either or both the productive and the using systems or even the creation of new using systems. This is apparently in contradiction with our assumption in the beginning of this section. However, it is in these cases, where the entry of a new product does not initially disturb the existing order that a Trojan horse effect, as described by Schon (4, p.107) is often observed, i.e., long term radical change entering unobtrusively via apparently innocuous products. The car is probably one of the best examples of this type (sec. 3.3). Another one is, perhaps, the present introduction of microprocessors into various products in many fields.

The barriers to entry for embedded products and/or for products which are mismatched with present productive systems are much higher and their evolution is connected intimately to the evolution of the systems in which they are located.

3.2 Evolution of Compact Sociotechnical Systems

This section deals with the evolution of compact using systems. A large part of the discussion applies to other system types too.

---

1 It is doubtful whether DOD design to cost procedures to counter this tendency will be very successful if the military push for maximum performance improvement in each generation.

A complex STS evolves through changes in either or both its constituents and its structure. System constituents include its personnel and equipment ("hardware"). System structure is only partially defined by its formal organization. Indeed, there is considerable flexibility in roles and relationships among STS constituents which amounts to a variable structure visible externally by all the operating modes of the system ("software"). This variable structure enables the STS to possess a repertoire of operating modes ("software" programs) selected according to the tasks at hand.

The evolution of a compact STS may proceed via the following paths:

1. Improving present system performance - fastest process.
2. Introducing new operating modes - creation of new "software".
3. Substitution and addition of equipment without structural change - "hardware" change; common path for introducing new technology.
4. Restructuring of the system, including further substitution and addition of equipment - this process is very slow.
5. Radical structural change without change of equipment-rapid response to crisis conditions.
6. Combined radical change - radical "hardware" and "software" changes. This path is rare.

1. Improving Performance

Performance using present operating modes may be improved by training, incentives, improved maintenance, etc. All this can take place without change in operating methods, equipment or personnel. Hence, it is the fastest process.

2. Introducing New Operating Methods - "Software Change"

A STS has a repertoire of operating modes, selected according to the task. This adaptability is due to flexibility both in interpersonal relationships and in personnel-equipment interactions. New operating methods can be introduced easily within the system flexibility range. This range depends on:

1. Range of personnel skills and easily acceptable roles and relationships changes.
2. Range of externally available equipment capabilities[1] (multi-purpose equipment).

Within this range new methods assimiliation time depends on required and available training time.

3. Substitution of Equipment Without Structural Change

The substitution of equipment in a STS is a lengthy process stretching over the many years required for development, production and full incorporation. Because of this delay, as well as risk aversion behavior common in older rigid systems, new equipment will often be based on second generation technologies, i.e. on technologies which have already been proven in stand-alone products.

Moreover, this new equipment, even if based on latest technology, must conform to and function within the existing STS and its operating modes; these are determined by the bulk of older equipment and, last but not least, personnel accustomed to the old methods, equipment and social structure. Their natural inclination is to make the new equipment fit the

---

[1] If the equipment is internally capable of additional uses but these are not available at the interface with the user, lengthy modifications may be required in order to make this capability available.

well known and tried, i.e. the old methods. Hence, no or minimal "software" changes will be introduced. Thus the STS operates as a filter which prefers changes causing minimum disruption (1). It is also in the interest of the producers, who want to introduce new equipment as fast and as smoothly as possible, to tailor it to the present using STS and to avoid riskier, more radical innovation.

This process was just described by Morrison (5) investigating problems of change in the United States Navy in the early 1900's.

Two more recent examples from two completely different fields will be cited here. When the first generation of air to air missiles was introduced into service they were designed to be fired similarly to guns, i.e. using the same dog fight tactics (tactics are the "software" in this case).

The second example is the incorporation of computers in business which in the beginning followed closely the path of mechanizing and copying existing routine administrative operations. In both cases system structure changes (see next section) took place much later.

In summary, this is normal change (1), using new equipment to perform present tasks more efficiently, while avoiding uncertainties and resistance involved in structure ("software") change.

4. Restructuring and Further Substitution of Equipment

Making full use of the new technologies may require radical re-structuring of the STS. This will be achieved, if at all, much later (possibly a few decades) after the "new" (by now old) equipment has been thoroughly assimilated by the STS. Hence, a novel STS structure may appear many years after the maturation of the underlying technology, via a lengthy process of accumulation of normal incremental "hardware" and "software" changes thus limiting uncertainty and resistance at each step. This is illustrated in Figure 4 which shows the long delay in the application of new technologies in existing systems.

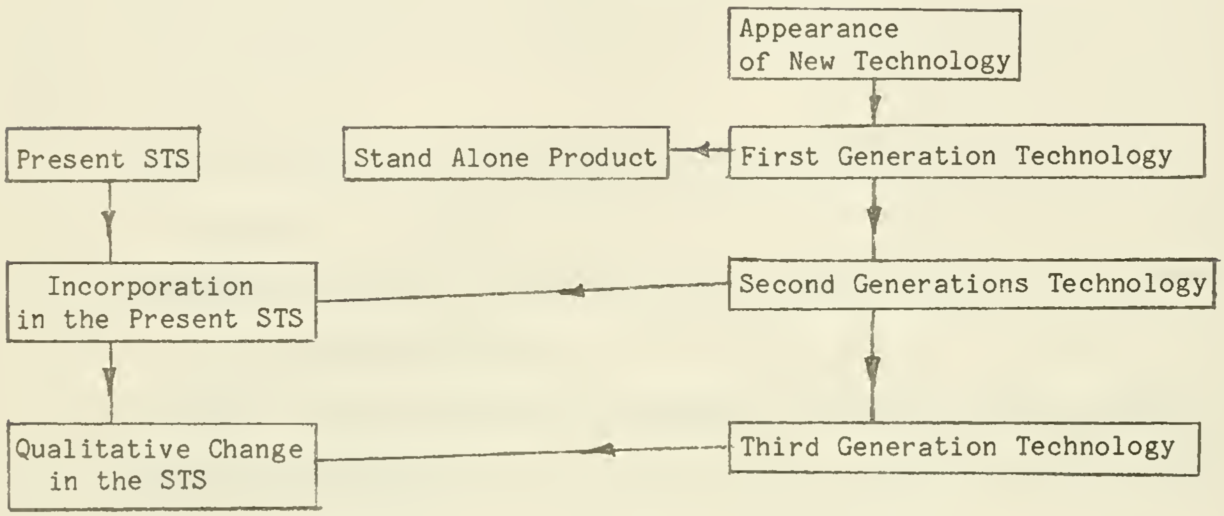


Figure 4

The introduction of computers (Electronic Data Processing) into banking illustrates this two-stage process. EDP was introduced for mechanizing account handling and other routine banking operations in the late 50's. However, radical innovative uses of EDP in banking, involving electronic fund transfer and automatic tellers, which may lead to radical changes in banking, have only been introduced during the last few years (6).

This slow transformation process may succeed if the environment changes slowly. Even so, in many cases the combined effect of many small, consensus oriented, normal changes does not necessarily add up to a coherent large scale radical change. On the contrary, it could bring the mature STS to a dead end (1) (going out of business, defeat in war).

The introduction of the tank into military use illustrates this lengthy and uneven process. After initial success in WWI technical improvement in the tank itself proceeded leading to improved and dominant (produced in large volume) designs in various countries (for example, the American WWII M4 Sherman tank. However, the required re-structuring needed to make effective use of the tank, i.e. the formation of independent armored forces supported by aircraft designed to fight a blitzkrieg was only acnieved in Germany (7). France and England dispersed their tanks in the infantry divisions, incorporating them merely as support units for the infantry. This led directly to their defeat in 1940. Thus the introduction of new equipment constrained by the old battlefield systems led to a dead end. The German case is an example of combined radical change described in section 6.

5. Radical Structural Change

In times of crisis, when the environment changes rapidly and system inadequacies become evident suddenly, the situation is basically different, requiring fast adaptation. Under this condition radical structural change which involves radical changes in the set of roles and relationships between STS members, may occur rapidly. An effective decision collective[1] is necessary to make and implement the risky and controversial decisions. Even so, it may fail because in a specific case structural ("software") change alone may not be sufficient to deal with the situation.

---

[1] The decision collective includes all people involved in making the decision, formally or informally, inside as well as outside the formal boundaries of the system.

This case may be illustrated by the very rapid change (days) in the composition and tactics of the Israeli forces during the Yom Kippur war in response to the suddenly revealed threat of anti tank guided missiles. The belief that tanks alone could break through the defense was shattered; it was quickly recognized that coordinated combined arms teams composed of tanks, artillery and infantry were required to deal with the situations. Note that this innovation was characterized by:

1. Revival of WWII doctrine adapted to the needs of the moment. It was not necessary to invent and trust a completely new idea in a risky situation.
2. Only existing hardware was used. Obviously, it was impossible to change equipment within a few days.

6. Combined Radical Change

In this process qualitative changes in equipment (technology) and structure (organization, operating methods and procedures) of the STS are designed and developed together.

Two main factors making this approach difficult are

1. The resistance of mature inflexible systems to radical and disruptive change, as described previously (1).
2. Multiple uncertainties involved in the combined change of equipment and structure.

The difficulties of multiple uncertainties may be clarified by looking at the interconnected development cycles of a complex STS and its equipment (Fig. 5). We have here two processes, equipment development and system development, each one of which comprises development cycles due to the uncerainties involved in new and unknown technology and structure. In the normal change process (secs. 3.2.3,3.2.4) these two occur in tandem (Fig.

5). First, the equipment is developed to completion, eliminating technological uncertainties and risk. After that, it is very often introduced into the system on a full scale (switch #1) without changes in system structure. Only then begins (switch #2) the long process of structure modifications leading back (switch #3) to demands for equipment modifications or even demands for complete new equipment.

Tandem Evolution of a STS

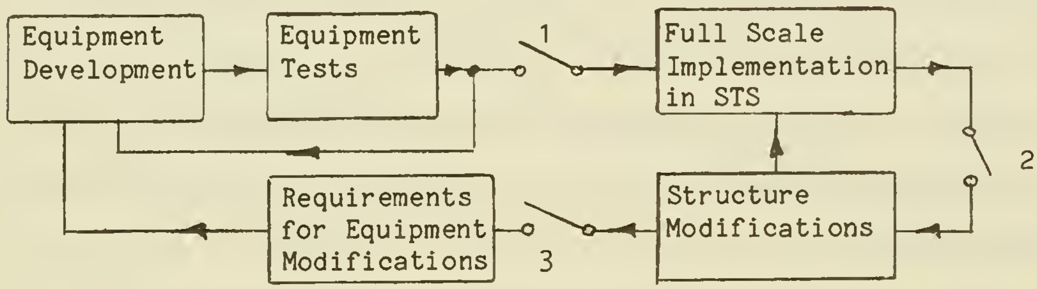


Figure 5

In the combined change process (Fig. 6) the development of structural changes begins much earlier, by experimenting with new structures and methods on a pilot STS, sometimes even before the equipment is built. This is the case when low technological risk in new equipment is combined with large radical structure change. In general, the proper meshing of equipment and STS structure development cycles depends on the location of the major uncertainties, these determine what should be tested at an early stage.

The planning of this experimental process will be described in a later paper. Difficult as it is to plan this process on paper it is even more difficult to implement it in a change resistant mature system.

Combined Evolution of a STS

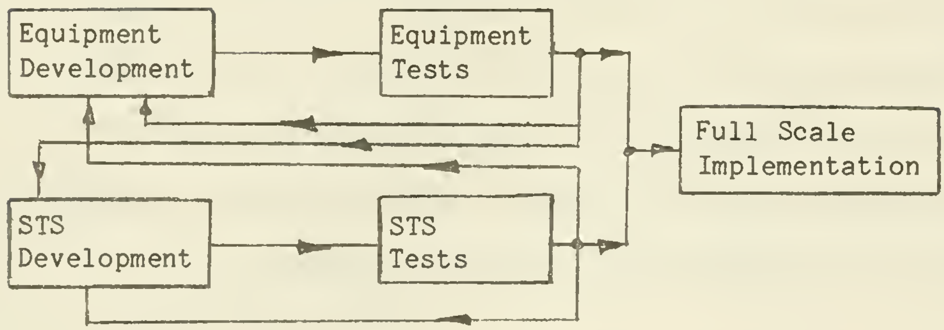


Figure 6

The various system evolution routes which may occur following the appearance of a new technology are shown in Figure 7. The normal conservative route 1 involving slow change and large technological gap has already been described (paragraph 3.2.4). An innovative system may evolve in two different ways:

1. Implantation of new equipment into an existing STS (Route 2) combined with radical changes in structure.
2. Creation of a new STS through a novel combination of various constituents, including new equipment. Here we must distinguish between a combination of inanimate systems taken from various sources (route 3) and combinations of parts of different man-machine systems, i.e. teams of personnel and equipment, taken from different STSs (route 4).

The deterrent effect of uncertainties and knowledge gaps renders an innovative evolution of an existing system more difficult, hence route 1 as described above is usually perferred to route 2. Creation of a novel complex sociotechnical system by combining individual inanimate systems (route 3) or parts of existing STSs (route 4) is usually even more difficult and slower process. Combination of various inanimate systems frequently requires a long period of engineering and industrial work. Only after this work has been completed, is it possible to test the entire system concept in the field. Such testing may require several development cycles, which may lead to updating both the overall structure and the form of constituents' integration.[1] These normal development difficulties are compounded by the opposition of well established systems operating in the same area. On the other hand, in an empty area where there is little or no opposition and/or competition, an attractive technological opportunity can lead to rapid radical change (i.e. international communication satellite system) by the creation of a new STS uninhibited by an old structure.

The development of a novel system by combining parts of different existing systems (route 4) is also a trial-and-error process which requires several development cycles, i.e., prolonged testing by actual operation in the field. To do this, parts of different systems must be combined or, in other words, parts of different organizations (units) must be integrated into a new pilot system. Such a process will probably encounter strong organizational, bureaucratic and political obstacles, both in decision-making and during implementation. Any novel proposal

---

[1] This is clearly similar to development cycles appearing in product development. The larger the knowledge gap, the more experimental the development, and the more development cycles, see Fig. 6.

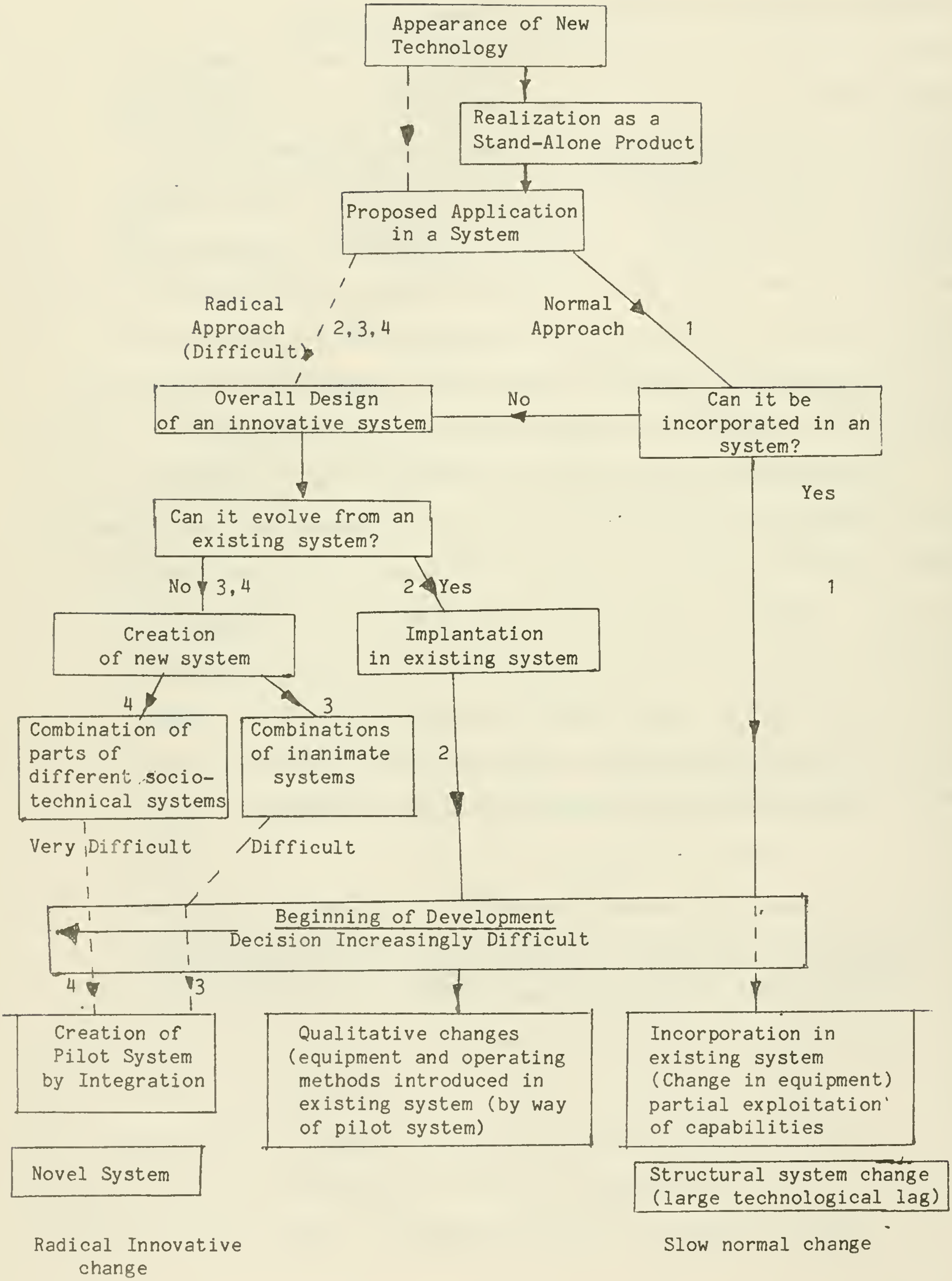


Figure 7 Evolution Paths

must not merely overcome these obstacles, but must also compete with the status-quo, i.e., must compete for the available resources with various incremental proposals (proposals for additions to existing systems), which are more attractive in the short run. It might appear that it would not be difficult to assign a small proportion of the available resources to an experimental development of a novel system (new venture). However, a satisfactory status quo obstructs innovative decisions and favors normal conservative decisions. Even when there is some dissatisfaction with the status gap (small or medium performance gaps), normal conservative decisions are prefered.

In order to surmount the above difficulties, champions devoted to the new ideas are essential. Even so, combined radical change of an existing system and its transformation into a fundamentally different system is rare; the usual case in the normal evolution by the path-of-least-resistance, i.e., short-range optimization, the minimum possible gap in technology and know-how, and the least possible institutional obstructionism.

As mentioned in section 4.2.5, radical change may be triggered by crisis, that is, by the appearance of sudden and big performance gaps (war, energy crisis). However, the implementation of combined radical change ("hardware" and "software") in a large and complex system takes at least 10 years. Hence, success in this difficult situation depends on having:

1. Length and seriousness of the emergency sufficient to give momentum to radical change actions.
2. Present system robust enough to survive a long period of degraded performance.
3. Available solutions and resources.
4. Last but not least, an efficient and future-oriented decision collective.

The case of the Israeli Navy missile boats System (8) is an example of path #3 - the creation of a novel system using equipment and weapons from various sources in one direct leap. The radical innovation was in the concept of using small-sized vessels as the principal and independent naval fighting system without any support from larger vessels. The vessel, its weapons and other equipment, doctrine and tactices, all were developed in parallel, using equipment developed or purchased both in Israel and abroad.

The decision to undertake this risky path was motivated by two reasons:

1. The old naval system based on destroyers had ceased to exist and had to be replaced.
2. No alternative satisfactory solution was available.

An interesting paradox emerges here. A low/no-risk situation, associated with a satisfactory status quo, hinders and may prevent even small, experimental innovative changes. A high-risk, no other choice situation forces radical combined change under difficult and sometimes impossible conditions.

3.3 Tandem Sociotechnical Systems Evolution

Returning to Fig. 2, consider now the combined process of productive and using systems evolution. A technological opportunity may or may not be selected by the productive STS for product development and production. Also the using STS/market chooses whether or not to buy and use. Both systems act as filters easily accepting perceived incremental changes and rejecting perceived radical changes. (Fig. 8)

Figure 8

In a particular case the same change may be perceived as a major one for one STS and a minor one for the other STS. The gamut of possible paths may be appreciated by the following diagram (Fig. 9) which depicts four extreme combinations.

1. Minor Changes in both productive STS and using STS.

This is very common, easy and fast. In both STSs a Trojan horse effect may occur later, i.e. a gradual transformation of either STS.

2. Major Changes in the productive STS, ninor Changes in the using STS.

Here the market is favorable. Cost of entry is high for an established specific productive STS. Cost of entry is low for new comers and invaders, for them there is no sunk cost in present systems. Hence, a specific productive system usually either rejects the opportunity or fails in its attempt to exploit it. It is exploited successfully by newcomers and invaders to build new productive systems. These, as they grow and evolve may later become inflexible and specific. There are many examples of this phenomenon (9) but only two will be mentioned here. The attempts by the old vacuum tube manufacturers to move into transistors ended mostly in failure. The diesel electric locomotive was introduced by General Motors, an outsider, and not by the established locomotive manufacturers.

3. Minor Change in productive STS, major Change in using STS.

Market penetration is slow and requires large efforts by the productive STS. Two paths are:

1. Entry via empty/favorable market niches creating gradually a new using system.
2. Crisis forces using system to change rapidly.

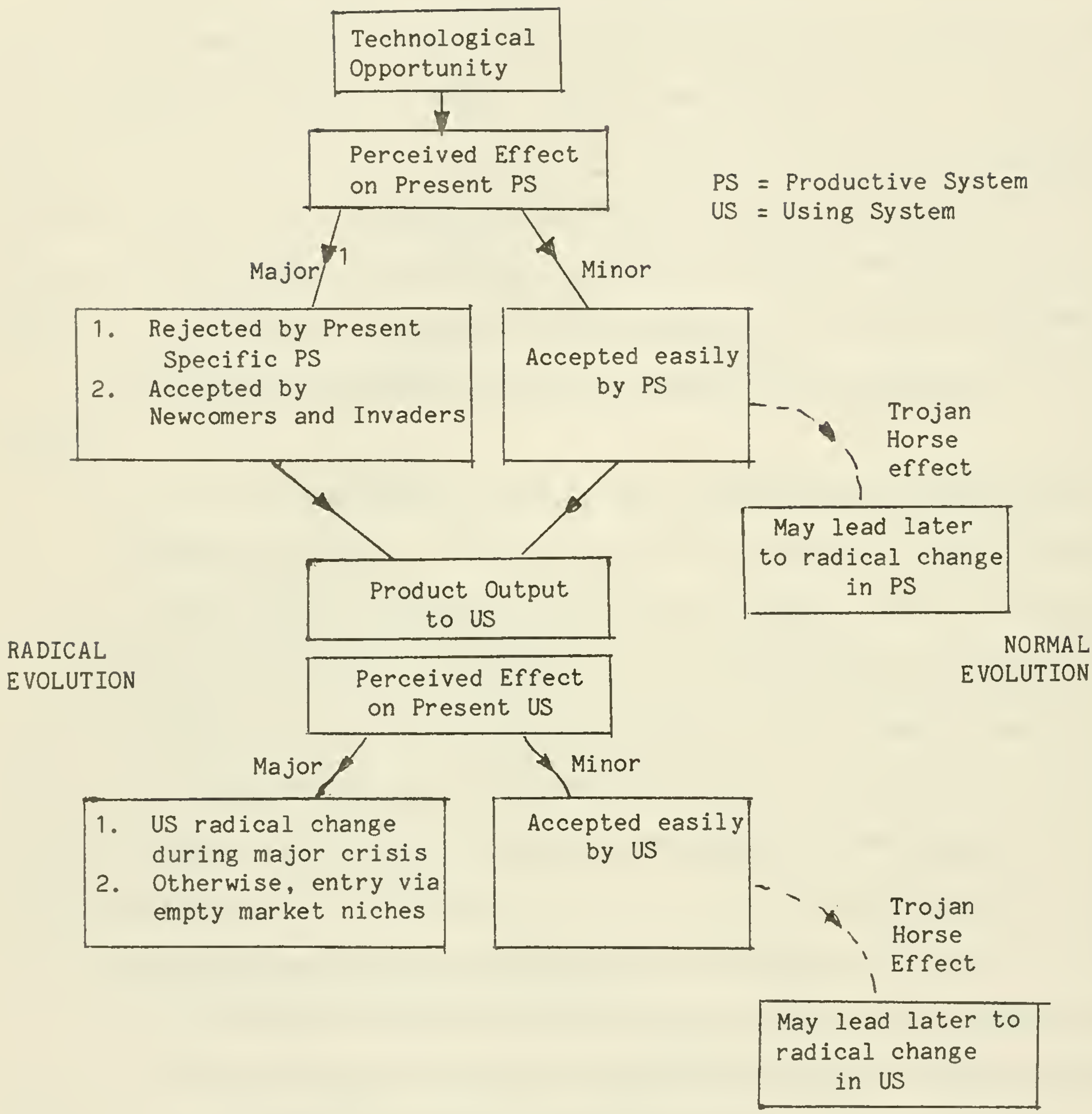


Figure 9

---

[1] Major change in present PS or completely new and different PS required.

The introduction of the helicopter into military operations illustrates this case. For many years the helicopter was used merely as a flying ambulance or taxi. Only the special problems of the Vietnam war finally transformed the helicopter into a combat platform [Note that force re-structuring (par. 3.4), to make full use of its capabilities, is still in its infancy].

4. Major Changes in both productive STS and the using STS.

Here evolution is very difficult; Newcomer productive STS entry via empty niches (if available) will face the combined strong opposition of the established productive and using STSs. Hence, a major crisis is usually required to start a change.

Two examples will be cited here.

1. In 1963 the U.S. Department of Commerce attempted to introduce innovation in the American building industry via a Civilian Technology Program. This attempt was easily defeated by a combined coalition of producers and users of building material (4, pp. 39-42).

2. Conservatism in tank development (10)

In any country tanks are developed by very few companies (in many cases one) and bought by one user (monopson). They have cooperated successfully and closely for many years in the incremental normal evolution of tanks. It is improbable that a completely new innovation will arise from this a combination of mature specific productive and using STSs without a major crisis.

Indeed, in many areas the accumulation of minor MiMi changes have over decades gradually resulted in the formation of highly inflexible and specific tandem systems combinations: e.g. the road self-transportation system which includes: the automobile industry, the road network, the fuel supply system and suburbia: all interlocked together and very difficult to change.

4 Summary

Normal evolution which involves small internal uncertainties is by far more common, being very suitable for dealing with small changes in the environment without disrupting present sociotechnical systems.

Radical change which is required in order to cope with large changes in the environment of the STS is a leap into the unknown, necessarily connected with large uncertainties and disruption of the present system. Hence, planned, purposive radical change requires an effective decision collective ready for radical change. This is not usually the case with mature and rigid sociotechnical systems, they will tend to filter out radical change proposals and follow in almost all cases the normal path of evolution trying to make best use of their present assets and environment. Radical change must therefore find other routes. It will be championed in most cases by newcomers committed to new ideas, creating new unihibited organizations penetrating where possible via empty niches in the environment. This is much more difficult in an area covered by a combination of interlocking sociotechnical systems.

Mature rigid sociotechnical systems will sometimes try to undertake a radical change when their environment shifts suddenly, creating a crisis situation. However, this attempt may not be successful.

It is evidently important to try to improve the procecss of evolution of sociotechnical systems. This problem requires much further study.

5. Acknowledgements

The author owes a great deal to fruitful discussions with Professors Roberts, Hollomon and Utterback in M.I.T.

References

1. Z. Bonen, "Evolution of a Sociotechnical System, a Model and some Implications," Sloan School Working Paper. No. WP 1054-79, March 1979.

2. W.J. Abernathy, and J.M. Utterback, "Patterns of Industrial Innovation," Technology Review, Vol. 80, June/July 1978, pp. 41-48.

3. E. von Hippel, "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovations," Vol. EM-24, May 1977, pp. 60-71.

4. D. Schon, "Beyond the Stable State", Random House 1971.

5. E.E. Morison, "Men, Machines and Modern Times", M.I.T. Press, 1966, pp. 33-40.

6. S. Rose, "The Unexpected Fallout from Electronic Banking," Fortune, April 24, 1978, pp. 82-86.

7. U. Macksey, "Tank," Two Continent Publishing Company, 1974, pp. 24-107.

8. S. Erell, "Israel Saar FPBs Pass Combat Test in Yom-Kippur War," U.S. Naval Institute Proceedings, Sept. 1974.

9. A.C. Cooper, D. Schendel, "Strategic Responses to Technological Threats," Business Horizons, Vol. 19, Feb. 1976.

10. A.J. Alexander, "Armor Development in the Soviet Union and the United States," Rand R-1860-NA, 1976.