Life Cycle Concept and Management Practice in Industry

E. RAZVIGOROVA and J. ACS: Editors

PROCEEDINGS OF THE WORKSHOP HELD IN SOFIA, BULGARIA
"Life Cycle Theory and Management Practice"
April 27–29, 1987

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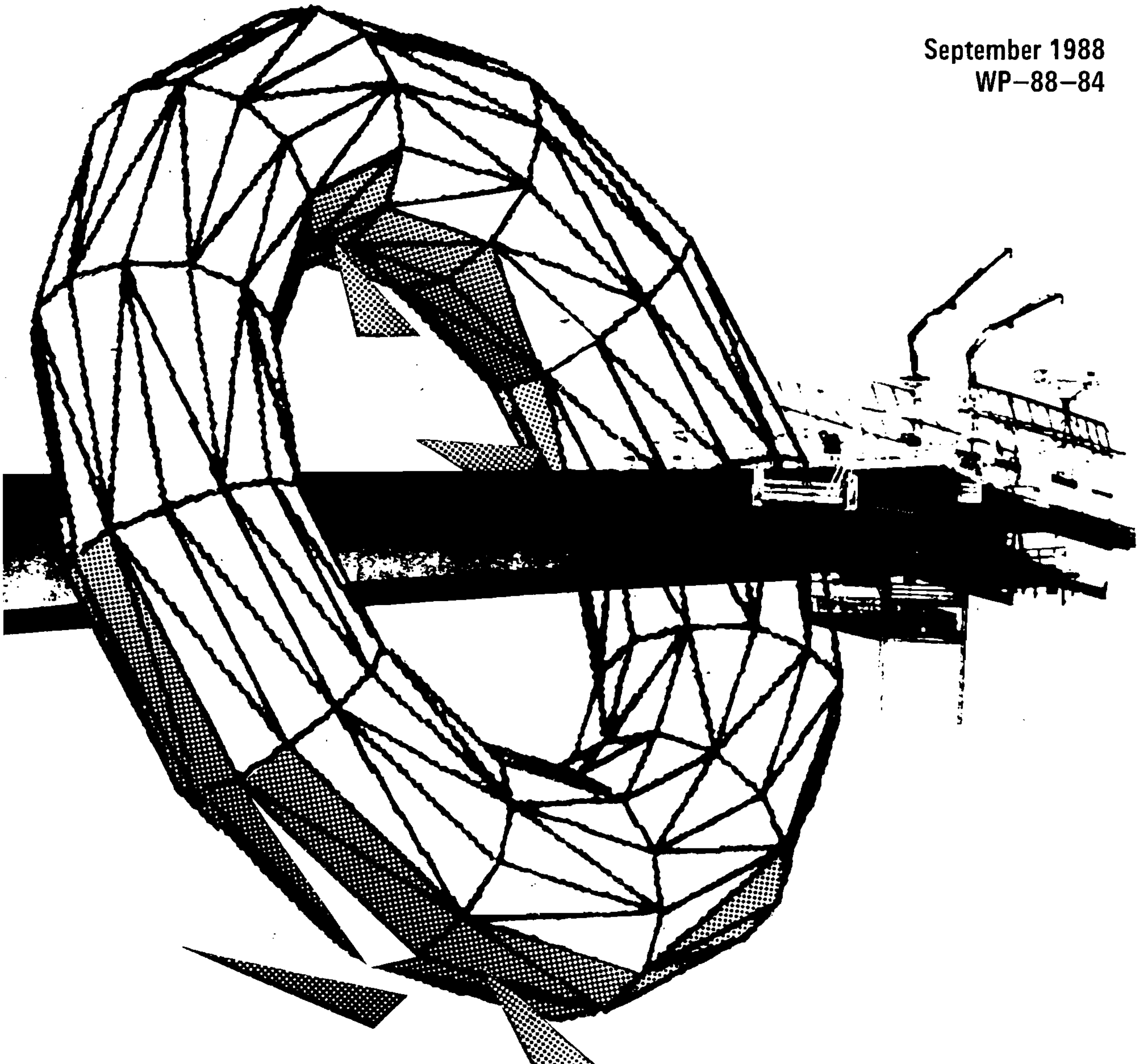

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
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FOREWORD

The papers included in these proceedings were presented at the workshop, "Life Cycle Theory and Management Practice," held in Sofia, April 27-29, 1987.

The objective of this workshop was to discuss the main lines of the life cycle concept and its possible applications in management. Special emphasis was put on company level. The example of steel industry was used for in-depth discussions, but some conclusions and illustrations from other industries (more or less related to steel) were also discussed.

The continuing need to innovate and develop technologies and products and their diffusion usually necessitates many changes: in market position, both international and domestic; in productivity and capacity utilization; in social impact and expectations. The transition periods between different stages of this development are sometimes painful and difficult. How management succeeds in coping with change and how management itself changes with the dynamics of technology are important research questions.

The workshop was designed in three main parts, which structure is reflected in the design of the proceedings. The first group of papers is devoted to the life cycle concept and diffusion patterns of different technologies. The second group of papers discusses different transition periods and applications of the life cycle concept in the steel industry, including practical examples of management and business strategies in different steel companies. The third group of papers concentrates on management issues and possible applications of the life cycle concept in management. Attempts to formulate some general issues and conclusions were made.

In order to use all the valuable contributions made during the workshop, the editors have permitted themselves to include transcripts of various discussions held during the workshop, as a great deal of important and interesting material was presented in this informal manner. Selections from the relevant discussions follow each group of papers.

F. Schmidt-Bleek
Leader
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SUMMARY

The workshop "Life Cycle Theory and Management Practice" demonstrated the widespread acceptance of the life cycle concept in the scientific community and in management practice.

Based on a summary of the main terms and the various stages of life cycles for products, processes, and industries, and an description of the relationships between these phases and various aspects of organizations, industries and products, the value of using different life cycle concepts and the importance of the managerial life cycle for a firm's strategic management was demonstrated and discussed. Examples were given from several different industries, including steel, to clarify the development, structural change, substitution and diffusion of technology within the framework of the life cycle concept. As the relevant discussions show, the life cycle concept can explain the various trends, developments, time-lags, and diffusion patterns and problems in the steel industry and others as well. A new approach making it possible to determine the end of the embryonic (or childhood) phase was also presented.

Critical remarks on the life cycle concept, presented both in papers and during discussions, have shown the need for further empirical tests and theoretical research. Some advantages in planning and realizing innovations in the steel (and other) industries based on the concept of the integrated life cycle as a tool in the management of innovations with broader time horizons were also demonstrated. The integrated life cycle includes the phases of invention, innovation, and (important for senescent industries) restructuring or liquidation. With the help of the integrated life cycle concept, the future state of a company could be simulated (in many aspects, better than by methods in use currently). Special software packages for computations are currently being developed.

Concentrating on the steel industry, its current problems and future development, possible changes in production and consumption were shown. The changing character of producer-consumer relations in the development of a company's strategy was emphasized. The improved methodology for technological forecasting was also found to be a contributing factor to the development of an appropriate strategy.

This, together with the growing importance of management issues during periods of industrial crisis based on the case of steel, as labor and social effects of technological change in this industry led to the conclusion of existing possibility to generalize management issues and tasks along the life cycle of products, processes, and industries.

Management of technological and organizational development and duplication of the life cycle concept in new technologies

show the importance of case studies in studies of process life cycles and clarified some relations between different phases and management options. Many participants stressed the importance of case studies on life cycles in various industries in different countries.

The presentations and discussions on the deeper connections of time, space, innovation management, and life cycle concepts as well as of systems approach to create a new model of innovation emphasize the inter-relationships of various sciences and necessity of inter-disciplinary approach to study the problem. In the above context, historical methodology was also discussed as a good contribution to developing an adequate management model.

Using the life cycle concept on the macro-level, the companies' behavior can be studied from the managerial and organizational points of view. Such studies could be done, not only in the steel industry, but also in other branches such as textiles or robotics. Analysis based not only on statistical data and questionnaires, but on case studies and on in-depth interviews involving companies could give useful insights for the theory and management practice of life cycles.

The role of product specialization and differentiation in the life cycle and in the companies' strategy was stressed by many participants. The problem of correct timing and the use of Foster's S-curve ought to be studied and developed as management tools. Interesting examples of how some companies prosper by switching from one obsolete technology to an upcoming one at the right time were discussed. In this connection, the timing decision was defined as an important one. Until now, there are no definite criteria available to determine the appropriate time to switch from one technology to another. At the beginning of a new development, many approaches evolve simultaneously before a winning paradigm appears.

Comparing behavior patterns in different companies within the same industry, or even between industries, was accepted as the direction of a study which could help to clarify the possible generalization of the life cycle concept as a useful management tool. An important issue in developing the possible methodologies for determining the right decisions in changing technologies was defined to be the use and development of proper indicators. The definition of parameters which could describe management behavior during the life cycle could deliver the necessary information for decision-making.

Prof. János Acs and
Prof. Evka Razvigorova
Editors

SECTION 1:

LIFE CYCLE CONCEPT:

Practical Applications in the Steel Industry, Possibilities and Problems

1.1. TECHNOLOGICAL PROGRESS IN ECONOMICS: ON THEORIES OF INNOVATION AND THE LIFE CYCLE

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With your permission, I will briefly review the life cycle as it applies to technological change. I apologize to those of you who know this already, and I hope that it might be of some help to the rest.

The life cycle concept, of course, has an origin in biology. We talk about conception, birth, infancy, childhood, adolescence, maturity, senescence, and death. It has occurred to many people at various times that these stages also seem to have some application to the rise and fall of civilization, the rise of business enterprises and industries, and the evolution of technologies. So what I have done here is to try to show some possible relationships between these stages and various aspects of organizations, industries and products (See Figures 1 and 2).

For example, during the "infancy" stage of a new product, immediately after its introduction, the product is unique. One producer is making something no one else produces. He is therefore a monopolist for a time, and he can furthermore set his prices to maximize profits. This ability to earn extraordinary monopoly profits is precisely the incentive for technological innovation in a capitalist (free enterprise) system, as Schumpeter pointed out seventy-five years ago. Monopoly requires uniqueness, in terms of design performance or function.

The "childhood" stage of the life cycle is usually characterized by the appearance of imitative innovators. These are people who, inspired by the original innovation, may want to try to achieve the same result in some other way, or perhaps to get a better result, perhaps just make it cheaper to produce. But in any case, there is often quite a diversity in the early stages. This was very evident in the early stages of the automobile industry, where you had a large number of producers producing cars that were very different in configuration. In fact, at one time, not only were there cars using internal combustion engines, but also electric cars and steam cars, all competing in the market at the same time during the first decade of this century.

The adolescent stage of a product would be characterized by an increasing degree of standardization towards one main configuration. This was certainly true in the auto industry. Standardization was particularly emphasized by Henry Ford with his "Model T."

The mature phase would be characterized by a very high degree of standardization of the product and markets beginning to approach saturation. One can tell when a market is saturated in economic terms when its price elasticity becomes low and it behaves like a commodity.

In the senescent phase, the product is effectively a commodity: something not changing, not evolving. It has its niche and within this niche, whatever it is, the product is now a necessity.

Now, as for processes, the life cycle has a different set of implications. During the first stages of the life cycle, production tends to be "custom." Organization is ad hoc. For a mechanical product, one would tend to use multi-purpose machines and multi-purpose labor. This labor is likely to be highly skilled. But as the product evolves through the stages of the life cycle, production shifts from small batches and job shops, with manual operation, to medium to large-scale batches with more and more mechanization. Gradually the skills of the workers tend to be more and more embodied in the machines. In the mature phase, the workers need not be highly skilled. They may be highly paid, which is a different matter, but in a modern automobile plant, for example, almost no training is needed. A worker with very little education can be brought into the assembly line and function adequately with two weeks or so of "on the job" training. This means that the skill requirements are minimal.

As regards strategic management, the life cycle has interesting implications. For example, in the early stage, the tendency would be to invest in improving the product. During the "childhood" stage, this makes sense because the product is being sold primarily on the basis of its performance. Later, however, as the product becomes more standardized, competition in the market place is more and more based on price. Both performance and price are involved, but the balance shifts from performance towards price as the life cycle moves from adolescence to maturity. And as the emphasis in competition moves from performance to price, similarly investment will tend to move from product R&D to process R&D, because when price is the critical factor, then the idea is to reduce costs as much as possible by improving the process. Finally, as a product becomes mature or an industry becomes mature, there seems to be a tendency -- we certainly see it in the steel industry -- to dis-invest, to sell technology assets and even physical assets to low-cost competitors. This tendency is very visible in the United States.

In its early stages, an industry is usually low in capital intensity. Some industries are inherently more capital-intensive than others, of course. The steel industry from its inception was relatively capital-intensive, but it was not nearly as capital-intensive in the 1880's as it is today. It is also, as a rule, more "contestable" in the early stages, meaning that the cost of entry (and exit) is lower before the industry becomes more highly specialized and capital-intensive. In the mature phase, it is less feasible for a new competitor to enter the arena, and so the "risk premium" declines. I shall return to this point later.

As regards strategic management, there are also locational aspects. During the infancy of a new product, typically the location selected (if there is some choice) is likely to be near the richest market. What is most essential to an entrepreneur at that stage is rapid, efficient feedback between the market and the design, engineering, and production activities. Thus, if something goes wrong in a marketplace, it can be fixed fast. There is one legendary story -- I do not know if it is true -- that one of the early Fords had the gearbox put in backwards so that when put into forward it would move in reverse! Fortunately the feedback between the market and the factory in those days was so good that only one car had that happen, and the fault was corrected immediately. Whether that story is true or not, it does illustrate the point that being near the market is important in the early stages of product development.

It also is important in the early stages to be near a pool of technical talent. That is probably the main reason why "Silicon Valley" exists. It is the pool of technical talent that existed in that area (and which was later attracted to that area) that made possible the great success of the semi-conductor industry. It is hard to build an industry requiring very highly skilled people in an area where such people are not available. But this is a problem mainly of the early stages of the life cycle. In the late stages, when most of the skills have been embodied in the machines, location is determined by other factors such as labor costs.

There is a life cycle in locational preference. This process was described very well by Vernon in his famous 1966 paper, from which Figure 3 is taken. In the early stages, production is near the most important markets. The successful producer becomes an exporter. Gradually, as the product becomes more standardized and more reliable, demand for it increases among more distant markets that may not be so wealthy. Then ultimately to meet the demands in those markets, the newest facilities are moved to those areas, because they no longer require such a high degree of technical skill and sophistication. Finally, those newer facilities, taking advantage of lower cost labor, tend to become exporters back to the original country. This is a process we have seen in the auto industry, in the steel industry, and many others.

Once an industry becomes mature, it tends to move to that area where the factor costs are lowest. Now it is true that we may have over-estimated the labor cost aspect of this pattern. Labor costs are not a really dominant factor nowadays, at least not in a very capital-intensive industry such as steel. But if all other factors are equal, then labor costs can still determine location. If capital equipment is the same and is marketed worldwide by specialized capital equipment companies -- which is true in this industry -- and they are willing to build a new plant in South Korea or in Brazil (or in Saudi Arabia for that matter) for the same price that you could build it in Texas, then labor costs still become a dominant factor in location. Of course, other factors are not always equal and sometimes some countries have cheaper capital costs, others have cheaper energy costs, and so on, but those are just variants of the general principle.

From the organizational perspective, again, there are characteristic features of the life cycle in different stages. During the early stage, it is important to have a very flexible organization. The product itself is not standardized; everything is changing all the time. And gradually, at least if history is a guide, the tendency seems to be to move from a very flexible organization towards a bureaucratic one. In the late stages of the life cycle, where production is on a very large scale, the product itself is not changing, and even the process becomes standardized, then cost control tends to move into the accountant's office. At this stage, it is very important to have an extremely well-controlled organization. At least, that seems to be the way firms have evolved in the past.

I could talk about other factors as well. What about labor in the different stages of the life cycle? I already mentioned that in the first stages the tendency is to use multi-purpose, highly skilled labor because nothing is standardized, nothing is fixed. But as the product is standardized, gradually mechanization is increased and labor skill requirements are reduced. Skills are also divided, as time goes on, into sub-skills, often becoming somewhat codified, at least in union contracts, and ultimately the highest skills are those needed on the management side rather than on the production end.

I can continue this even further. I can talk about economic measures, for example. In the earliest stage of a product life cycle, the idea of price elasticity is perhaps not even appropriate. But as the sector moves through the various stages, at least as I see it, the tendency is for markets to become more clearly defined and for price elasticity of demand to fall from a high initial level towards a very low level in the last stage as the product becomes like a commodity.

As noted earlier, "contestability" or ease of entry and exit is an interesting feature of the cycle. In fact, I believe perhaps one of the best objective tests of the transition from the childhood to the adolescent phase is in terms of entry and exit. During the childhood stage, entry is obviously easy. All you need is a better idea. Also during the childhood phase, a lot of new entrants typically come into the industry, usually from "neighboring" industries with some relevant capability. And at some point, the number reaches a maximum and then -- after a "shakeout" -- begins to decline rapidly. That is a typical pattern. We are seeing it now in the personal computer industry; we saw it long ago in the auto industry and the steel industry. The shake-out consists of rapid mergers, combinations, bankruptcies, and people simply leaving the business. During the mature phase then, the shake-outs are over, and typically the number of companies in the industry stays constant or nearly constant for a relatively long time. (Not absolutely constant and "a long time" is not forever, but it may last for decades.) And then during the senescent stage, there may be a renewed period of turmoil and more mergers, bankruptcies, and departures from the industry as we are beginning to see now, I think, in the steel industry.

From a competitive point of view, one can say that in the very early stages there exists a natural monopoly of the innovator as Schumpeter described. In the mature stage, there is typically something like a stable oligopoly. Perhaps in the childhood and adolescent stages, the industry is closer to a pure competition, During the latest stage of senescence, again things become quite unstable. The boundary between "childhood" and "adolescence" might best be characterized as that point where the number of different vendors reaches its peak. I want to mention the interesting study by Prof. Rosegger on the auto industry. He did not use the number of vendors, but rather the number of "makes" as a measure. But still the pattern, I think, is quite similar. In any case, a pattern something like this could probably be found in the steel industry too.

I think I have probably said enough for the present. Many of these propositions are conjectural. Some of them are subject to empirical tests. In fact, some of them we could probably test using the data base that we have assembled for this workshop. Others would require special studies. I am very much interested to know what you all think about these ideas as applied to the steel industry, which of them should be tested further, and how we should go about it.

FIGURE 1

Summary of Modified Life-Cycle Theory

Life Cycle Stage	Product Technology	Process Technology
Conception	Conception (idea)	NA
Birth	Prototype	NA
Childhood	Diversity of models and designs	Machine specific skilled labor* General purpose machines
Adolescence	Improved designs, fewer models, reduced rate of change	Product-specific labor skills Special adaptations of machines, e.g. tools, dies, etc.
Maturity**	Standardized product, slow evolutionary changes	Semi-skilled labor large-scale automation***
Post-maturity** (senescence)	Commodity-like product	↓

*Product-specific skills do not exist at this stage, but machine skills are especially important.

**During the mature phase, introduction of major new product or production technologies is likely to be very disruptive to established oligopolists; new entrants can appear or small marginal producers can achieve dominant positions.

***Automation may be "hard" or "flexible", in principle. The key to combining scale economies with continued technological change is flexible automation.

(cont'd)

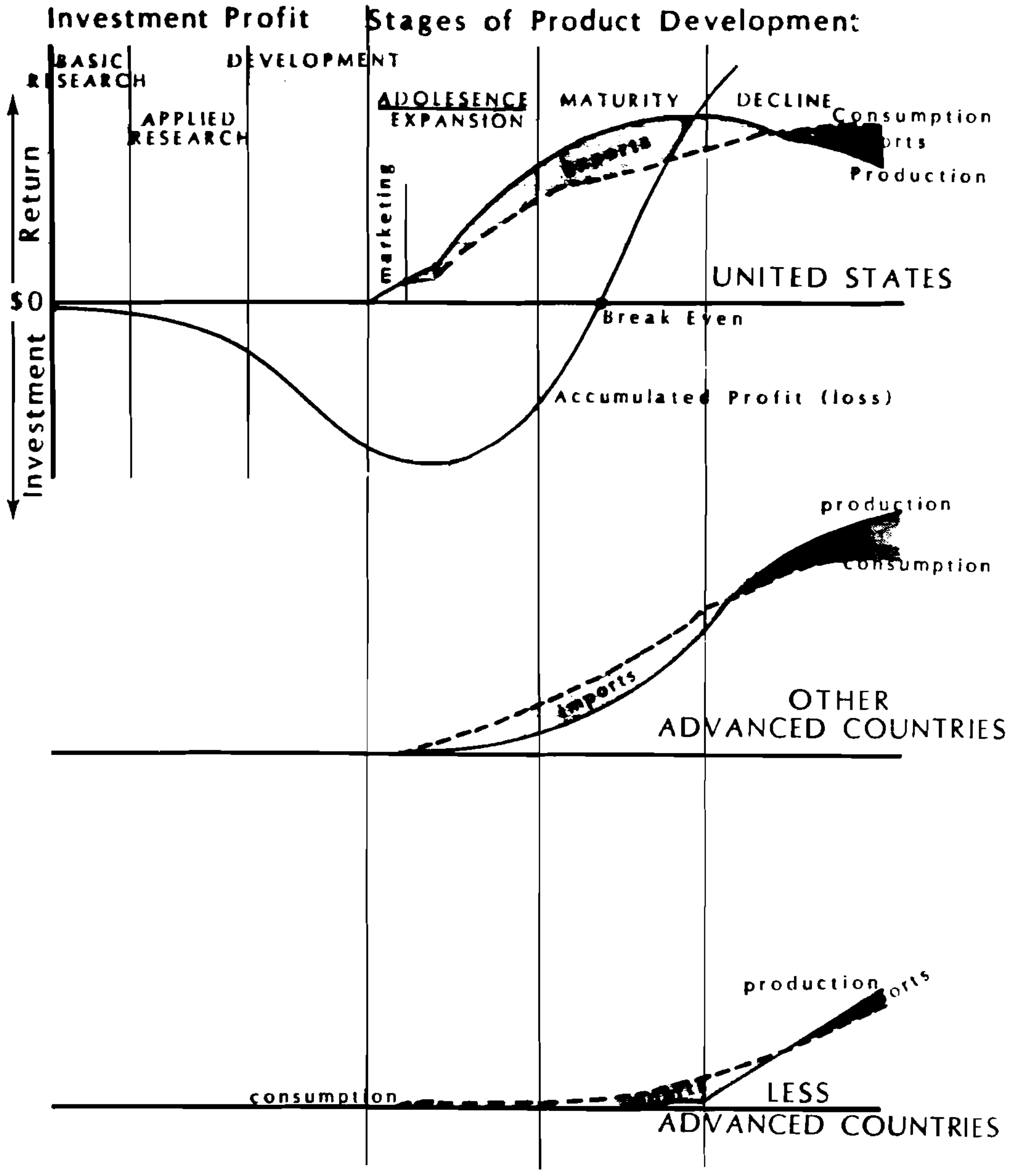
FIGURE 2

Summary of the Modified Life-Cycle Theory (cont'd)

Life Cycle Stage	Industry Structure (Contestability)	Characteristic Competitive Strategy
Conception	NA	NA
Birth	NA	NA
Childhood	Low barriers to entry Many early competitors and imitators	Performance-maximizing Production near markets
Adolescence	Entry rate declines, many mergers and dropouts	Market-share maximizing Emphasis on marketing, distribution and service, Exploitation of scale economies
Maturity	Oligopoly No new entrants, some mergers	Factor cost minimizing Production worldwide, Investment in fastest growing markets
Post-maturity (Senescence)	↓	Disinvestment: sell technology, turnkey plants, management services, etc.

FIGURE 3

The Product Life Cycle



1.2. THE TECHNOLOGY LIFE CYCLE IN THE STEEL INDUSTRY: A FEW SKEPTICAL QUESTIONS

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1. METHODOLOGICAL ISSUES

I have presented some methodological problems with the technology life cycle. The first related to its inability to supply a specific recommendation for management of a firm concerning technological choices. Perhaps the direction of evolution suggested by technology life cycle models supplies a "general time line" describing the probable change of technological and industrial environment. Dr. Razvigorova alluded to the unpredictability of Sofia weather; Henri Poincarre's famous unstable weather equations were capable of predicting that snow is less probable in Sofia in April than in February, but not that we would have snow at the end of April here to keep us indoors at the IIASA workshop. In other words, the general direction of evolution of technology described by the technological life cycle is not sufficiently precise to help a manager make technological choices at any moment of time.

1.1. Unit of Analysis

At this meeting, I have heard people use the technology life cycle on at least three levels: 1) the unit, 2) the industry itself, and 3) the technology. What is the unit of analysis whose life cycle we are talking about? The unit of analysis must have some durability in time (if you want to perform an analysis of a life-cycle) and display some solidarity between its elements.

Personally, I am not convinced these units of analysis fare very well. Perhaps the concept of technical system which has some stability could be taken as a unit of analysis. At this juncture, I would like to come back to something which is dear to this Institute. The concept of system is well elaborated (Lange, 1965; Von Bertelanffy, 1968). The concept has been used in technology by Thomas Hughes and Bertrand Gille, the historians of technology. Technological system is stable at least for a certain time. One can predict that all the parts will move in a similar direction.

But even the concept of technical system has some limitations. A technical system is not an organic system, i.e. the organ does not die with the unit. One can unbundle the technical system and recompose it. People in industry know that basically by reverse engineering one can sometimes do away with the rigidities within a technical system.

Kuznets' suggested very long-term declining returns of technical lines. He suggested "dinosaur effects," i.e. over-specialization and complexity. One of the examples he gave was the pulp and paper industry. He saw it in the 1930's as witnessing declining returns. Yet since the 1970's, it is undergoing a quiet revolution. There is no long-term declining in returns in pulp and paper. Some of the technical systems have been unbundled, and they have done away with the declining returns. Foudrinier has been replaced by twin wire paper-making, chemical pulping by thermo-mechanical pulping, etc. One can also abandon the technical system and replace it by another (Figure 1).

1.2. Discontinuities

The second methodological problem with the technology life cycle is even more damning. In observing the technological behavior of firms, we do not seem to have any predictable smooth functional relationship. In order to have a functional relationship, as Augustin Cournot, one of the first to apply mathematical principles to social sciences in 1838, found, one has to assume continuity. In Cournot's 1838 "demand curve," he specified that he assumed that for every intermediate price of a commodity there is a corresponding quantity in the function. This is not the case with firms' technological behaviors. These latter display discontinuity. In testing the Abernathy-Utterback technology life cycle model on a few longitudinal case histories, I have found marked discontinuities (See Figure 2).

These discontinuities correspond to wrenching organizational changes that a firm has to make in order to move along the general "time line" of technology in the industry (Figure 3). The first implication, however, is that the firm is not obliged to move down the curve; it has a choice, a costly choice. The firm can also choose to keep producing in a batch mode. Although there are pressures to decrease unit price and standardize production, it may choose to target a higher price (and higher margin) segment of the market. The second implication is that different forms of the technology and forms of production coexist as a technology matures. The coexistence is not always peaceful; it encompasses strategic games between firms, but there is coexistence, and one of the things I found on the innovation data bases is that basically there were very few cases of transition that correspond to the Abernathy-Utterback, but very stable forms of organization. The third implications is that a firm can reverse -- and often does -- its course (Figure 4).

1.3. Metaphors and Analogies

Professor Haustein made us aware that in the French edition of the book Capital, by Marx, there was a reference to life cycles in steel technology. But there were a lot of things in his manuscripts that Marx decided not to publish. In general, Marx declined competence when it came to technology. In his two editions of the first volumes of Capital, he deleted a lot of ideas contained in the Grundrisse. One particular intriguing footnote is at the end of the machinery chapter, where he says one should use a Darwinist approach to look at the history of technology. But if one reads the Ethnological Notebooks where he comments on Maine and Morgan, he said that to look at social organizations as organisms is probably not very fruitful. The purpose of my remarks is to instill some skepticism as to this road of research: Marx had few pretensions on the subject.

I will just summarize briefly some of the pitfalls. Metaphors like the life cycle are useful because we do not have a theory of technologies. They are very useful to communicate things -- vividly. If I say, "I fell in love" or "I built a relationship," you immediately understand what I am talking about.

Analogies are also good heuristic devices. In the absence of theory, we have a set of observations in some kind of disorder which is troublesome and creates anxieties. So we draw an analogy from a number of signs and make sense out of them by putting them in a certain order with the help of analogy.

A more general methodological problem with the technology life cycle is related to mastering analogies. Analogies are powerful heuristic devices to order observations in the absence of robust theory of technological change. But unless one can find isomorphism (or homeomorphism), the analogies have to be dropped. At the International institute of Applied Systems Analysis, you are intellectually well situated to benefit from Ludwig von Bertelanffy's advice, as he is, with Oskar Lange, one of the founders of systems theory. In his treatise on general systems theory (1968), he specified how to use analogies. If you can prove that there is an isomorphism or homeomorphism between the different causal links, then you can master your analogy. But even once you have done that, it is not because you have mastered your analogy that you can infer a similar set of causes and origins. This is one of the useful criticisms that Stephen J. Gould has made to E. O. Wilson's socio-biology. You cannot infer similar causal relationships from isomorphism. So even if we did find an analogy between technology and biological life cycles, we would still have to find rationale of causation for the phenomenon.

I have used the Abernathy-Utterback model technology life cycle for quite some time until a point where I decided to drop it because I felt that one could not satisfy the above conditions. My tests were based on an analysis of the Science Policy Research Unit (SPRU) data base and my Canadian data base across all industries from 1945 to the late 1970's. I found no empirical corroboration of the Abernathy-Utterback model. The model was not totally satisfactory, and so I tried to build an alternative.

Today let me suggest some relevant questions about the steel industry relating to the technology life cycle. I will focus on two questions which I am curious about. These questions are those of someone who knows very little about the iron and steel industry besides what I have learnt from the specialists in this room.

The first aspect concerns some of the diffusion curves about the basic oxygen technology that we have been presented in the workshop. I would like to suggest maybe a slightly different interpretation to explain the same facts. The second point focuses on the following question: why has steel-making been stuck in a batch mode for so long? Except for continuous casting, the production of iron and steel is still basically in a batch mode.

2. DIFFUSION CURVES, STEP INCREASES AND TECHNOLOGICAL THRESHOLDS

One of the advantages of not knowing anything about an industry is that you are encouraged to learn from those who do and allowed to pilfer from you colleagues. I have proceeded to do this by taking data from Prof. Maly's very interesting paper. Maly supplies us with observations about the diffusion of the basic oxygen process in steel-making (Table 1 and Figure 5a). How do we make sense out of these observations? I think there are a number of possible ways. As mathematically-trained social scientists, we are a bit arithmo-morphic and calculus-morphic (Georgescu-Roegen, 1971): we try to use the least squares to fit all our data points to some continuous function, and we adjust this with an "r" or an "s" curve of some type. In using these curves, we are making all kinds of assumptions as to the causality which would generate such a distribution.

I was struck in Maly's data that in 1957 and 1958, and again in 1963 and 1966, there was a big jump in the number of adopters. The best fit of the data points would be to a staircase with slanted steps (Figure 5b). Perhaps it is not as elegant mathematically, but it is a better fit. And it also makes more sense. In terms of economic rationale, it makes much more sense. Thresholds of performance are reached through the accumulation of improvements. When you adopt, you adapt, learn, modify and fit the new technology. Because learning is a cumulative process, all past improvements eventually lead to qualitative step increase. A threshold is a very convenient notion to pass from a quantitative change to a quality change. The new technological threshold will open up opportunities for adoption of the technology to a whole new set of actors.

The notion of threshold has been used by development economist, René Passet, to look at why there were Giffen goods in less developed countries. In a poor country, the price goes up for wheat and people rush to buy more wheat. It is the contrary to demand theory, and in a developed nation the reverse relationship is true. Passet suggests that a development threshold must be reached before Giffen goods disappear and the standard "law of demand" becomes operative.

Paul David's work on the mechanization of reaping introduced the concept of threshold to diffusion research. New levels of performance of a technology will make it available to firms with a different scale of production. I think it is a very useful concept.

It is not hard to find some evidence of such thresholds of performance in oxygen steel-making from Prof. Lynn's 1982 account. These two adoption spurts in 1957-58 and again in 1963-66, may be due to such threshold improvements. The basic oxygen process was known for a long time, but what made it possible was the recent availability of oxygen production technology. Initially, there were tremendous pollution problems with the basic oxygen process in Austria. Until 1954, all the vessels had a maximum size of 35 tons. When the refractory problem was solved, a new scale of vessel was made possible. By injecting the oxygen not only by the top, but to the bottom and the side, another step increase in performance enabled a number of other adopters to access that technology. This might explain why, by 1961-62, some of the major improvements of the technology had been made and cumulatively a new threshold level had been reached which made the technology available for a number of new users, resulting with a lag in the spurt of adoption.

What I am suggesting here is nothing new. Another steel specialist, Bela Gold, recommended (1980) in an article on shortcomings of innovation diffusion research that we should accept the idea that innovation never stays the same. The innovation is new in each adoption. It mutates constantly. We cannot look at innovation as a commodity which has fixed characteristics. The learning process is constantly changing the technology.

In this sense, we can use a biological metaphor. In an evolutionary approach, we think in terms of irreversible learning processes and cumulative learning (Usher), but we do not have to extend the metaphor to a tighter organic analogy with a life cycle. We have to drop the assumption that innovation stays identical to itself during the diffusion process. We explain some of the step increases in diffusion by the major thresholds improvements which are reached. Thus we would satisfy one of

Donald Schon's (1967) old suggestions that one consider innovations as a process of incessant change.

Consider technological know-how as a stock which increases. Consider the stock of innovations in use as indication of technological know-how. Levels of adoptions in an industry are related to this stock level.

Technical development is an irreversible process registered in ordinal time -- not cardinal time (one of the distinctions between the two dimensions is that, in ordinal time, you cannot subtract, you cannot go back). One can use the notion of thresholds as Paul David (1975) does, and it should explain the new spurts of adoption. I think this approach would be less mechanistic and less deterministic.

3. WHY IS STEEL-MAKING STILL IN BATCH MODE?

My second query about the steel industry is: why does steelmaking seem to be stuck in a batch mode? Some of the literature I have read seems to say that there are technical reasons for this. Perhaps. I would think that there are also some market demand reasons for this, i.e. some purely economic reasons. Let me just recapitulate the problem: the crucible was a batch system; the Bessemer is a batch process; Thomas is a batch process; the open hearth is a larger patch process; the basic oxygen process is still a batch process. With some electrolytic vacuum processes, there may be possibilities of a continuous line process. Continuous casting of ingots and lamination trains are a line process which is exerting up-stream pressure towards a more continuous production process. But all the main steel-making processes are batch.

There are batches of various sizes in terms of tonnage and length in terms of time, in terms of minutes or hours for each of them. What is surprising is that there is not any set pre-determined trajectory of evolution. With the open hearth, we get larger quantities, but longer batch time, than in Thomas processes. In terms of economics of speed and economics of scale, it does not make that much intuitive economic sense. The importance of economics of scope is perhaps what explains it. Firms try to remain flexible and retain a capacity to produce a variety of different products. If economics of scale were the sole preoccupation, one would expect a transition from large batches to line production, but this does not happen.

The precondition for scale is standardized homogeneous goods. Where is there a sufficient demand for standardized goods in steel? The demand for rails, nails, armor plate, roofing sheet, barbed wire, ingots, casts will lead toward line processes because these standardized goods would have fairly large demand. Mass standardized demand is where you might expect line processes. We have seen some of that in end-products. But is there a stable homogeneous, standardized demand in the first stage of steel-making which actually justifies locking oneself into a line process, even if it is a technical possibility to do it?

My hunch is that scope economies are more important in the first segment of steel-making, where firms are supplying a semi-finished material to changing specifications. That would explain why one keeps a batch organization which is relatively more flexible. Economies of scope are realized by sharing input cost, the know-how, and the competence across a variety of products. Being able to mix different qualities of inputs in different ways depending on the client's requirements for different qualities of steel is essential for firms. You do not need always the same characteristics of the steel output. The user might need sometimes higher quality, sometimes less, depending on its end use. Firms want to reduce the constraints and have some flexibility to address various market segments as demand shifts.

There is a trade-off between economics of scope and economics of scale. Beyond a certain scale, you are going to have to reduce the scope of your products. Vice-versa, if you stretch the scope and variety of your products, you are going to have to keep your scale down. My graphics are still in a suitcase which is somewhere between Madrid, Rome and Sofia, so I have had to reconstitute them very quickly. It is a bit complicated, but I think you will understand (Figure 6). Baumol, Panzar, and Willig have a graphic device to compare joint and separate costs: trans ray convexity. Let us suppose two products: Product 1 and Product 2. Each have geometrical scale for the amount produced by unit of time. We are comparing individual costs, unit costs, on the vertical axis of each product individually to the joint unit costs of producing them jointly. It does not matter really what individual cost curves are for the purpose of this comparison as long as they are the same for the two products. We are only comparing individual costs with joint costs. Here we chose arbitrarily monotonically increasing returns to scale.

My proposition is the following: there is a limit (which is different according to each industry) where you go from positive economics of scope to negative dis-economies of scope. Economies of scope would be expressed by the equation (1) that the joint cost c_{p1}, c_{p2}, and dis-economies by the reverse (equation 2).

Economies of Scope (1)

$$c_{P_1P_2} < c_{P_1} + c_{P_2}$$

Dis-economies of Scope (2)

$$c_{p_1 p_2} > c_{p_1} + c_{p_2}$$

There is a scale limit where you lose your economies of scope (Figure 6) if you stretch the technical distance between your products (the angle). If you are further away from your technical field, then you risk -- there is an indeterminancy and uncertainty, which may yield punishment -- to find yourself into dis-economies of scope (Figure 7). If one plots the technical distance of a firm from its established technical experience, there is a limit beyond which you do not know what you are going to get: positive economics of scope or negative diseconomies of scope. If you are close, you have a greater probability of economics of scope. For instance, producing two very close types of steel may yield scope economies in the same furnace. But if the firm goes further from its technical field of competence, there will eventually come a point where it will not know whether it still is going to have economics of scope by joint production. Then the probability of having economies of scope is non-zero, but it is indeterminate.

René Thom called this a catastrophe in the sense that it is a functional discontinuity: you do not know which way it is going to go. Here functional analysis breaks down.

So to sum it up, economics of scope at technical proximity and diseconomies of scope at technical distance induces firms to acquire flexibility in order to share their input cost. The batch process is the ideal flexible organization to reap economies of scope.

In as much as the demand for steel grade is not homogenous, staying in business requires to design a furnace to adapt flexibly to future unknown shifts in demand. Perhaps -- just an hypothesis for the steel specialists -- this explains the economic inducements to produce steel in batch mode.

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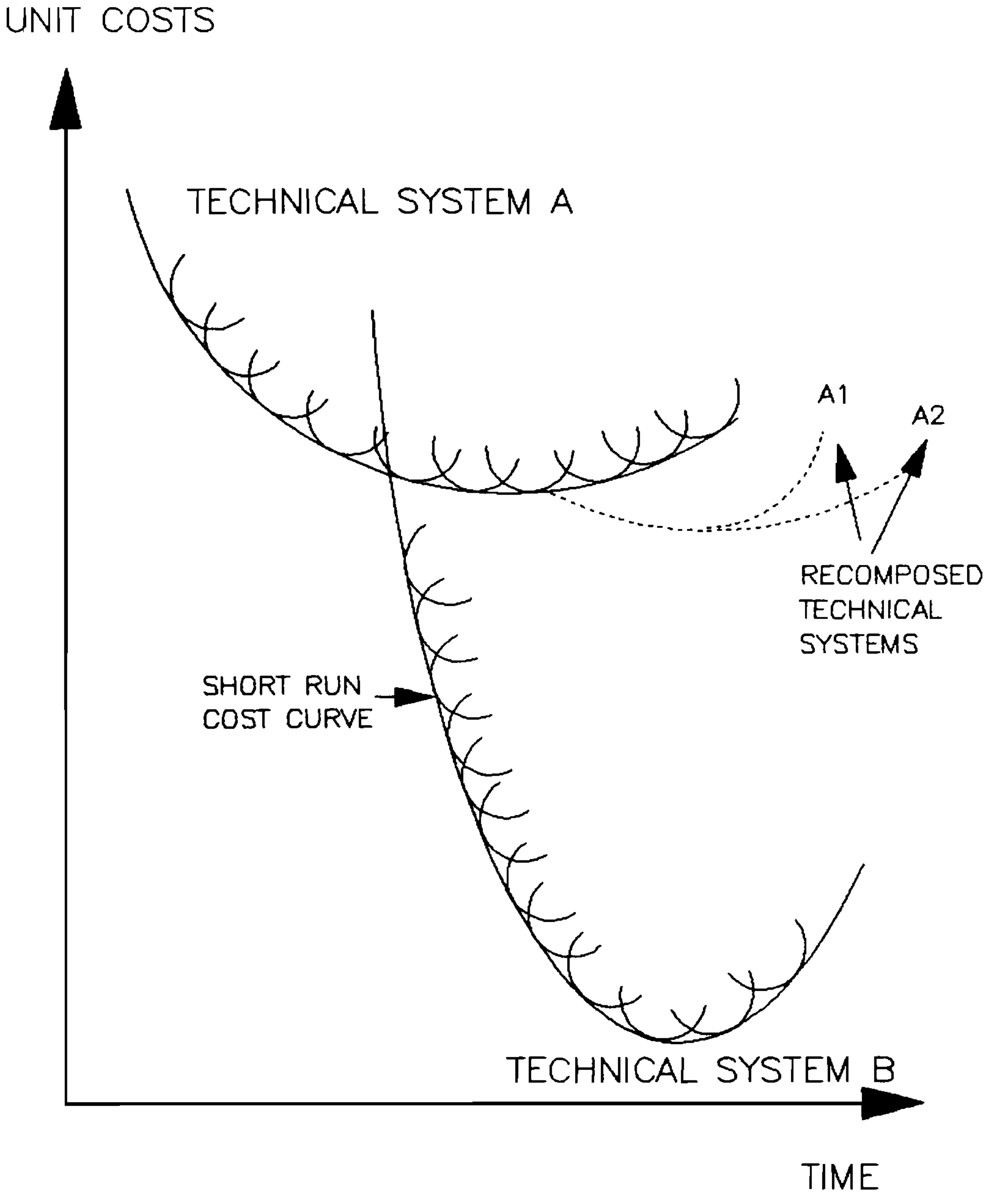


FIGURE 1: Very Long-run Average Cost Curves, Technical Systems, & Declining Returns

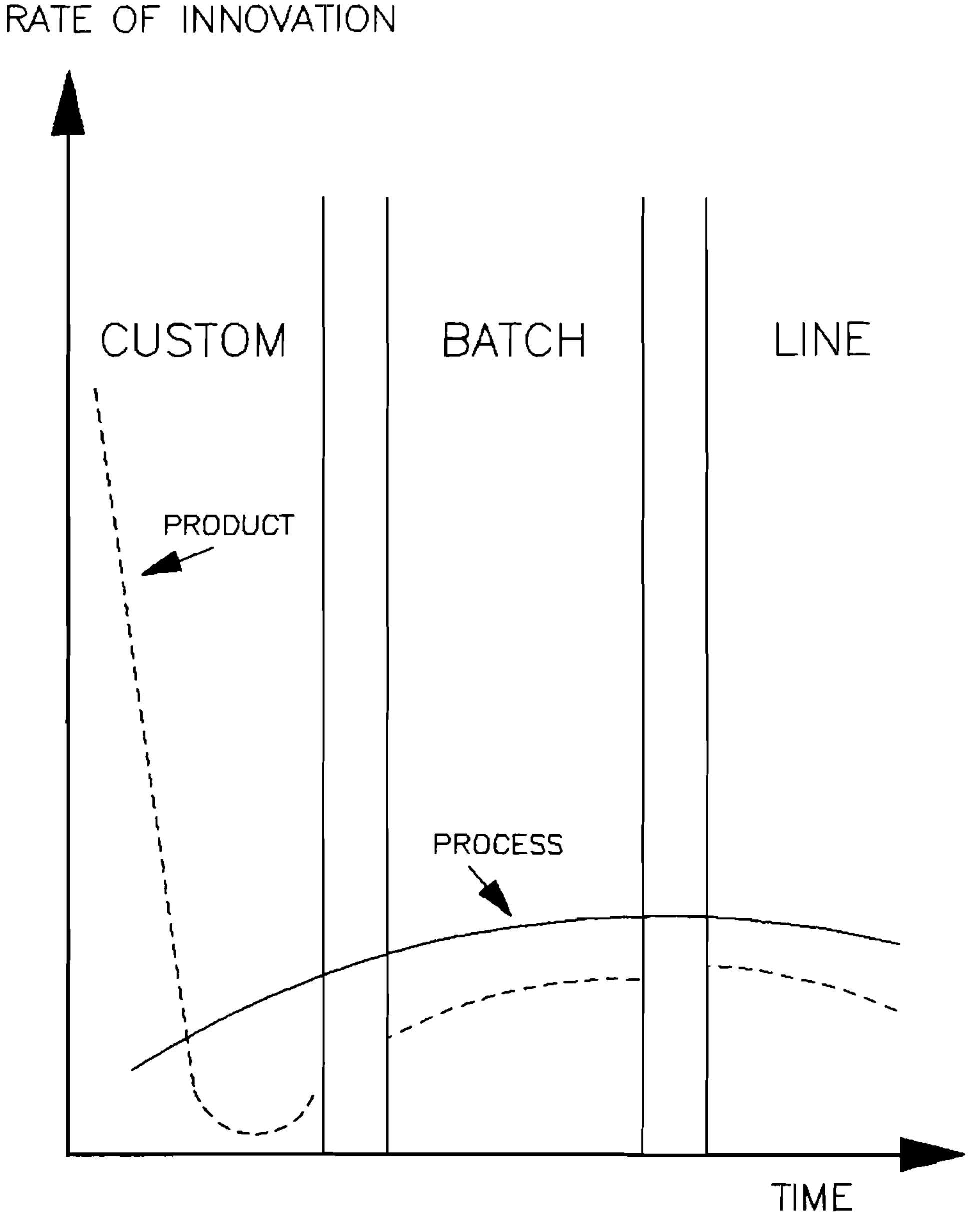


FIGURE 2: Discontinuities in a Firm's Evolution on the "Technology Life Cycle"

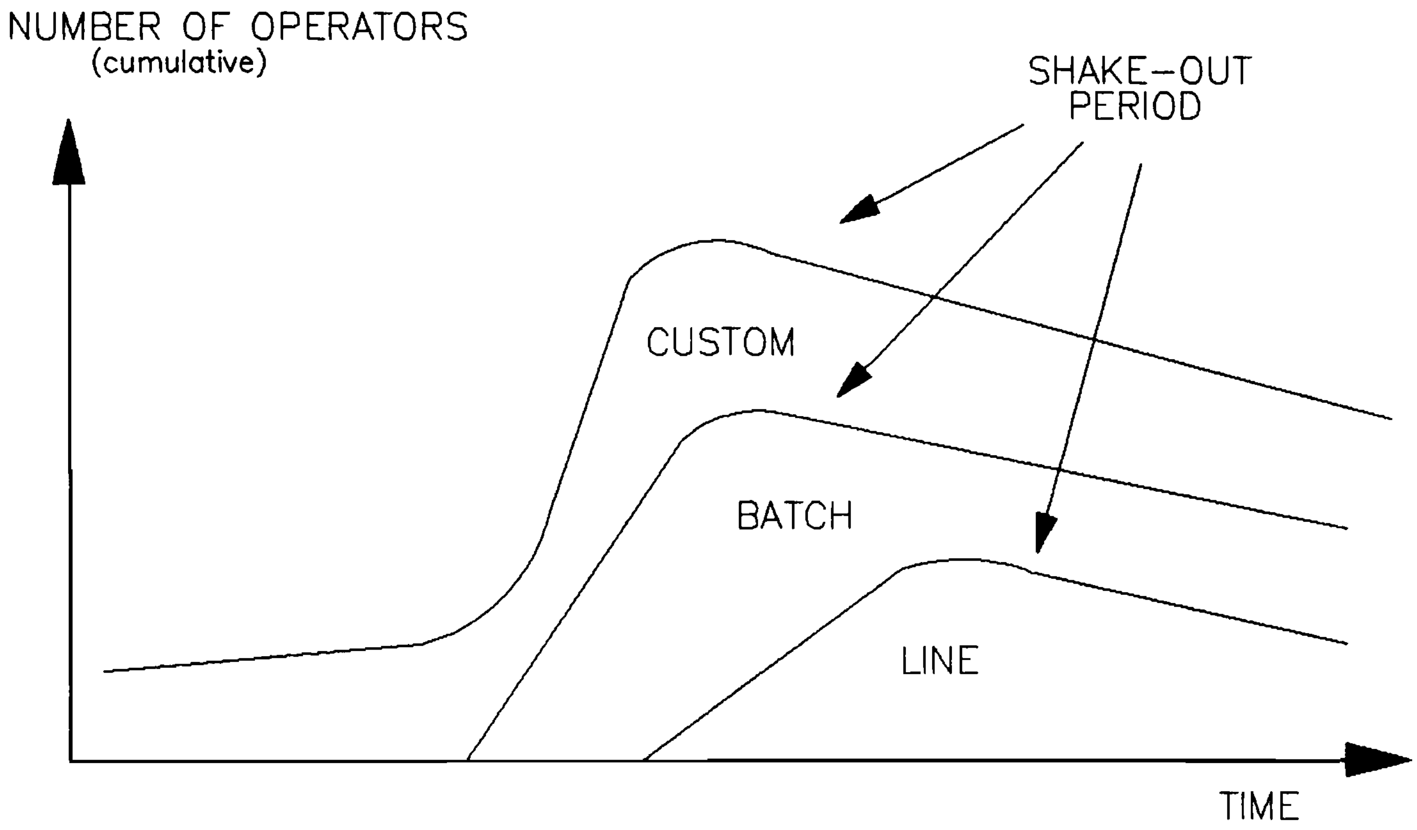


FIGURE 3: Numbers of Operators in Different Production Modes within a Set Product Technology over Time

From: De Bresson & Lampel, 1985

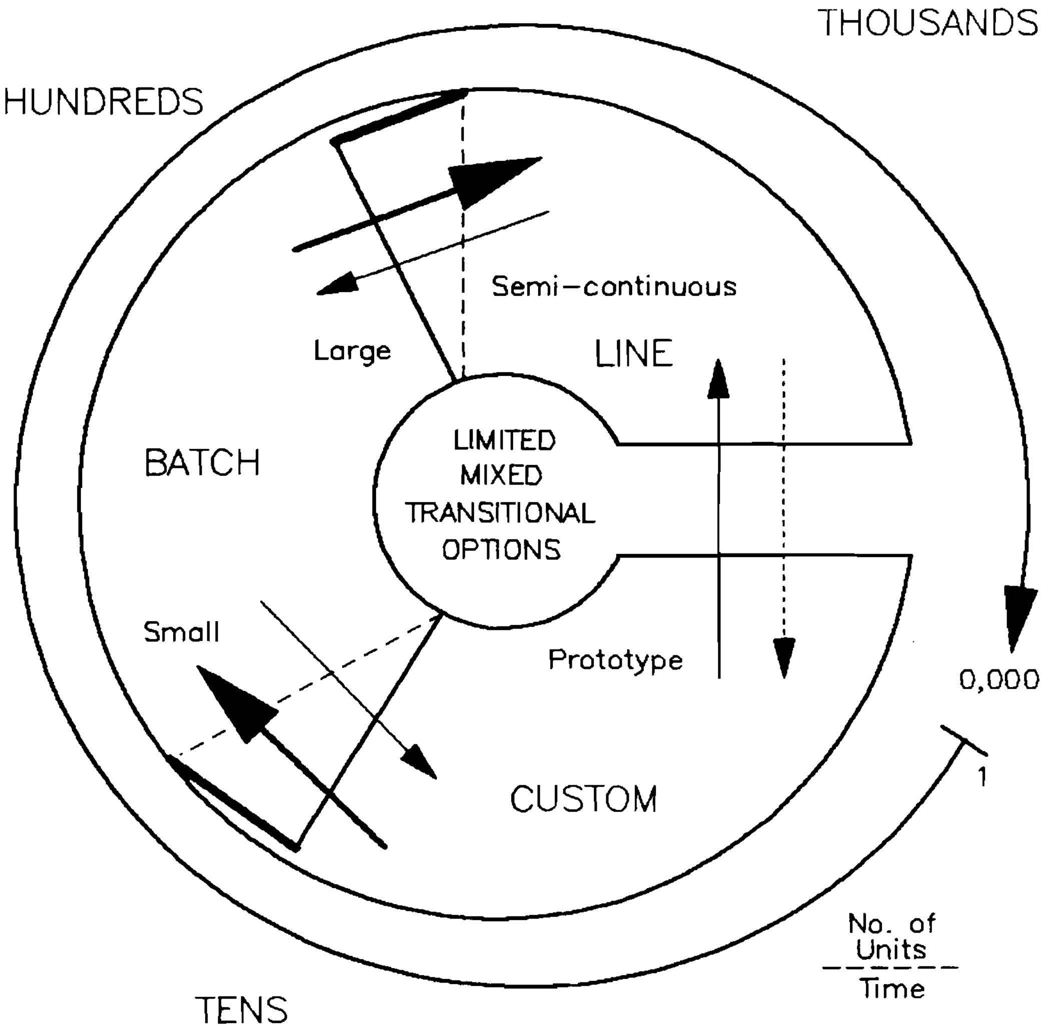


FIGURE 4: The Three Basic Production Modes

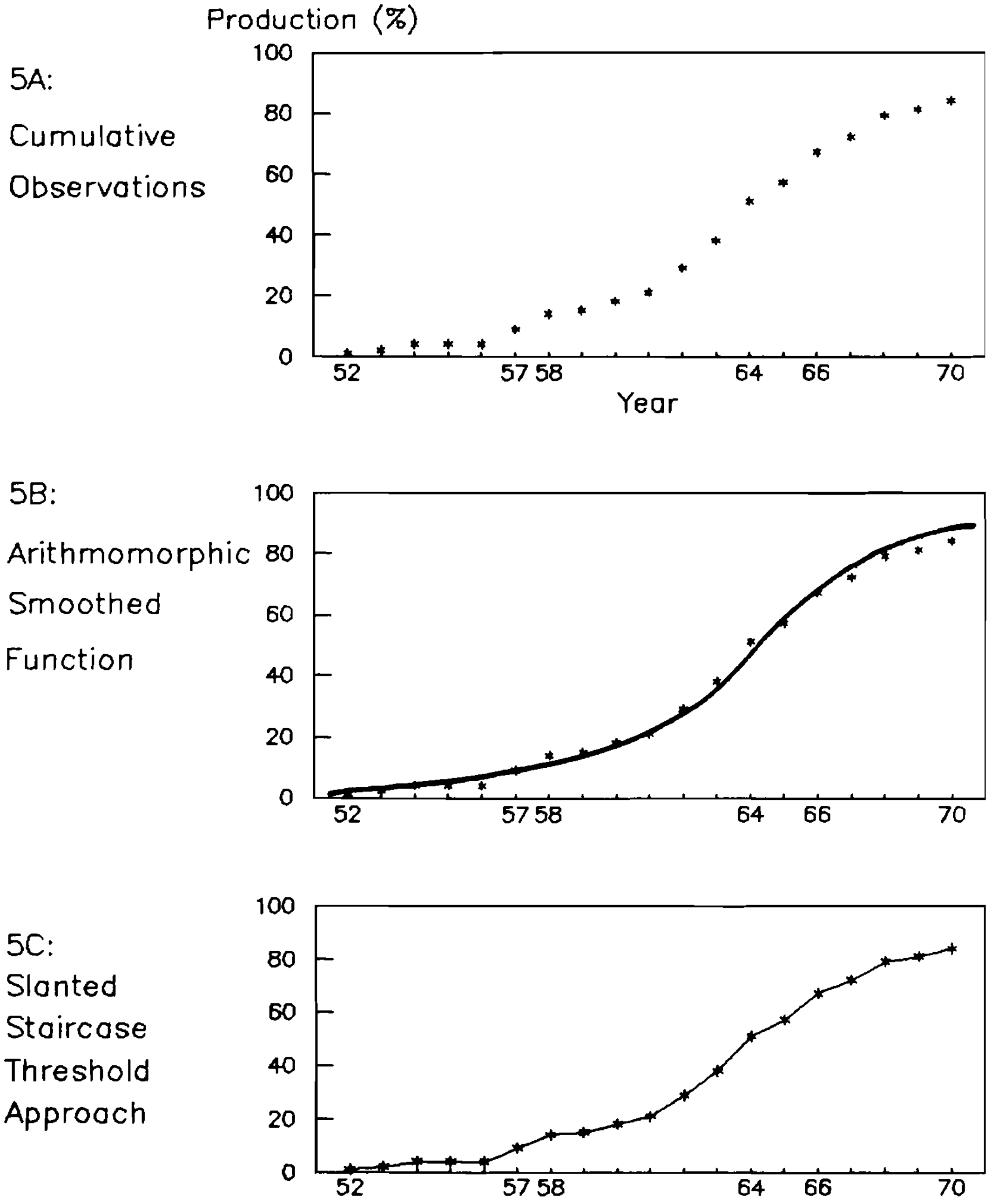
Each triangle represents a distinct production mode. The two lines separating each denote the discontinuous organizational change necessary for a transition from one to the other. Arrows denote the possible direction of change. A circular axis around them plots geometrically the order of magnitude in the number of units produced over time which are compatible with each mode.

From: De Bresson & Lampel, 1985

TABLE 1: ADOPTION CHRONICLE

DATE	NUMBER OF FIRMS ADOPTING	CUMULATIVE NUMBER HAVING ADOPTED
1952	1	1
1953	1	2
1954	2	4
1955	0	4
1956	0	4
1957	5	9
1958	5	14
1959	1	15
1960	3	18
1961	3	21
1962	8	29
1963	9	38
1964	13	51
1965	6	57
1966	10	67
1967	5	72
1968	7	79
1969	2	81
1970	3	84

From: Lynn, 1982; Moly, 1987



5A: Cumulative Observations

5B: Arithmomorphic Smoothed Function

5C: Slanted Staircase Threshold Approach

FIGURE 5: INNOVATION DIFFUSION OBSERVATIONS

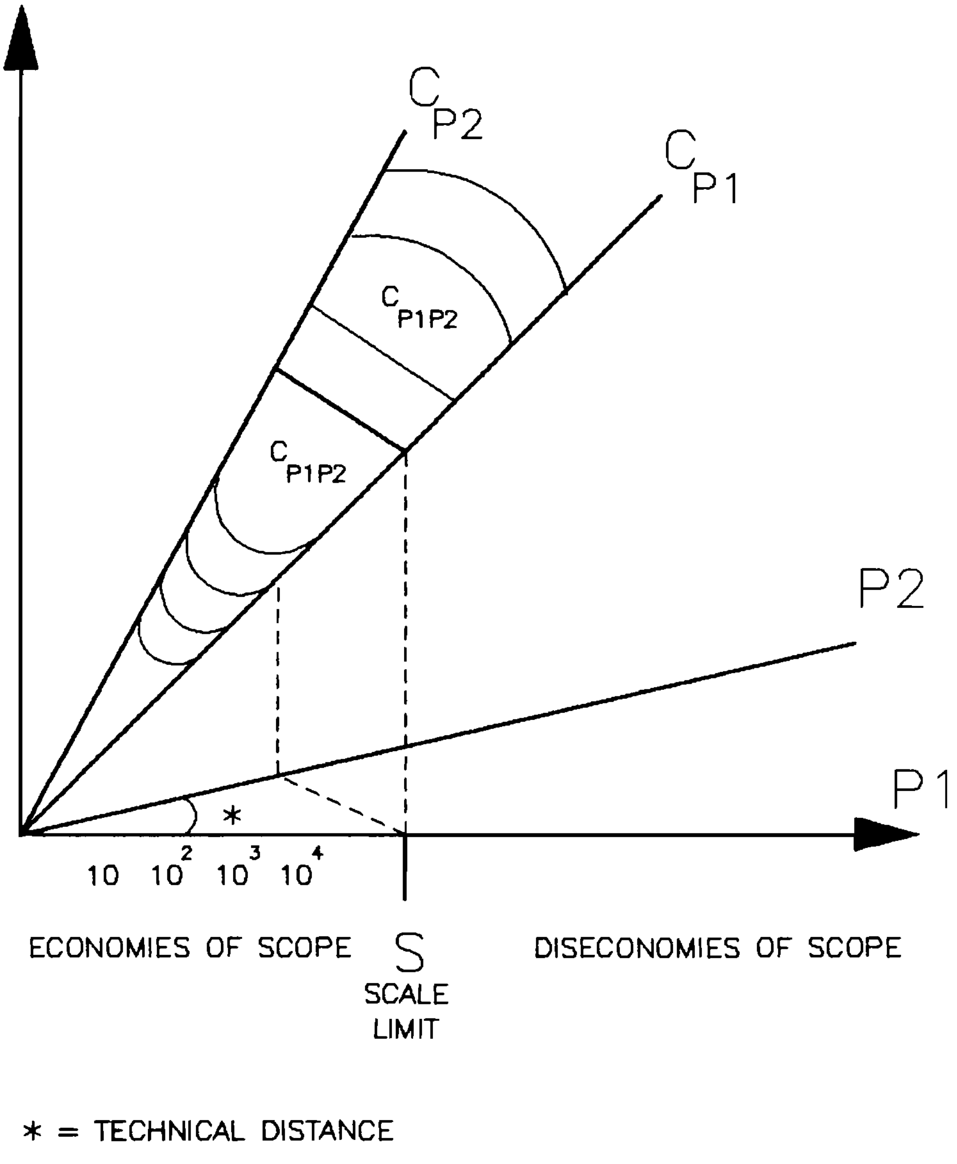


FIGURE 6: Trade–offs Between Scale & Scope Economies

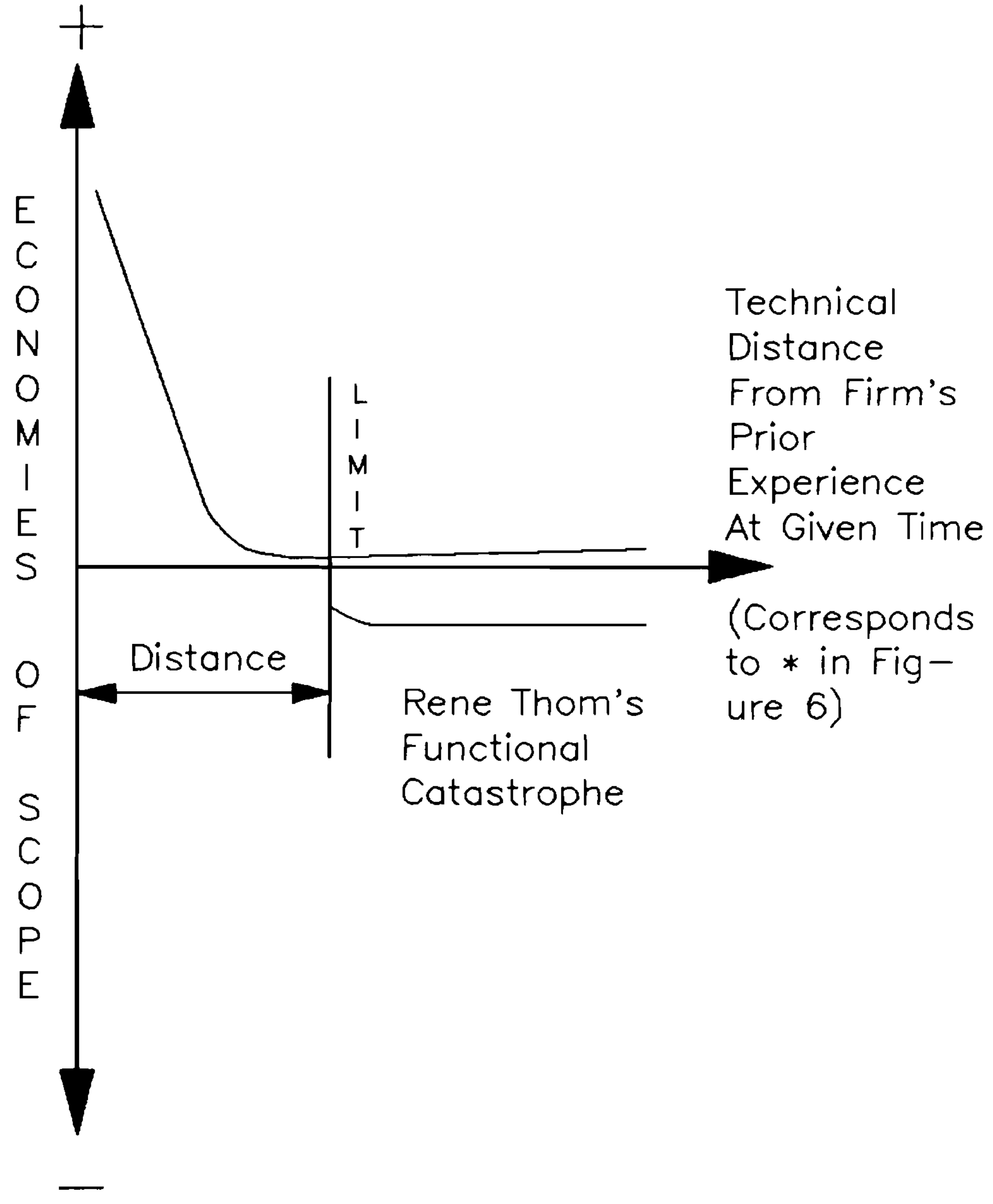


FIGURE 7: Economies of Scope & Technical Distance

1.3. DIFFUSION RATES OF STEEL PRODUCTION TECHNOLOGIES BUSINESS CYCLE ANALYSIS

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SUMMARY

A new approach to technological life-cycle analysis is proposed here. It is based on the use of business cycle analysis to suggest statistical means of determining where the embryonic (childhood) phase of the life cycle ends and the expansion (adolescent) phase begins.

The method appears to be applicable mainly to the introduction of new process technologies over a fairly long period. A test of the proposed method for two cases, i.e. the adoption of the open hearth and of electrical furnaces in steel production, is discussed in this paper.

1. INTRODUCTION

A well-known approach to the diffusion processes investigation is based on the following scheme: there are four phases in a technology life cycle: (1) embryonic or childhood (t1 - t2), (2) expansion or adolescence (t2 - t4), (3) saturation or maturity (t4 - t5), and (4) declining or senescence (t5 -..)[1]. These phases are illustrated schematically in Figure 1.

The new technologies diffusion, measured by share changes, can be described by S-shaped curves [4, 8, 9, 14, 17]. These curves usually represent the first three stages of a technological life cycle: embryonic stage, expansion, and maturity. The stage of a declining technology share completely depends on the dynamics of the next, evolving technology, which is at its embryonic or expansion stage. The penetration will be more complicated if a third technology appears on the scene before the first one is completely replaced. This is why the real trajectories never go along with a mathematical curve. The divergences depend also on the economic environment, parallel inventions, and the business cycle situation.

It is potentially important for managers or other decision-makers to determine exactly when the diffusion process will pass

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[1] In [12] the fifth phase (revival before decline) is detached.

from the embryonic to the expansion phase, because this is also the transition from a period of rapid technology or product evolution to a period of increasing standardization and exploitation of the scale effect in production. Potential adopters also have a much lower risk once the embryonic phase has passed.

In short, there are differences in driving forces, economic conditions, and dynamic features of the diffusion process in these two phases. For instance, a new technology in the embryonic phase might not yield profits to the innovator in the embryonic phase. It demands very high-risk investments and a stream of parallel inventions or improvements. The conventional technology is regarded to be more reliable and profitable (to users) in this period. The new technology has to be adapted to many new fields of applications and penetrate new sub-markets. This is why a new embryonic technology is sometimes limited at first to big companies with very strong financial positions, good marketing organizations and R&D experience. This is an advantage associated with scale (scale monopoly).

At the second stage (expansion) the new technology becomes more reliable compared with the conventional technology. Also, the number of vendors is growing moderately or stabilizes (as new entrants are balanced by consolidations) and barriers to entry rise. Thus profitability for the major firms increases. The diffusion growth rate depends mainly on economic parameters: relative profitability, relative cost (differentiated into its main elements - labor, capital, material, and energy), investment capital availability, fixed-capital vintage structure, etc.

To summarize, there are quite different theoretical approaches as well as analytical methods applicable to technological life-cycle investigations in these two phases. Thus the determination of the boundary point t1 is quite important for purposes of refining the analysis of life cycles, as well as for providing guidelines for managers.

2. EXISTING APPROACHES

Life-cycle analyses have been traditionally based on investigations of product life cycles, especially for consumer durables.[2] When a new product is introduced, the number of early producers (measure of the degree of monopoly) is very important. But for a new process technology the number of early users or acceptors is more important than the number of producers. A competitive end-user market situation determines the life-cycle dynamics in a product case. However, for new process technologies

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[2] There are also investigations of a corporate life cycle, see, for instance [12].

the users are themselves producers who are strongly affected by the business cycle. Most past research of the technology life cycle has dealt with the problem of interaction between old and new technologies. For statistical definitions of the different phases or stages of diffusion processes two main approaches have usually been used. One can demonstrate them by means of two concrete examples.

The first approach to dividing the life cycle into several phases is based on the scale of production. For example [2], production is divided into three types or modes: custom, batch and continuous line. The "custom" mode is characterized by tens of units produced a year in a "job shop". The "batch" mode covers a range of hundreds of units, and the "line" mode covers a range of thousands of units a year.

It is convenient (and probably not misleading) to associate the "custom" mode of production with the embryonic phase, the "batch" mode with the expansion phase and the "line" mode with the mature phase (see Table 1).

For the case of the history of Bombardier's snowmobile de Bresson and Lampel [2] determined the length of the three phases as 11, 22 and more than 20 years, respectively.

However, this approach seems to be most applicable for a consumer product where the life cycle and the life-cycle evolution was primarily determined by the market environment. The snowmobile did not substitute for any predecessor. This is why the absolute numbers are applicable instead of penetration or diffusion rates.

The absolute values for the definition of boundaries between different stages cannot be universal, because they are dependent on a product's specific features (especially on its complexity and cost), market size, etc. Some products can become mature without even reaching the "line" mode of production. Large trucks, aircraft, turbines are examples in point.

Another approach to the determination of the phases based on the number of producers has been suggested by Gort and Klepper [3]. They divided the life cycle into five stages, based on the number of vendors. The first phase begins with the commercial introduction of a new product by its first producer. The end of this stage is reached when the total number of producers is no more than three.

The second stage in this scheme is the period of sharp increase in the number of producers. Stage III is the period in which the number of entrants is roughly balanced by the number of existing firms, and net entry equals zero. The fourth stage starts with the net entry becoming negative, and the fifth one is reached with an approximately zero net entry again, but at a lower level.

The authors investigated the specific features of the stages by using information for 46 different product innovations. These included consumer goods (like electric shavers and blankets, shampoo, zippers, etc.), chemical inventions (like DDT, styrene, saccharin, nylon) and a lot of high-tech examples (computers, lasers, guided missiles, transistors, nuclear reactors, etc.). The aggregated results are shown in Table 2.

The main distinction of this approach from the first one is that the former is predeterminantly based on the production side. But the shortcoming of the Gort-Klepper approach is that the number of producers does not reflect either the volume or mode of production, or (more important) the share of the new product in relation to the competing products.[3]

Neither of the above approaches is applicable to the case of a new process technology. As noted previously, the diffusion of a technology among a number of acceptors or users vis á vis conventional process technologies is the critical measure.

That is why we are going to propose an alternative method of differentiation of technological life-cycle phases, based on analysis of relative shares of new process technologies over a succession of business cycles. The steel production case has been chosen as a basis for illustration of the method due to its "attractive" features:

- long-term statistical time-series are available;
- the total production, as well as the shares of different technologies are measured in physical values (tons) of the homogeneous product (steel).

3. THE CASE OF STEEL PRODUCTION

The traditional approaches to the technological life-cycle analysis are based on the use of long-term statistical time-series of the new technology diffusion or penetration rate. They are usually smoothed or interpolated to reveal the main parameters of S-shaped curves (i.e. logistic curves) and do not reflect the cyclical fluctuations, which are usually regarded as "noise" [10, 11, 13, 14, 20].

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[3] The example of PC's shows that the new market was created by a number of small new entrants, but the dominating firm in this field -- IBM -- was merely waiting for its time to come. In fact, the entry of IBM probably defined the end of the embryonic phase in that case.

However, when we investigated the substitution of major process technologies over long periods of time, covering several business cycles, we found an interesting correlation between changes in the shares of "new" versus "old" technologies with respect to their maturity during periods of recession. These results are shown in Table 3 for the steel case in the USA.

Putting it another way, the new technology's behavior in recession periods depends on its share of total production. When the share is below 9-10% of total production, the value of the share tends to decrease during recession periods. On the other hand, when the new technology's share increases from the 9-10% level up to the end of the saturation phase (point t5) its share tends to rise during recessions, especially in the expansion phase t2 - t4. And after t5 (in the declining phase) the technology's share decreases sharply during recessions.

Based on this analysis, one is led to postulate that the open-hearth steel technology passed out of the embryonic phase in 1887. The expansion phase lasted from 1887 up to 1940, the saturation phase from 1940 up to 1957, and the declining phase began in 1958.

We can observe comparable results for the electric-furnace technology in steel-making. In this case the embryonic phase lasted from 1909 up to 1957, while the expansion phase began in 1958 and has continued to the present. There were only 3 exceptions to the rule (1931, 1932, 1975) when the share of the embryonic technology did not decrease in the first two cases and the share of the expanding technology decreased in the last one. But the deviations from the rule were very small.

Unfortunately, we could not get the same results for the embryonic phase of the basic-oxygen furnace (BOF) technology because it grew too fast and passed out of this phase between two widely-spaced recessions (1958 and 1967). But after 1964, when the share of the BOF technology reached 12%, it behaved like an expanding technology.

During the 60 years of the decline in the Bessemer process share, 50% of the reduction took place during 24 recession years. In only three years (1893, 1896, 1908) the Bessemer process share dropped by 18 percent points. The same situation is observed in the open-hearth declining phase where 1/3 of the total reduction (from 90% in 1957 down to 7% in 1983) took place during 4 recession years: 1967, 1970-71, and 1975.

The growth of electric-furnace steel-making during its embryonic phase was interrupted by decreases in recession years. The total growth was from 0 in 1909 up to 9% in 1959 and at the same time there was a 3 percent point reduction of its share during 13 recession years.

In order to confirm these results we tried to check the situation in British steel-making, but we could not get the same results for all recession periods because of the high instability in steel production in Great Britain [1, 3]. This is why we can present only the aggregated data.

During the expansion phase the share of the open-hearth technology increased during 12 recession years and decreased slightly during only two years (1924 and 1925). In the embryonic phase of the electric-furnace technology (from 1914 to 1963 when it reached 10%) there were two stagnation periods in steel production: 1918-1931 and 1940-1945. The share of this embryonic technology decreased from 1.3% in 1917 to 1.1 in 1931 in the first period and from 4.4% to 4.1 in the second one. But in the expansion phase the share of the electric-furnace technology increased from 16% to 32% when the total steel production reduced from 27 million tons (in 1970) to 15 million tons (in 1980). In the expansion phase (reaching the 9% level in 1961) the share of BOF increased up to 68% in 1980 in spite of the stagnation in steel production.

The main proposal we can draw from this analysis of the steel case is the determination of the boundary between the embryonic phase and the expansion phase concerning the cyclical behavior of the new technology's share. In the case of steel production the criterion level of the share (Y_2 in Figure 1) might be defined as 9-10% of the total production.

Naturally, there are exceptions to the observed regularities. For example, as was shown in [21], military-oriented industries were under non-economic pressure and during cyclical recessions new technologies' shares sometimes went up in these industries.

Researching the situation in other industries, we also found several cases which showed tendencies similar to the ones demonstrated for steel production [19]. For example, Piggyback Train Service as a kind of new technology in transport [11] and NC-machines and welding robots as elements of computer-integrated manufacturing behaved like embryonic technologies in the middle of the 1970's and at the beginning of the 1980's, respectively. Their shares moved down in recession periods, and grew in economic growth situations.

These effects can be explained from the economic point of view. In the embryonic phase the competitive position of a new technology is very low, the rate of risk in investments is too high. This is why firms prefer, during recessions, to rely on conventional technologies and the share of a new technology declines.

On the other hand, in the expansion phase the competitive position of a new technology becomes stronger, the firms gain the scale effect by using the new technology, and the rate of decrease in production, when the conventional technology is used, is higher than in the case of the new technology during recessions. Moreover, the share of the decrease rate of the conventional technology is higher in recession periods than in growth periods.

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Table 1. Bombardier's snowmobile making operations [2]

Modes	Environment Technological	Market	Production & Development	Capital & Equipment
Custom: 1926-1936	Use of Model "T" components & adaptation to snowmobiles	Hotel managers, doctors, veterinarians, ambulances	Highly skilled machinics	General purpose equipment
Batch: 1937-1959	application of sprocket-thread systems	Defence, petroleum, forest management, municipalities	Many mechamics & seasonal labor for hand assembly	Bombardier learns machine making some specialized vulcanizer for tread low and variable utilization
Line: 1965-present	Ski-Doo simple, reliable performant & dominant design distribution & servicing network	Unit price as low as 6000 $; assembly line produced 100,000/year 1980: captured 30% of North American market	Routinized automative assembly line with overhead serpentine	1967-1972 fixed capital investment phase specialized machinery

Table 2. Gort and Klepper's estimates for 5-stages life cycles

Average estimates/stages	I	II	III	IV	V
Number of years in each stage	14.4	9.7	7.5	5.4	-
Annual net entry rates	0.5	5.7	0.1	-4.8	-0.5
Percentage change in output*	57.0	35.0	12.0	8.0	1.0
Percentage change in real prices**	-14.0	-13.0	-7.0	-9.0	-5.0

*for 25 products
**for 23 products

Table 3. Changes in technology shares (percent points) versus changes in steel production (%) in the USA

Years of decrease in production	Changes in steel production	Changes in Shares of Technologies, p.p. Open hearth	Electr.
1883-84	-10.7	-0.7	-
A--	------------------	------------------	---------A
1888	-11.3	+1.2	-
1891	-9.0	+2.7	-
1893	-18.6	+4.7	-
1896	-13.8	+5.9	-
1903-04	-7.3	+4.7	-
1908	-39.4	+7.1	-
1911	-8.4	+3.0	-0.1
1914	-24.9	+4.2	-0.0
1919	-22.3	+0.2	-0.1
1921	-53.1	+1.3	-0.4
1924	-15.4	+3.5	-0.0
1930	-27.8	+0.4	-0.2
1931	-35.8	+0.7	+0.2
1932	-44.0	+0.1	+0.1
1945-46	-25.7	+1.6	-0.9
1949	-7.0	+0.6	-0.8
1954	-20.9	+1.0	-0.3
1957	-2.2	+0.9	-0.4
B--	------------------	------------------	---------B
1958	-24.4	-1.2	+0.7
C--	------------------	------------------	---------C
1967	-5.1	-8.0	+0.8
1970-71	-12.0	-13.6	+3.1
1975	-20.0	-5.4	-0.2
1980	-18.0	-2.4	+3.0
1982	-38.0	-3.0	+2.9

A-A line means t1 for open hearth (~ 10%)

B-B line means t2 for open hearth (~ 90%)

C-C line means t1 for electric-furnace technology (~ 9%)

Sources: [7, 18].

1.4. SESSION ONE DISCUSSION (Excerpts)

Lynn: It strikes me that in the commentary of at least the U.S. sources the argument is often made that the emphasis was put first on product research, and then on process research. The comments made in terms of the loss of international competitive strength of the U.S. steel industry were that it continued to emphasize product research and became less and less efficient in terms of production, its processes, whereas the Japanese and other rising industries emphasized the production research and thereby gained that edge over the U.S.

Ayres: I have to say that these relationships are not laws of nature. Probably every scholar who has looked at some industry in depth will be able to identify places where the pattern did not hold, and sometimes that can be a guide to management. It may be that in the case you mentioned the U.S. industry went wrong by not following the pattern or it may well be in other cases (for example the auto case) perhaps precisely by not following the pattern that the Japanese industry has been so successful. Those are matters which I think are very debatable and which I hope to hear some debate on, and I am very happy that you began it with that comment.

Anderson: During the 1950's, the U.S. steel industry was the most modern in the whole world. It was highly productive. It was based on large open-hearth furnaces. There was no reason for them to introduce new technologies.

The Japanese industry was almost non-existent. It started to grow. The Japanese businessmen and government had made it their policy to hitch future economic growth first to the development of the steel industry. Now that is one of the decisive differences. Here was a country taking off and of course making use of the most modern technology. They first had open-hearth, but then increasingly only BOF and some electric-arc furnaces. So a research mistake might have also been involved, but the incentive for innovation was completely different in both countries.

That is why I believe that the management strategies we are going to discuss here are not only linked to the life cycle of processes or products, but they are very much linked also to development cycles, to industrialization cycles. These are going on in parallel. Whereas we have some countries that are mature themselves and have therefore a mature or maybe a senescent steel industry, there are others that are just taking off and are therefore in early childhood. So you have this, in German they say "miteinander," the parallel existence of all these phases.

Rosegger: I just want to make one additional comment. A lot of the product innovation that quite clearly took place in the steel industry in the United States in the 1960's and 1970's had its roots first of all I believe in the fact that you could achieve improved product quality at much lower R&D costs and a lower risk than you would commit in investment to major process innovations.

But the second and equally important factor is that of course a lot of these product improvements/innovations did not come on the initiative of the industry, but from a kind of tremendous pressure from the industry's major customers who simply insisted on improved quality, improved product characteristics. So it is to my mind also one of those cases where the dividing line between R&D, which I take to be something a firm initiates, and sales engineering, which is something the customer initiates, becomes very, very fuzzy and unclear, especially if you have a customer like the automobile industry.

Stepanov: What time lag did Dr. Nakicenovic get between market-type economies, planned economies, and developing economies? There were comparable curves for three types of economies and certain time lags.

Nakicenovic: One of the best ways of describing these curves as far as dynamics are concerned is what we usually call T. It is the time that elapses between the period when a technology captures a 1% market-share to the time where it captures about a 50% market-share. Those time constants were roughly the same for all three regions. You see the T is essentially the same for market economies and centrally planned economies, and it is on the order of about 100 years, slightly over 100 years, 110 years. The T for the newly industrialized countries is a little bit faster so they have managed a similar transition in about 70-80 years, as I would estimate offhand. The time lag in this similar life cycle for these countries is roughly about 70 years.

Anderson: So you have not found significant differences, I mean, except for the newly industrializing countries? So that to some extent what I said this morning should also be determined by the existing capital stock. If you have reliable equipment which can be run under economic conditions (this goes for the open hearth in both the Soviet Union and the United States), the introduction of new technologies such as the BOF could be slightly or even very much delayed.

De Bresson: I am also an economist who in his younger age has tried to look at business cycles with the Schumpeterian hypothesis and long cycles, but I take a more skeptical look at it now. I want first of all to insist on and commend the authors for one aspect which I think is very important in this type of research, and that is when looking at diffusion curves, not to look in isolation at one product, but to look at it in the context of other products. I think during the last quarter of a century too much of applied micro-economic research on diffusion was done ignoring the context.

Perhaps one could go, however, one step further and consider complements and not only substitutes, because the presence of complements in an economy, sometimes in other industries, will greatly influence the diffusion trajectory that you have. Too much of the Schumpeterian paradigm in looking at technological innovation has been obsessed (rightly so in a way) by the competition from the outside and the substitution. But complements play a great role in either accelerating development or holding it back. What would be the computer without the transistor? What would have been the car without petroleum, etc.? They are a junction of things.

I am somewhat skeptical, though, with the second presentation by Ing. Grübler as to what these curves, these different curves right next to each other, mean. At one point, you overlaid the different steel processes with the two major pulses which had been identified before. I think that if we had stayed a bit longer on it, we would have found that the second pulse originates earlier than the new technologies. In other words, it is when the recovery is already well underway that the new steel processes start up again.

Now one can say, well, steel is no longer a major technological field, but that is the case also for computers, which started in the late 1950's in the commercial sense, or semiconductors, which start after the second long economic pulse, if you want to call it that. So the fact that we see a certain similarity in time does not tell us much as to what the causation is.

Nakicenovic: I think Dr. De Bresson has addressed several issues. Let me just try to respond to two of them. The first one with respect to the substitutions and complementarity of various technologies or innovations is, I think, a very good point. I would even, personally, take a more complex view of that situation than he seems to suggest, because not only is complementarity important among different technologies (let us say steam, railroads, coal), but furthermore there are certain complementarity substitution changes over the life cycle.

Let me briefly just suggest one possibility. When the automobile was introduced initially, it was certain that it was not substituting railways because it was not adequate for long-distance transport. Rather it was enhanced by the existence of the railways because it could match better with the high performance, higher tonnage per unit of time. I think we see that today between aircraft and automobiles. Rental cars are certainly promoted by the airlines.

So I would say that the complementarity aspect appears with many phases and many facets. I think the situation is very complex. But I think it is worth looking into. For the time being, we looked at the dynamics in the steel technology from the perspective of the substitutions of one broad class of technologies by the other and have not looked at this micro-detail at the time of the introduction of the technology.

Goldberg: I have tried to put together a few of these ideas in an analytical way. This looks like a life cycle curve, and to some extent it is, to some extent it is not. It shows the consumption, the steel demand, GNP per capita in a country. This is the GNP per capita development in the world. Here you have the less developed countries; here you have the newly industrialized; then it goes down to a fairly low consumption in kilos, GNP per capita. I think this coincides very well with what you presented. I am just turning it a little bit around to get a new perspective. Here is production in the different countries plotted against roughly consumption (for example, United States, Sweden, Germany, Great Britain, Japan). This is about 8 years ago.

An interesting case here is Bulgaria. The highest production over consumption is found in Czechoslovakia and to some extent the Soviet Union. Bulgaria is on the opposite. This may lead to some speculation since Bulgaria has a tiny, but highly efficient industry and a very high level of technology. Only about a fraction of 1% are employed in steel and only a fraction of 1% in the contribution of the steel industry to the Gross National Product.

This picture also says about the market economies that the steel crisis essentially is a crisis of the highly developing countries where one has to take into consideration two or three phenomena. Number one, steel here and steel there is absolutely not the same. It is ridiculous and misleading to talk about the same product.

It is also misleading to say about the steel industry that it is not dynamic. It is highly dynamic as a matter of fact. Let's look at car steel, since the car example has been used repeatedly. If you look at steel plate for cars, in the big car industry, everybody knows that the weight has a certain relation to fuel consumption, and we want to reduce fuel consumption, so the weight of the cars must be lower.

At the same time, the steel industry has developed two great leaps forward. One is thinner, lighter steel with greater resilience today than it had 10 or 15 years ago which maintains or improves the crash-proofness of the car despite the fact that the steel is thinner. Number two, today cars are always produced in stainless steel. It is double galvanized. There was once single-side galvanized steel, this technology had to be scrapped because the industry demanded double-side galvanized steel. In parallel, the welding technology had to develop, because it was impossible to weld galvanized steel some 15 years ago.

So I want to just take this as examples that the value-added quality of the steel here is very different and that it is misleading only to talk in crude steel equivalents. It also shows that theoretically production caused consumption, so the steel crisis in the highly developed countries is natural. Steel will be produced in those countries. There will be world trade mainly in quality products.

If the United States decides to protect their steel industry in order to give it an opportunity to revitalize itself, then the world as such will not stand still. So the U.S. may come out after such a period with inferior capacity to meet the high quality demands, for example, for the Alaskan pipeline. This is just as an example, but you cannot wait and just improve your quality. You must put a lot of research into it, and I would say the steel industry has a much higher research intensity than what usually is obvious when you only extend curves. Very often one says the crisis or crises first appeared in carbon steel or ordinary steel. This delineation between carbon and quality or alloy steel is highly flexible. Today many carbon products are used as substitutes for alloy steel, and the alloy steel has moved into other areas yet is still not totally capable of meeting high demands, for example, from the nuclear energy industry. Many of the accidents we have had in nuclear energy come from not being able to meet the market demand for quality.

I would say it is no longer adequate today only to look at the basic integrated processes. You have other processes, for example galvanizing and what have you. This may have another consequence in the long run to the life cycle. It brings the steel industry a little bit closer to what the textile industry has been suffering through which the final treatment very often follows fashion waves. We seem to have experienced some rather short-lived fashion waves in improving steel to meet the demand of customers or users.

Anderson: I agree particularly with Prof. Goldberg's last comment. What we must have is researchers (some pity for these people, because to get the statistical information that they would really need to do a good job is almost impossible). But coming back to this curve, the International Iron and Steel Institute accepts full responsibility for that. That is the famous steel intensity curve, the one that shows the kilograms of steel used per GNP per capita. We have based two attempts of forecasting steel demand on this, by working with geographical and historical analysis, and both forecasts were terribly wrong. We have recalculated the curve, because the influence on (as you have GNP per capita data in there) exchange rates is a terrible trouble. We have taken the data for Japan out of that curve, and the whole thing collapsed completely.

All we are sure of is that it is in the early stages of growth where you need the heavy investment, where you build up your industry, where you go into mining, where you build up your road network, and so forth. There is a very, very close correlation and a very steep increase in steel use, and it follows GNP growth.

The second part of the curve after the peak (in fact for lack of data at that time, we only had the United States, Sweden, part of Germany and Switzerland in there), the theoretical curve, was really based on a very flimsy calculation. So, I must say, we have abandoned this curve and have said in a book we have written on methodology of steel demand forecasting where it is all explained, that you can only really use the first part of the curve for forecasting.

Then of course your remark is very important on the quality of steel that is used simultaneously in one part of the world building up infrastructure and the other part of the world at advanced stages of industrial development where they compete with high technology, with new materials, composite materials, and so on. So you have different steels at both ends, but again I tell you immediately, you have no hope to find anything better. We are also, all of us, not smart enough to replace the tons by values which would be the thing to do, because that is even more complicated.

Uziakov: From my point of view, a very interesting question is the problem of connection between the possibilities of management strategies and some technological determinations of life cycles which we have seen with this thesis of Prof. Nakicenovic and Ing. Grübler. The problem is does it have a meaning, that notion of optimal configuration of life cycles, or must we facilitate or overcome some tendencies of dynamics of new technologies. Can we act on these tendencies or must we influence only some decisions which can effect the main macro-economic and technological tendencies.

Haustein: I have two comments to today's session. As you all know, Schumpeter was one of the major investigators of innovation in the Western world, but he himself pointed to Ricarldo and Marx as his predecessors, and Marx himself was the first to use the term "innovation" in the French version of the first volume of Le Capital. Therefore the figures presented by Ing. Grübler were very interesting to me.

What I wanted to say is that the iron and steel industry was also a vehicle for innovation thinking in the past. The early economists did not have such excellent figures as we have now, but I think that they had maybe a lot more imagination than we have, at least more fantasy, which is needed to find our way into the future.

One of the major statements in the morning session was by Dr. Razvigorova: management is a function of the life cycle of a technology. This is obviously true, but not in a simple deterministic way. Technology is normally changing faster than management does. It is so in our country; I suppose it is the same in other countries. Fundamental approaches of management and organization change according to certain transitions in the mode of production. There exists not only efficiency cycles or life cycles in the micro-sphere, but also efficiency cycles of the whole mode of production. We are now at the beginning of a transition period to a new mode of production which will be characterized by more flexibility, a higher degree of combination instead of the old principles of Charles Babbage or the principles of Taylor, principles of division of labor, shorter cycle times, a new type of automation, and so on. We can make a list of such features of the new mode of production which will come to us.

My conviction is that a change in the paradigms of management will be even more important than the different requirements of the various innovation phases. IIASA should, in my opinion, look also at the general mechanism of the evolution of management and not only at this field of the technology life cycle.

Ayres: I would like to ask a couple of questions about Prof. De Bresson's presentation. The first question concerns the Abernathy/Utterback model. You commented that one of the difficulties with using the life cycle is that there are managerial discontinuities, but it is not obvious to me what they are, and I wonder if you would expand on that a little bit. The second point concerns your transparency where you talked about what would be appropriate definitions of the entity which is having a life cycle. It starts with industry at the top, and you mention technical systems at the bottom. Why do you reject industry as being appropriate to talk about a life cycle? In fact, is there not quite a bit of stability about the usual way of defining an industry? Granted, I am thinking about the way the census defines an industry typically, which is to some extent based on clustering, but it seems to me that ordinary common sense tells us that industries are relatively stable, especially major sectors. So why would you reject that as an entity?

De Bresson: On the managerial discontinuities, I think they are more or less explicit in the article that was distributed to you, although on this basis I am an economist; I like to work with people in business studies and historians. So that work is mainly that of a Ph.D. student business strategy. What I have seen from observation is that there is a lot of difference of style (and I am talking at the level of units of production) whether you are in a batch shop or a line production. It is fairly obvious that the levels of numbers of hierarchies that you have in a line production is much greater, that it is very important to define very closely the areas of responsibilities of each person within a line production. It is hierarchical. Whereas when you are in a batch mode, even in a large batch mode, there are areas of responsibilities of different people in the firms which are defined, but the levels, the numbers of hierarchies within the organization, are not as great, and there is more flexibility.

Actually, this results in some kind of tension between the levels of responsibility within the firm. There is not as much distance between the skills and the management decisions, and the customers, because there are a number of orders which initiate the production of batches. Whereas in a line production usually, you have to anticipate and build your marketing system. So that has implications in terms also of corporate management styles.

In other words, you cannot have the same criteria of performance for a batch producer of sophisticated industrial vehicles or for that matter for sophisticated military systems and standardized series. There are incompatibilities between the different production units, and so the corporate management has to take into account the different ways of functioning that these different units have. However, I have been told by market specialists that there are also marketing strategy discontinuities in doing one thing or the other, but this is not my field.

I think that if we are going to choose a unit of analysis to look at a life cycle, we have to assume and look for some internal solidarity between the components so that the thing evolves as a whole for some period of time. There has to be some duration, and it is on that basis I felt that a technical system (what I mean by that is a group of interconnected, interdependent technical components) might be a good element to work with. We do not have much, so why not use this analogy? At least some of the system draws the components to evolve in a conversion direction. It does result in temporary rigidities of declining returns, so we do have a phenomenon of maturity. There are some long-term technical constraints that might be useful in a general time-line of the industry. The problem with looking at the whole industry is that it involves a whole mix of different technologies within it. I think Abernathy in his 1983 book himself referred to the rigidities of the previous model he had done with Utterback, saying that there can be industrial renaissance because you can uncouple things and reorganize things in different ways. Because of the mix, it is very hard.

You would have to take an industry like Japan's where there is only BOF. In other words, there is this one basic technique being used. Then I guess we could make some analysis, but then you cannot compare it with another with this mix. The problem is the industry definitions have such a mix; this is what plagues the problems of technical coefficients in an input-output matrix is such a mix. So I do not know if this answers your questions. I am not saying that one cannot say some things, but what we are saying is just so opaque, if we reason at the level of a whole industry.

Goldberg: We have process life cycles (the Abernathy/Utterback model is of this type). We have market life cycles, which in the extreme case become fashions. Fashion life cycles were discovered and brought into the literature in the 1930's, four-year kind of life cycles. We have, and I think it is a very important kind of a life cycle, the managerial, which is not a single life cycle. It is the manager's life cycle, a real biological life cycle. The manager who becomes trapped into certain ways of understanding how the system works. Stability versus controllability, achieving high productivity, is one example. Management lives in a kind of world where here we have change, radical change, and here we have stability. Stability gives you productivity. You have objective data to base your decisions upon, and you have subjective data. Management is moving between running production systems, stable systems, with objective data (hopefully) and at the same time, putting in another kind of organization, a matrix where you think about the future and change, and where you have practically only subjective data, rather little objective data, to work on.

So this is a problem. Where is the managerial life cycle positioned, for example, in the steel industry or in any other industry? We have a kind of life cycles, or let me say waves, when it comes to management models. Some 15 years ago, diversification and divisionalization was very, very much in vogue. Diversification cost industry many billions of any kind of currency. We have management models, metaphors, and cultures. We have even consulting models (for example, the Boston matrix, which is a kind of life cycle model) which makes management today a Latin square kind of an exercise. You shift between different Latin squares which means four-field tables, two-dimensional models which make a very simple method (and the Boston model is an outstanding example of this) of how to choose a strategy in a two-dimension system.

I think the manager's capacity or the work of managers essentially is to provide visions of what business we are in, how our corporation is functioning, the management of shared meanings within the firm. This is a very important thing. Who designs the meanings which are to be shared in the firm and for how long a time will those meanings be ruling the company? That is decisive, for example, in a company's life cycle.

We have also social models, for example, the quality of working life. Social models come very close to political models, but social models have a strong impact on managerial models or life cycles, and social models of course also have an important impact on technological life cycles.

Sweden is a very illustrative example of a political life cycle. Shortly after the war, the so-called Swedish model was invented with the vision that Sweden would not have enough labor to produce enough industrial products in order to promote a steady growth of social income. So the Swedish model was a way to bring people from low productivity lines of business (agriculture, forestry, textile industry) into high productivity lines of industry.

Today, we are in a very different situation. We are looking at how we can keep industries at a high level of productivity and growth and still prevent unemployment. We have a very different situation. So political models go through life cycles.

The regional life cycle has been very important as a political model having a strong impact on requirements of management, management as agent or firms as agents of political will; choosing profit-oriented firms as agents of political will rather than building up political bureaucracy which is sluggish and bureaucratic.

We have environmental requirements, which certainly have had a strong impact on the steel industry and are also a kind of a life cycle. Some 20 years ago when the environmental movement came about, to many managers this was the last coffin nail to be put into the firm's future existence. But some managers said this is our own future, let's grow on this. We have ideological political models of course, for example, the steel ideology.

Let's take the example of France. Steel means strength; France has to be strong; France has to have steel. This is a kind of a steel ideology. So this is also a kind of life cycle which rules our understanding of what kind of business we are in and what we require our industries to do.

So to sum up, there is systemic interaction between different kinds of life cycles. You not only have technology life cycle. The technology life cycle is not the only ruling one. Incidentally, we have also a science life cycle. Director Price was a professor of the history of science and one of the proponents of scientometrics. He proposed a model saying that science grows at a very steady growth rate, irrespective of what politically is being done. It is very difficult to push science, but very easy to push technology. So science is predictable; technology is not predictable. It was easy to put a man on the moon because the scientific problems were solved. It was a technical achievement. The transfer of will to put a man on the moon was essentially a technological problem. The scientific problems had been solved at large; there were only some marginal problems still to be solved. So there is systemic interaction between the cycles; there is not a science, a strict science/technology relationship, which means technology is not controlled by science. Technology is very much controlled by political, social, and managerial will. There is not a technological developmental law which the life cycle might give. Most, if not all, the cycles are human artifacts. They are hindsight phenomenon. They may be of limited usefulness for forecasting.

Those are a few points which I think we should have in mind. I do not have a ready-made answer to what kind of a metaphor would be the most useful one to approach technological change for all those purposes, to help us move forward to better times, and to solve labor, regional or environmental problems. But I think this is one of the tasks we should look into and one of the extremely difficult tasks which are being put into IIASA's basket.

SECTION 2:

World Trends, Strategic Options, and National Differences in the Steel Industry

2.1. THE FUTURE OF STEEL: INTERNATIONAL OUTLOOK

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I. INTRODUCTION

In a classic paper entitled, "Retardation of Industrial Growth" [1], Simon Kuznets adduced three major causes for what, in the language of today, would be called the maturing of industries:

1. Technical progress slackens, changes in methods of production being more numerous in the early period.
2. Slower growing industries exercise a retarding influence upon faster growing complementary branches.
3. One nation's industry may be retarded by the competitive influence of a branch of the same industry emerging later in another country.

Although this was written in 1929, we would not be surprised if we found a similar list in some of our contemporary diagnoses of industrial stagnation. At the same time, however, the paper should make us properly skeptical of our ability to make long-run projections of the outlook for individual industries: one of the branches examined by Kuznets, because he considered it representative of "retardation," was iron and steel.

With this caveat in mind, I want to speculate first about the outlook for the industry on the basis of some reasonably clear-cut, recent evidence on global developments. In keeping with the theme of this workshop, I shall turn next to an examination of the symptoms of a life cycle, using the U.S. as an example. What I hope to show is that these two perspectives -- one international, the other one national -- yield entirely different pictures. I conclude from this that in the case of iron and steel, the third of Kuznets's causes for stagnation is the most important one in explaining the difficulties of the old industrial economies. This is, of course, a conclusion entirely in keeping with the international life-cycle model of Vernon [2].

II. THE GLOBAL PICTURE

In the last two decades, the contours of a worldwide shift in steel production have emerged quite clearly. Its future dimensions are difficult to predict, depending as they do on national industrial policies as much as on developments in demand and technology.

II.1 Aggregate production.

If we look at the long-term output trend, we find no evidence of stagnation or decline. As Figure 1 shows, raw-steel production has grown exponentially since the turn of the century. Whether the apparent slowdown of the last five or six years signals a break in this trend or whether it is due to cyclical factors, surely must remain an open question.

What is remarkable about this growth in tonnages produced is the fact that it has taken place against a background of technological changes which have (a) increased the yield of semi-finished products from a ton of raw steel, (b) steadily improved the performance-to-weight ratio of the material, and (c) more generally caused a blurring of the boundaries between commercial-grade and specialty steels. As a result, many characteristics that used to command premium prices (such as workability for difficult applications, corrosion resistance, and cryogenic resistance) have become available in the more common product ranges. To put the matter differently: in terms of service-units, which can be defined in a variety of ways, depending on specific applications, a ton of raw steel in 1987 is likely to represent a multiple of a ton of steel fifty years ago. There are no simple dimensions along which to account for this aspect of the growth in global steel output.

To these considerations one can add that the specific energy requirements for the production of steel are lower than those for all other basic materials except concrete; that its price per unit of tensile strength is roughly one-quarter that of aluminum alloys, and one-tenth of glass fiber-reinforced plastics [3]; and that, even if this were not the case, there are many applications in which technological advance has not yet resulted in feasible substitutes for steel.

On the basis of such observations, one may safely conclude that steel will continue to be one of the crucially important materials for economic development, even if its production in the old industrial economies drops off further, as it is very likely to do.

II.2 Shifts in the location of production.

The steady growth of aggregate, global output obscures the remarkable shifts in the geographic distribution of production that began in the 1960s and have accelerated since then. Among the many reasons for this shift, developments in process technology play a major role. Quite in keeping with the life-cycle hypothesis, these developments have amounted to a reduction in the know-how component of steel production and thus have contributed to the rapid diffusion of steel-making, from the traditional members of the "steel club" to many newcomers.

It is well to recall that, only a quarter-century ago, many experts regarded the establishment of steel facilities in the second and third world as motivated by no more than a desire to build political monuments to the idol of "modernization" [4]. Meanwhile, many newly industrializing countries quite rightly regarded steel production as an optimal launching pad for the take-off into development, setting aside all issues of static efficiency. In these efforts, they were no doubt aided by technological advances as well as scale increases in bulk ocean transportation, whose effect was spectacularly to reduce raw-materials assembly costs [5].

Whatever the specific motives and mechanisms for the rapid transfer of steelmaking technology, the results are entirely in keeping with Vernon's hypothesis. There are many ways in which one could document the transformation, each of them beset by some conceptual or statistical problems. One is to look at countries' raw-steel production per capita and to relate this to their respective GNP per capita. The results are shown in Figure 2. If we take a per capita GNP of $5,000 (in 1982 dollars) as an arbitary threshold and a per capita output of .3 tons of raw steel as the requirement for membership in the "high-level producers' club," we see a cluster of old members in the upper right-hand corner. Only the United Kingdom, one of the club's founders, has already fallen below the .3-ton limit. Others will no doubt follow.

Meanwhile, such notable newcomers as North Korea, South Korea, and Taiwan have already crossed that limit, with several other new producers approaching it. I have to point out, however, that the diagram includes only countries that produced more than 1 million short tons in 1985. Had I drawn the same picture in 1965, I would have omitted, for example, South Korea (which then produced 143,000 tons) and Taiwan (with 275,000 tons).

Twenty years later, these countries produced 14.9 and 5.6 million tons, respectively. There is no need to belabor the special cases of China and India, where absolute output levels are quite high, but where low levels of per-capita production and of GNP imply great potential for further growth.

Only a country-by-country analysis would enable us to assess the future implications of these developments for the distribution of production across the globe. In lieu of such an analysis, which would exceed the scope of my presentation, Table 1 simply shows the difference between 1975 and 1985 raw-steel output for all countries that produced more than 1 million tons in the latter year. The rankings clearly suggest who are the rapid-growth producers and who are the potential "drop-outs" from the club.

At this time, and until the national industries at the tail-end undergo further shrinkage, there is global excess capacity, with all this implies for a demoralization of markets and for, actual or potential, political pressures toward protectionism. The outlook is complicated by the fact that many of the most rapidly growing producers are also among the largest international debtors. Debt-service requirements may force them to push steel into the world market even at prices that do not cover nominal production costs, in the interest of earning hard currencies. At the same time the creditor countries, whose steel industries are threatened by this cut-throat competition, could erect protectionist barriers only at the risk of pushing the new producers further toward total default.

A further consequence of depressed prices is to dampen incentives for investment in the modernization of steel-making capacity in the old industrial countries. The resulting realignment in the regional structure of steel production is illustrated in Table 2: the United States plus Canada experienced a dramatic decline, the European Community a lesser one, and both lost share in global output. The Eastern European producers held their own, while Latin America and the Far East managed to increase their shares substantially.

One has to be careful in projecting these trends. For the global outlook it clearly matters whether, in the medium term, total output will follow roughly the path shown in Figure 1, or whether the often-predicted worldwide stagnation will eventuate. In the former case, loss of share would not have to accompanied by a concomitant absolute drop in output for those traditional industries that manage to remain in the business. In the latter case, what amounts to straightforward displacement competition is very likely to force all old, high-cost producers to drop out of the game. So-called "industrial policies," may retard the process, but they are not likely to stop it.

III. The U.S. Steel Industry -- Life Cycle Prototype?

The United States provides what is probably the most dramatic example of stagnation and decline in the iron and steel industry. The case is instructive, because it illustrates how changes in markets, in competitive forces, and in technologies interact to bring about the kind of drastic shrinkage we can observe.

III.1 Steel and aggregate economic growth.

Looked at from the market side, an industry can be said to have reached maturity (or stagnation) when its output no longer keeps pace with the aggregate economic growth of a country. Figure 3 shows the relationship between GNP growth and apparent steel supply (domestic production plus imports, minus exports). It is apparent that this relationship was positive and reasonably stable until the middle 1970s. From then on, we see steel supply following a cyclical path that appears to have little connection with continuing aggregate economic expansion.

Although the steel data series is conventionally labelled "apparent supply," each observation reflects, of course, the interaction of demand and supply conditions in a given year and thus shows the relative decline of steel's role in the national economy. This point hardly would be worth making, were it not for the fact that domestic producers in the United States as well as in other old industrial economies frequently blame their difficulties entirely on import competition. To be sure, imports have taken an increasing share of a declining market, but the "temporary protection" frequently called for will not revitalize the industry.

Whether different strategies during the past quarter-century might have resulted in another time path for steel's life cycle, must remain an open issue. However, if there are "laws" governing the rise and decline of industries in individual economies, then the eventual breaking of the linkage between aggregate growth and the performance of mature branches would seem to be inevitable. The implication for the American iron and steel sector, according to reasonable forecasts, is a shrinkage of capacity and output to approximately 40 million tons raw-steel equivalent.

III.2 The role of technology.

The evolution of basic technologies is generally assumed to be the main determinant of industrial life cycles. Therefore, assessments of national industries' competitive performance frequently focus on the rate at which they adopt and utilize innovations. In the case of steelmaking, the basic oxygen process (BOP) has served as the centerpiece of such assessments for some time, with continuous casting added more recently as a second key indicator of "progressiveness."

Even though it has formed the subject matter for an extensive body of research, such a concern with key technologies is not entirely fortunate. First, comparative studies often ignore the specific technical and economic (and perhaps even political) conditions that govern investment decisions of firms and national industries [6] Second, they fail to recognize the many less spectacular, and less well documented, process and product innovations whose combined impact may be as important as that of the key technologies [7]. And finally, they tend to divert attention from all the non-technological components of industrial strategies that will also influence competitive success or failure in a significant way [8].

Having made these cautionary remarks, I want to reflect briefly on the role of basic technologies in the American steel industry's future. In raw steel production, the BOP reached the highest absolute output level in 1973, with approximately 75 million metric tons, and the highest share of total output (63 per cent) in 1976. It has been declining ever since. In 1986, BOP shops produced roughly 43 million tons, while they still had a nominal capacity of 65 million tons. Since 1977, twelve major plants with an aggregate annual capacity of 24 million tons have been idled.

Meanwhile, electric-furnace production has gained steadily, accounting for over one-third of all raw-steel production in recent years. The rapid expansion of the industry's mini-mill segment has been the development that mainly accounts for this change. The open-hearth process, which persisted in the United States longer than in most other industrialized countries, is now gone altogether.

According to recent estimates [9], approximately 25 million tons of BOP capacity will survive the long-term restructuring of the industry, with plants accounting for another 9 million tons of capacity hanging on until the 1990s. At that time, the BOP capacity of integrated mills will be in line with their continuous-casting facilities. The latter technology is, of course, also widely diffused among the mini-mills.

The point of these brief observations is that the capacity of American BOP shops will be largely irrelevant for the industry's future performance. Actual production is not likely to come even close to capacity until many more mills have been decommissioned. This means that the technologies embodied in production stages upstream and downstream from the steelmaking stage will have a dominant influence on who the survivors among the integrated plants will be. Improved blast-furnace productivity (through innovations in input preparation, equipment, and process control), new techniques for quality improvement (rapid analysis, argon-oxygen decarburization, dynamic process control), and a long list of innovations in the mechanical and heat treatment of steel are among the factors that will shape the technological characteristics of the new, much smaller, American iron and steel industry.

III.3 Some other determinants of the outlook.

Were one to ask industry representatives about major obstacles to improvement in competitiveness, they would surely place the problem of wages and labor relations at the top of their list. Although output per man-hour has risen by more than 30 per cent in the last decade, hourly employment costs have gone up even more sharply. The average cost per hour (payroll plus fringe benfits) in recent years has been approximately $22, more than 60 per cent above the average for all manufacturing [10]. Equally burdensome have been restrictive work rules, which have acted as brakes on further productivity advances. It is interesting to note that the three major integrated producers currently in bankruptcy (McLouth, LTV, and Wheeling-Pittsburgh) have been engaged in the renegotiation of labor contracts in order to return to financial soundness.

A second set of problems has to do with the capital market's attitudes vis-a-vis a declining industry. The old steel firms are caught in a vicious cycle: low or non-existent profitability means a lack of internally-generated funds for investment in more competitive facilities; poor financial performance also means that access to the equity and credit marktes is essentially closed; and thus continued low profitability seems preordained. Put in the simplest terms: investors in a capitalist economy see little promise of satisfactory returns in iron and steel. It is significant, however, that firms which pursued strategies of diversification into other sectors have been able to obtain the necessary financing. With no prospects for the kind of governmental subsidies that have kept the old steel industries of other countries going, if only in the interest of employment stability, pessimistic forecasts for the traditional, integrated producers of the United States is likely to be self-fulfilling prophecies. This is, of course, quite in contrast to the mini-mills, most of which are profitable, and whose much lower investment requirements appear to have been met without difficulty.

The extent to which governmental policies will influence the future performance of steel must of necessity remain an open question. The last two decades have seen the imposition of tightening environmental-control requirements; as a consequence, the industry had to incur substantial investment and operating costs that it regards as "non-productive." Whatever the arguments pro and con existing standards, it seems clear that compliance has been essentially completed and that, furthermore, the abandonment of the oldest plants has served sharply to reduce environmental problems.

Despite continuous industry pleas for protection, the effect of past policies has been mixed, at best. This is most obvious for the first major move on the government's part, the negotiation of "voluntary" import restraints in 1968. Since quotas were expressed in tonnage terms, foreign producers, leading among them the Japanese, had an incentive to shift their exports to higher-priced products. Thus, they gained strong footholds in many markets that had previously still been the domain of American firms. A later experiment with the so-called "trigger price mechanism" had equally dubious results [11]. The more recently negotiated quotas also have done little to prevent the industry's decline. The political pressures for protectionist measures are as likely to continue in the United States as in the other old, steel-producing countries.

IV. <u>CONCLUDING OBSERVATIONS</u>

The "hard" data suggest that the American iron and steel industry is facing further decline. Indeed, one may venture the guess that Western Europe's old steel industries, whether private or nationalized, will follow the same path, especially as the fiscal burdens of maintaining them through a variety of subsidies increase. In Japan, the strategic withdrawal from the large-scale production and export of commercial-grade steels may proceed in more orderly fashion, but the signs of such a withdrawal are, in any event, unmistakeable. Meanwhile, expansion in the newly-industrializing countries is bound to continue, while recent experience suggests a more measured pace of growth in the socialist economies.

All of these observations raise one other question: to what extent have managerial attitudes and strategies contributed to the stagnation or decline of the old steel industries? Critics have often held managements responsible for pursuing short-term goals and ignoring the longer-term health of their firms; they have also spoken of "managerial fatigue and irresolution" in the face of competitive challenges; and they have pointed to the companies' failure to attract outstanding new managerial and technical talent.

Such contentions, even they sound convincing, are of course difficult to prove. There can be no doubt, however, that a change in mood and attitudes occurs as an industry evolves to maturity, though sorting out the technological, structural, and environmental causes of this change turns out to be a major task [12]. In keeping with the life-cycle theme of this workshop, it seems appropriate therefore, to conclude this brief survey with two contrasting quotations that illustrate this change in outlook. The first comes from an observer of the steel industry who, in 1907, described what he called "the American practice:"

> The principle ... was to destroy anything from a steam engine to a steel works whenever a better piece of apparatus was to be had, no matter whether the engine or works was new or old, and the definition of this word "better" was confined to the ability to get out a greater product.

> Such a course involved the expenditure of enormous sums of money, it involved the constant return of profits into the business, it involved mistakes, but it produced results, and the economies from the increased output soon paid for the expenditure [13].

The second quotation projects an entirely different image. Since it is from an analysis of the industry's situation in 1948, long before stagnation and decline set in, it might even be considered prophetic of further developments:

> The kaleidoscopic changes inherent to the early years of the industry, when comparatively new plants and facilities were replaced overnight by better methods and equipment, contrast strangely with the more ordered tempo of the present. Management today is no less aware of the need for progressive methods and equipment, but the infinitely higher cost of replacement and the meager financial returns do not allow for the gambling spirit bordering on recklessness that always accompanies lush rewards in a new industry. The law of diminishing returns grinds remorselessly in a fully matured and stabilized business, and the fantastic rewards that deservedly belong to the pioneers are inevitably replaced by a mere and sometimes precarious living for their followers [14].

If there exists a more picturesque and yet hard-hitting description of the life cycle's most crucial phase, maturity, I have yet to find it.

NOTES

1. Kuznets, S. [1929] "Retardation of Industrial Growth," Journal of Economic and Business History, August; reprinted in Kuznets [1953] Economic Change (New York: Norton).

2. Vernon, R. [1966] "International Investment and International Trade in the Product Life Cycle," Quarterly Journal of Economics (May).

3. Hiebler, H. [1984] "Die Zukunft des Stahls - Aus technischer Sicht" (mimeo; Montanuniversität Leoben).

4. Manuelli, E. [1963] "Present Structure of World Steel Industry and the Setting-up of Steel Plants in Underdeveloped Countries," Review of Economic Conditions in Italy, Banco di Roma (November).

5. In some cases, however, port facilities (i.e., the absence of deep-water dockage) may act as a constraint on the utilization of the benefits of very large-scale bulk carriers.

6. See, for example, Gold, B., G. Rosegger, and M.G. Boylan [1980] Evaluating Technological Innovations (Lexington, MA: Lexington Books - D.C. Heath).

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8. Gold, B. [1982] "Managerial Policies to Strengthen the Competitiveness of the Steel Industry," Iron and Steel Engineer (January).

9. Stubbles, J.R. [1986] "An Overview of Oxygen Steelmaking in North America" (mimeo, LTV Steel Company Research Center).

10. Council of Economic Advisers [1986] Economic Report of the President (Washington, DC.: U.S. Government Printing Office), p. 300; American Iron and Steel Institute [1986] Annual Statistical Report, (Washington, DC: A.I.S.I.)

11. Rosegger, G. [1982] "Trigger Prices under Floating Exchange Rates: A Dubious Experiment in Trade Policy," Journal of International Law (Summer)

12. Gold, B., W.S. Peirce, G. Rosegger, and M. Perlman [1984] Technological Progress and Industrial Leadership: The Growth of the U.S. Steel Industry, 1900-1970 (Lexington, MA: Lexington Books - D.C. Heath).

13. Campbell, H.H. [1907] The Manufacture and Properties of Iron and Steel, 4th edn. (New York: McGraw-Hill), pp.470-71.

14. King, C.D. [1948] Seventy-five Years of Progress in Iron and Steel (New York: American Institute of Mining and Metallurgical Engineers), p.170.

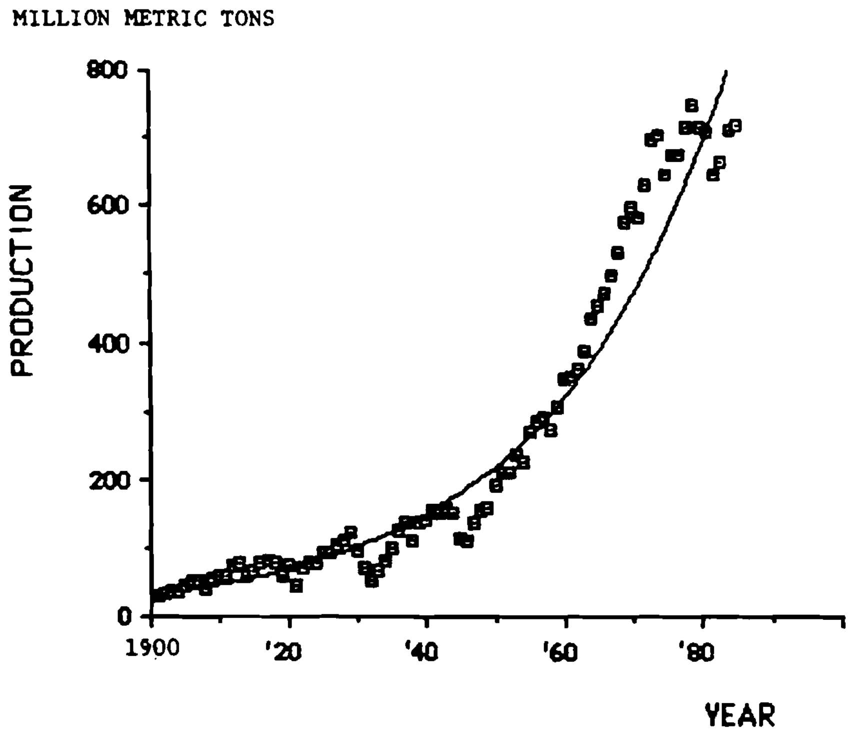

FIG. 1. WORLD STEEL PRODUCTION, 1901 - 1985

Source: **International Iron and Steel Institute,**
Steel Statistical Yearbook 1986 (Brussels: I.I.S.I., 1986)

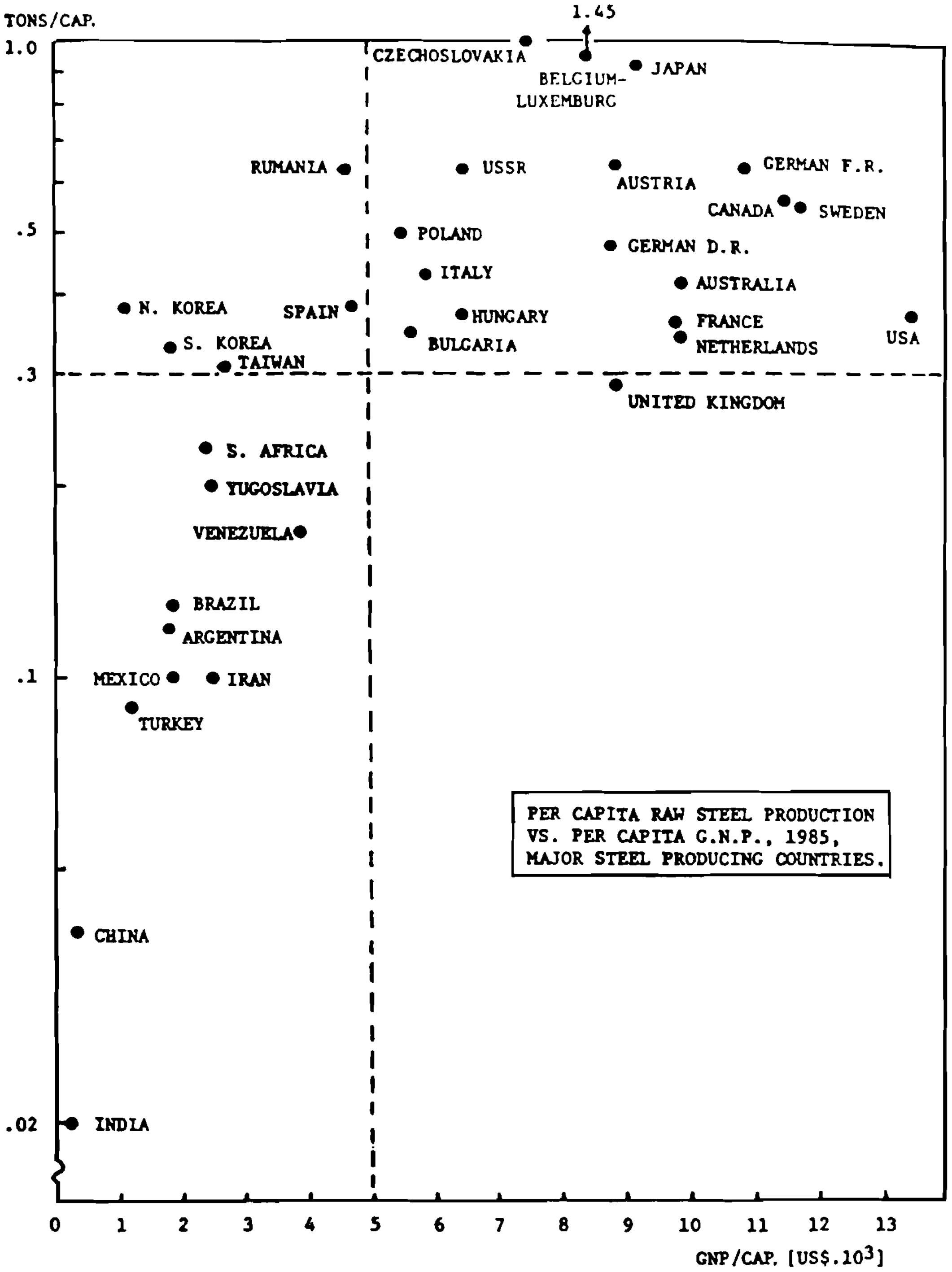

FIG. 2. PER CAPITA G.N.P. VS PER CAPITA RAW STEEL PRODUCTION, 1985; MAJOR STEEL-PRODUCING COUNTRIES.

Sources: American Iron and Steel Institute, 1986 Annual Statistical Report; U.S. Department of Commerce, Statistical Abstract of the United States, 1986.

TABLE 1.

CHANGE IN RAW STEEL OUTPUT, 1985 COMPARED TO 1975

1. SOUTH KOREA	641.4%
2. TAIWAN	404.0
3. TURKEY	190.6
4. VENEZUELA	187.3
5. BRAZIL	144.1
6. NORTH KOREA	140.4
7. IRAN	84.4
8. FINLAND	55.9
9. CHINA	55.7
10. YUGOSLAVIA	54.1
11. INDIA	39.4
12. RUMANIA	37.6
13. MEXICO	35.4
14. ARGENTINA	32.9
15. SPAIN	28.3
16. BULGARIA	25.2
17. SOUTH AFRICA	24.3
18. GERMAN D.R.	20.6
19. AUSTRIA	14.6
20. NETHERLANDS	14.5
21. ITALY	9.2
22. U.S.S.R.	8.8
23. CZECHOSLOVAKIA	5.3
24. POLAND	4.6
25. JAPAN	3.3
26. GERMAN F.R.	0.0
27. HUNGARY	- .8
28. CANADA	- 2.3
29. BELGIUM-LUXBG.	- 9.8
30. FRANCE	-12.6
31. SWEDEN	-14.2
32. AUSTRALIA	-18.6
33. UNITED KINGDOM	-20.8
34. U.S.A.	-27.5

Source: American Iron and Steel Institute, Annual Statistical Report (1976 and 1986 editions).

TABLE 2.

CHANGE IN RAW STEEL OUTPUT, 1985 COMPARED TO 1975, AND SHARES IN WORLD OUTPUT, MAJOR REGIONS

	CHANGE	'75 SHARE	'85 SHARE
NORTH AMERICA	-20.4%	18.2%	13.1%
EUROPEAN COMMUNITY	- 3.6	19.2	16.8
OTHER WESTERN EUROPE	28.7	4.6	5.3
EASTERN EUROPE	10.8	29.7	29.7
LATIN AMERICA	93.7	2.8	5.0
FAR EAST	31.2	22.8	27.1

Source: See Table 1.

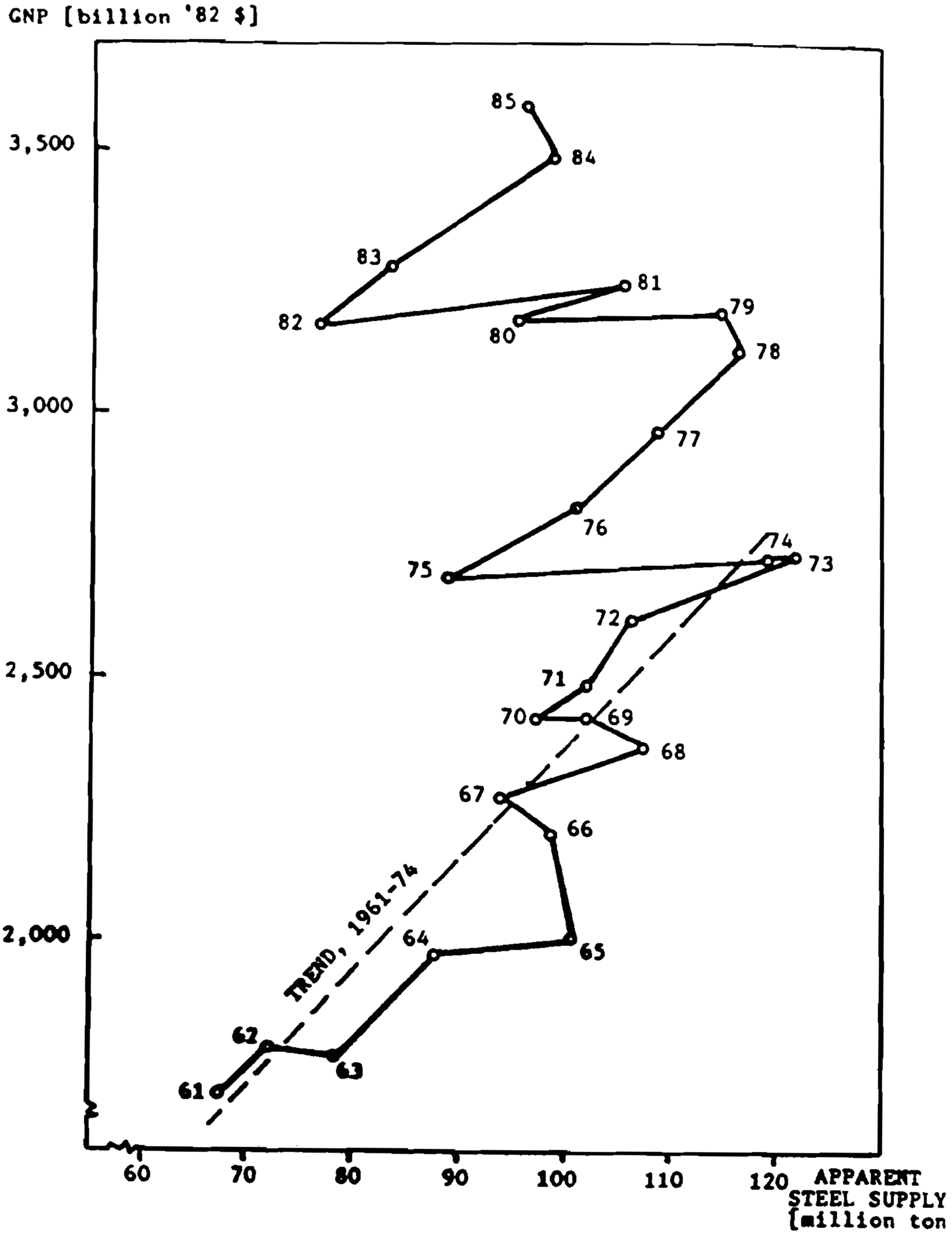

FIG. 3. U.S. GROSS NATIONAL PRODUCT AND APPARENT STEEL SUPPLY

Sources: American Iron and Steel Institute, Annual Statistical Report, 1986; Council of Economic Advisers, President's Economic Report, 1986.

2.2. MANAGEMENT ISSUES IN INDUSTRIAL CRISIS: THE CASE OF STEEL

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SUMMARY

The crisis in integrated steel, now approaching its fourteenth year, is essentially confined to the highly industrialized countries. The crisis implies a high degree of turbulence in the industry because of the fierce fight for market shares, but also due to defending markets which are in danger of being lost to other materials, either because steel has been slow in responding to (changes in) market needs or because steel has become too expensive a material or not cost-efficient enough for certain purposes.

A range of strategies and measures to improve the survival potential for steel firms are explored in brief, ranging from scanning for new products, market needs, production and process technology, over mergers (for capacity reduction), personnel development, as well as reduction of environmental, local, and regional dependencies on big steel policies to deal with those issues, to the needs for strengthening managerial competence.

THE PROBLEMS

The demand and supply of steel at large follow patterns as shown in Figure 1:

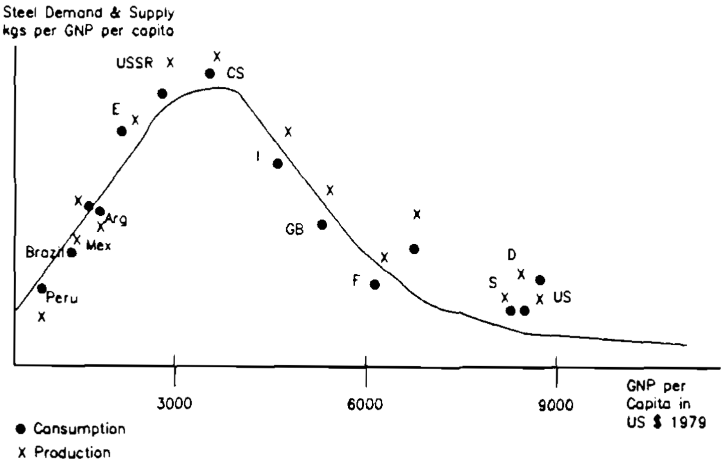

Figure 1: Steel supply and demand in relation to GNP/capita, based on Goldberg, (1986), pp47f, 54.

Several remarks need to be made:

a) Steel is not of uniform quality. The qualities/properties of steel shift along the curve shown in Figure 1. The curve may, as a matter of fact, be depicted as a sequence of sinus curves and their envelope, where the sinus curves represent demand curves for steel with certain properties (grades). The sinus curves in the left and lower part of Figure 2 represent (much) lower grades than the curves to the right and above.

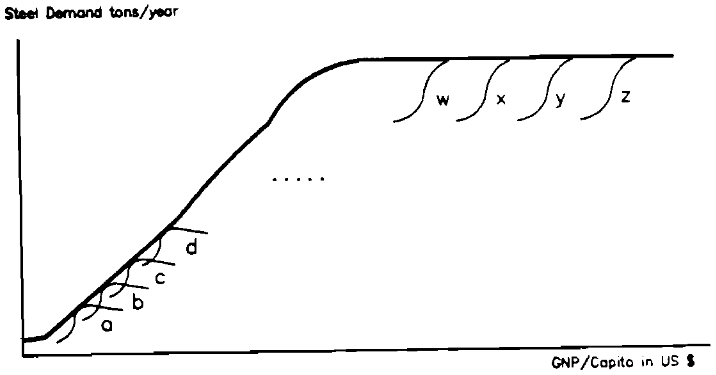

Figure 2: Development of steel demand, quality- and quantity-wise as a function of growing per capita income (based on Figure 1). Legend: a ... z shifting steel qualities or grades, a=lowest and z=highest quality.

b) Steel production follows steel consumption at large: steel consumption (quantity- and quality-wise) in a region tends to coincide with production. World trade in steel covers (temporary or structural) gaps in supply of certain grades as well as specialty steel supplies produced by specialists.

c) As the standards of living, of infrastructure, and the degree of development/industrialization progress, the "steel spectrum" of a country or a region will gradually move to the right (cf Figure 2), abandoning lower grades, adding higher ones in order to meet changes of market demand. One may talk about "appropriate steel demand/supply" according to the level of development. The borderline between carbon and alloy (or specialty) steel is mobile over time. In a similar mode, production technology will gradually shift from one principle of technology to one or several other ones.

d) There is also a general development in steel production technology as well as in steel grades, which contributes to changes in steel qualities as well as to changes in production technology. If steel production and consumption are disaggregated by region, one will see that steel grades and steel technologies "stay alive" in some plants or countries whilst they are abandoned elsewhere, because of shifts in standards of living and consequent shifts in demand, particularly in advancing regions. This means in other words that the most modern steel technologies will only be adopted by the more developed "steel spectra," whilst less developed regions may employ "appropriate steel technologies."

A phenomenon depicting this development is the positively skewed curve as shown in Figure 1 above, which tells us that steel consumption per capita will grow as a function of increasing standards of living to a certain "spectrum." Then it will level off and later decline. This reflects shifts in demand, moving from heavy to lighter investments, but also to higher quantities of steel which tend to be lighter and often at the same time even stronger. (An illustrative example is that when the Eiffel Tower was erected about 100 years ago, approximately 7,000 metric tons of steel were used. In 1987, slightly more than 10% of steel weight would suffice to erect a similar construction with similar properties.[1])

e) The development of new qualities of steel is not evenly distributed over time. The same is true for production technology. The recent steel crisis (which is confined to highly developed economic regions) has triggered vivid R & D activities aimed at counteracting the increasing tendency to replace steel where technically and economically feasible by other materials and at developing entirely new steel qualities (having new properties such as higher resilience and strength or corrosion resistance together with -- much -- lower weight per square meter, e.g. of plate for automobile bodies). The steel industries in the highest developed countries are fighting desperately to defend and regain market shares from substitute materials.

f) Some of the new grades require new combinations of shaping (e.g. high precision thin plate or coil rolling) and finishing (like single or double side galvanizing). There is a tendency for these processes (in particular for finishing) to be subject to rather fast technological change. In some respects, one may compare this development to similar tendencies in the textile

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[1] Oral communication at the Sofia workshop from Dr. D. Anderson.

industries some 20-30 years ago, implying rather quick shifts from bottlenecks to over-capacities in finishing processes.

g) A related tendency is the appearance and fast growth of the mini-mill sector, which very successfully has been able to put integrated steel makers out of business in certain market sectors. Several properties of the mini-mill sector account for its successes:

  * Utilization of highly refined, energy-intense raw material (scrap) with consequently lower input -- and production costs -- and drastically reduced needs for environment-induced investment.

  * A combination of low transportation costs and closeness to the market, because of its possibilities to establish plants near the markets with high and/or growing demand, where often also scrap is locally available. Within certain product ranges, they may be able to respond to market need shifts better and more quickly than larger integrated mills are able to do.

h) Large steel plants put heavy burdens on the environment, in several respects:

  * For one ton of refined steel, between 5 and 6 tons of input are needed: ore, fuel, limestone, water, and several other kinds of materials. The remaining waste material which does not go into the refined steel either leaves the plant through chimneys and waste water pipes or goes into large heaps of waste to be taken care of -- or not.

  * The supplies of inputs, but also the output and the waste, require heavy infrastructural investments, often to be provided by third parties: waterways, water supplies, roads, railroads, etc. Those infrastructural investments are particularly done and shaped to meet the steel plants' needs.

Thus steel works cause environmental and infrastructural costs and burdens of specific and tangible character. The steel producers have been asked during the last 15-20 years to take care of the cost and burden caused by the environmental and infrastructural aspects. This at least to some extent has contributed to the predicament of the industry.

i) Despite the massive, heavy, and widely visible physical investment an integrated steel plant requires, it is labor- rather than capital-intense (although it costs a lot to build it). On the average, labor costs range between 35-40%, raw materials at about 25-30%, energy at about 30%, capital costs at about 3-5% of the cost per ton of solid steel.

Steel plants thus employ much (male) labor. This has a number of consequences of concern to management:

- Steel often becomes the dominant employer and wage-setter of the region.
- Steel often "kills" other employment options, as independent businesses will find it difficult to compete for (male) labor in the region.
- Steel firms will often have to provide for housing/living space for steel workers.

j) For several of the mentioned reasons, steel will exert -- an often dominant -- influence upon local and regional public administration, which thus may become rather dependent upon the steel corporations.

The above comments are examples of strategic issues with which the management of steel producers/corporations has to cope, during periods of success as well as under conditions of decline. The difference may be that under adverse conditions many (more) problems at the same time require managerial attention and action (cf Dutton 1986, who summarizes scant research in crisis management by claiming that, when confronted with strategic issues representing crisis, management will increase the level of resources expended on an issue, enhance control on issue relations, and increase the level of issue-related exploration).

The steel industry of the highly industrialized countries, after its best year ever, 1974, slumped into a deep crisis, which thirteen years later is by no means overcome yet, despite heavy losses of markets, massive lay-offs and closures, desperate individual struggles for survival, and grand scale national as well as international (European Community) programmes for adjustment and capacity reduction.

SOME PROPOSALS FOR ACTION

Once symptoms of a crisis are experienced, firms tend to use strategies that have been used to gain past successes (cf the Atari-case, Sutton, 1986; Nyström, 1984; Cyert March, 1963). This usually means three things:

- The recognition of a virtual crisis situation is postponed as its symptoms to begin with are treated as a sign of transient occasional trouble. Valuable time is thus lost.
- Reactive decisions are taken, taking stock of successful strategies in the past and trying them on the present crisis.

- Slack resources, if available, are devoted to attempts to maintain/regain a status quo rather than to innovative strategies (Goldberg, 1973). This is what also happened in the steel industry.

- The new structural crisis was regarded as being a temporary business cycle decline, at least to begin with.

- Attention rules were not changed. Essentially the same data sources is used as before. Since the forecasting activities of the International Iron and Steel Institute (IISI) has proven to be reliable in the past, and, if off the real development, so to the conservative side (below real demand), further capacity increases were implemented or decided upon.

- As the first oil price increase, that of 1973, struck the industry in 1974, steel prices were increased, but hardly any steps were taken to change the energy technology used (except in Japan).

- Few, if any, innovative products (lighter, stronger, more corrosion-resistant, etc.) were developed.

Probably the first country to seriously take issue with the crisis was Sweden. There were far gone plans to build a new large steel plant in northern Sweden (Steel Works 80, in 1975 renamed Steel Works 80/85). In the spring of 1976, the government appointed a national steel commission. It was requested to look into the market, to take issue with capacities and structure as well as with organizational problems of the industry. The commission was instructed to regard Steel Works 80/85 as a reality. Seven months (and a General Election implying the displacement of the Labour government) later, the project was taken off the agenda. The commission's instructions were changed thoroughly to produce a solution implying drastically reduced capacity for (carbon) steel in Sweden (cf Goldberg, 1983).

The European Community took the initiative to reduce overcapacities in its member countries a few years later. The process was lengthy and cumbersome, as many of its member countries recently had installed large modern plants and were also enlarging and modernizing their capacity. Only Britain had rather drastically reduced its capacities since the beginning of the 1970's as a consequence of massive financial losses.

Japan, standing outside of economic blocks, had a highly modern productivity -- as well as quality-wise an outstanding steel industry, when towards the mid-1980's it also had to reduce capacities.

The US steel industry was under shelter -- with short interruptions -- since 1964. The capacity reduction came through a number of bankruptcies (for a full account of the steel crisis 1975-1985, cf Goldberg, 1986).

Whether with or without Community or government industrial policy support, the heaviest burden of retrenchment had (and has) to be carried by the firms themselves.

Management Strategies

Management strategies will be discussed in a sequence of order which roughly follows the account for **PROBLEMS** faced by the industry.

Closeness to Customer Needs

The most vitally needed strategy is staying close to customers' needs and to maintain as well as to develop credibility in the market. Corporations should, whenever possible, help the customers to define their needs, as this often requires a good knowledge of what is technically feasible. This implies that qualities and grades should be developed, in many cases, in close cooperation with the users of steel, i.e. industries of different kinds, having the need of the ultimate consumer/user demands in mind. This is essentially a never-ending process. As an example, the automobile industry is used. It is one of the remaining large customers of steel, although it has reduced the steel content of cars quite drastically, in particular for passenger cars, in response to increases in fuel prices over the last 15 years, as a close relationship between car weight and fuel consumption has been established. The almost steel-free chassis (bottom plate) is not very far away. Once it is operational -- most likely within the next five years -- the industry will lose this customer. If the chassis can be produced with minimum steel content, then most other parts can be done without steel as well, including engines. The steel industry's only strategy is to come up with better solutions, faster and even cheaper.

Another large steel-using industry is the construction industry. Even there steel has to fight hard in order to maintain its markets, e.g. by lighter steel having the same or even improved qualities, such as resilience, workability, stability, corrosion-proofness. For steel to be used for weather-exposed surfaces, much higher degrees of corrosion resistance are requested. To the user, this should mean reduced maintenance costs such as painting, but also aesthetic values, such as color and shape, fit with other materials, or for functional purposes.

Exploring known and developing new uses of steel and technologies of steel forming and manufacturing in the steel-using industries requires extended technical competence, quality management, cooperation with customers on developing and testing new steel grades, but also ultimately cooperating with customers on joint product and process development. It seems to be necessary in many cases to see the production and forming/shaping of steel and its transformation to a final product as taking place in an integrated system, although under differentiated ownership and -- often -- location.

Cooperating with steel users in such more advanced ways, however, also in many cases makes necessary closer and more advanced cooperation between steel producers and producers of steel technology as well as with producers of iron ore, fuel, additives, furnaces, furnace linings, etc. Such cooperation is necessary in order to not only meet new requirements, but also to offer research and development services to steel-using industries (cf Goldberg, 1986, p276).

As briefly indicated above, the steel industry must adapt and extend its systems view, by integrating the final utilization, servicing and maintenance of steel in a wide variety of shapes, forms and products throughout the life cycle of the end products into its way of thinking in qualitative terms.

Within existing uses, there seems to be a great need for qualitative development of steel to be used under heavy-duty circumstances, such as off-shore constructions, pipelines (e.g. subjected to severe climatic conditions) as well as nuclear power plants, where the majority of production stops seem to be due to cracks and leaks in steel vessels, tubes, and pipes.

Scanning

In order to support strategies aimed at better and even new grades and qualities to increase the usefulness of steel, the steel industry management will have to scan various sources for information on:

* New steel technology for steel making, finishing, shaping, corrosion protection,etc.

* New iron production technology, new qualities of ore, fuel, additives, etc.

* New customer-related technology and material needs. The steel industry at large does not serve the ultimate user/consumer of steel, but rather the steel-using, forming, shaping industry. Thus the steel industry has to keep in close touch both with the steel-using industry and also with the

needs of those industries' customers. This implies that it has to explore means to meet such needs better at lower costs during the entire life cycle of the user products in order to be capable of competing with new substitute materials.

- The steel industry also needs to scan into spheres which are or ought to be of interest to steel technology suppliers or producers, e.g. for new heating or melting technologies like plasma technology (cf Goldberg, 1986, p265ff on potential technology changes in steel industries, and Lynn, 1982 and 1984, for technology change monitoring).

- Scanning should also be extended into competitive materials' development and uses as well as into changes in demand of industrial and consumer markets.

Productivity Issues

The steel industry, i.e. its individual corporations, urgently needs to improve the productivity of production processes whenever possible. The productivity improvement efforts in the first place must meet the present productivity performance of the best Japanese steel plants and, beyond that, try to surpass the best Japanese performances (which will be very hard to achieve).

Productivity targets should not only be confined to production figures for input of manpower, but also to energy inputs for units of output: ore, coke, oil, gas, etc. Oil prices will increase again within a not too distant future because of the exhaustion of easily tapped sources.

Another productivity measure is process yield (and its improvement).

Already mentioned is the labor productivity, where the best Japanese performance (of 15 plants) is over 2,000 tons of finished product per worker and year. Many plants in the United States and Europe still produce less than 1,000 tons per worker/year.

Several other productivity measures are in use, e.g. (the reduction of) capital costs per ton of capacity.

Environmental Issues, Pollution Control

For one of the world's largest and most integrated steel plants, Nippon Kokan's Ogishima Works, once devoted about 20% of the total physical investment budget to environmental purposes -- otherwise, the plant would not have been allowed to be put into use.

Steel plants are not only large; they are also large polluters. They have until quite recently been permitted to pollute. Thus, their backlog has been substantial in this field. Many old sins and their scars had to be removed, new stringent requirements be met. Steel will hardly be allowed to enjoy any privileges with respect to the environment in the future. Thus, the causation principle will be employed without pardon when it comes to avoiding further pollution.

Tighter rules have also come into use concerning costs of transportation facilities (investment and use), which may severely hit an industry dependant on heavy bulk logistics.

Unfortunately, environment-induced investment will have to compete with productivity and quality-related investment on the one hand and with profitability target investment on the other.

Labor

Employment issues emerging from the steel crisis are also rather complex:

* Management and corporate staff face many new requirements as far as competence, in depth and in width, are concerned (see e.g. above, re: needs to think and act with a system view in mind), not to forget the many urgent R & D tasks to be taken care of.

* Production management and personnel must also meet rather thorough qualitative changes; new technology with considerably sharpened quality, but also timing requirements, etc. will be introduced.

* A most delicate task is to manage severe layoffs, often affecting several thousand persons. It is of utmost importance that necessary layoffs are managed in most responsible ways. The heaviest burden hits those who have to leave. This requires not only careful planning, cooperation with unions, labor market, social security offices, etc. Most of all, it requires thorough consideration of each individual's personal case.

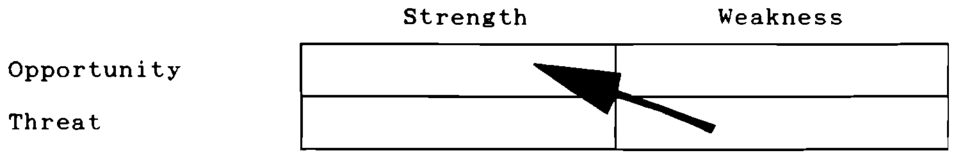
Regional Issues

Regional structures grow slowly over time. Steel usually has been a dominant employer for a century or more. Thus economic, but also administrative and political structures have been shaped by steel. The dominant firm has often become the "ruler" of the region (even as large owner of land and housing). Thus it is often highly necessary to reduce the region's dependence on steel. If it is done in crisis, many old dependencies are abruptly broken up, since no safety margins are available any longer.

A differentiation of the economic structure in the region is often highly necessary. As a rule, it has effectively been kept "mono" by the steel firms in the past. Other firms will hardly find the neighborhood of steel attractive -- even if steel's attitudes would change.

Steel corporations need to develop and implement strategies for local regional restructuring/rejuvenation together with local regional administrative and political organizations and offices, often also employing consultants of different specializations.

- A popular mode of approach to strategic management is the strength -- weakness --threat -- opportunity analysis:



In brief, management is expected to move the corporation from the lower right "south-east" to the upper left "north-west" corner of the square.

The approach requires proper identification of strengths and weaknesses of the firm and of opportunities and threats stemming from the firm's environment to be recognized and defined, as well as ways and means to be found to move towards "north-west."

A crucial question to ask oneself in the first place is what makes the difference between a threat and an opportunity. Are they objective realities or not? A closer look reveals some simple facts.

The signals by which change -- implying either threat or opportunity -- announces itself are almost without exception identical ones. The difference between their meaning the one or the other lies in:

- How early the signals are recognized and acted upon;
- The values and attitudes of management vis-a-vis the signals (it is management's subjective inclinations and decisions which make the signals mean the one or the other);

* The resources management disposes of for action:
  + time
  + human resources, creativity, proactivity, preparedness to venture and innovate
  + if the last two sets of resources are at hand, financial resources only in rarest cases will be lacking.

In a similar way, weaknesses and, in particular, strengths are subjective imaginations in the minds of management. Supposed strengths have often proved to be virtual weaknesses. Steel is full of sad cases of proof of this.

The lesson to be learned from this is that management competence and values mean more for the fate of a corporation than almost anything else. Another paradox of management is that management's attention has to shift ever so often between issues concerning productivity and future business orientation. It is often claimed that top management should only deal with "doing the right things," i.e. with strategic issues, whereas the sphere of "doing things right" should be left to supervisory management.

In reality, this is applicable in exceptional cases only, e.g. in very large firms.

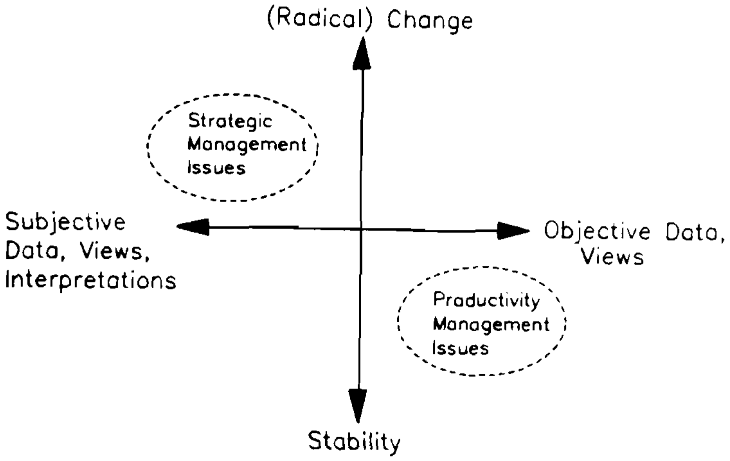


FIGURE 3

Dealing with productivity is taking place in rather stable, well-defined, and predictable systems and based on data of relatively high objectivity.

Dealing with strategic issues and change, on the other hand, implies high degrees of subjectivity, i.e. estimates, uncertainty and rather ill-defined systems conditions.

These two species of decisions require quite different mind sets, which in "normal" cases may be classified as antagonistic personality types. Management has to combine the two "characters" under one hat.

One may question if steel has had the right managers before and at the time the crisis came. Possibly quite a few steel managers rather static or imitative thinking. Moving integrated steel out of crisis requires a combination of the two decision styles mentioned above, that is, thinking in high productivity and in strategies to exploit new fields of business.

To conclude, it may be restated that steel corporations in crisis are in desperate need of management's possessing many very high competencies.

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2.3. RISK RETURN PARADOX AND INNOVATION MANAGEMENT IN THE STEEL INDUSTRY

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ABSTRACT

The paper presents some of the empirical evidence for the common assumption that the willingness of many firms to innovate is definitely stronger in a crisis than in a "normal" situation (risk return paradox). In this respect, the majority of 20 firms of the steel industry behave like most other industry sectors in the Federal Republic of Germany. This suggests clearly that the classical (Schumpeterian) risk return thesis is not valid in most cases.

In the absence of more empirical research, a generalization of this result for the steel industries in other countries is not justified. However, there are some signs that the steel crisis has had stimulative effects on the innovation willingness of some steel firms. Because innovation in a crisis situation generates very high requirements on the quality of management, and an unsuccessful innovation can jeopardize the very existence of the firm, the paper considers the possibility of using the concept of the Integrated Life Cycle (ILC) as a management tool to improve the timing of the decision and, hence, the probability of success in the steel (and other) industries.

ACKNOWLEDGEMENTS

The author wishes to acknowledge detailed and helpful comments on an earlier draft from Robert Ayres. Any shortcomings or errors which remain are entirely my own responsibility.

1. INTRODUCTION

One of the problem of the life-cycle model is that its microeconomic underpinnings are not entirely convincing. In everyday language, it would seem that firms with a history of successful risk-taking (and profits to show for it) would tend to continue to be innovative. At least, this is a simplistic interpretation of Schumpeter's conceptual model of innovation behavior. One can, with some justice, call this kind of behavior Schumpeterian. On the other hand, evidence for a different pattern of managerial behavior is accumulating. In brief, it appears that firms tending to enjoy high returns on their existing businesses are less likely to take risks than firms enjoying lower returns.[1] Empirical evidence for this management behavior in U.S. firms was found by Bowman who called this phenomenon "Risk Return Paradox."[2, 3] This seems to confirm the results of previous research in Utility Theory by Allais, known as the "Allais Paradox."[4]

2. EMPIRICAL EVIDENCES OF THE RISK RETURN PARADOX IN VARIOUS FIRMS IN THE FEDERAL REPUBLIC OF GERMANY

Perlitz and Löbler undertook a similar empirical research in 212 firms from 10 sectors in the Federal Republic of Germany. The average rate of return of every firm was related to five risk measures:

- average absolute change of rate of return (Risk 1);
- average relative change of rate of return (Risk 2);
- trend corrected (smoothed) average absolute change of rate of return (Risk 3);
- trend corrected (smoothed) relative change of rate of return (Risk 4);
- variance of rate of return (Risk 5).

The calculated rates of return and the five risk measures of each firm were related to the average respective sector values; they were clustered into "high" and "low" groups. Figure 1 shows the results for the steel industry.[5] Note that normal or Schumpeterian behavior would correspond to a pattern in which the majority of firms would be located along the NW-SE diagonal of the risk-return matrix and conversely.

The results confirm the validity of the risk return paradox holds for the steel industry at a significance level of 0.4. For risk of type 5, no definitive results were available.

In comparison to the steel industry, the engineering, electronics, and metal construction industries investigated by Perlitz and Löbler reveal even more negative correlations; the risk return paradox is even stronger than in the steel firms. The other branches have similar results. The single exception is the brewery industry for which three risk measures correlate positively with the rate of return.

Another empirical test was arranged in order to demonstrate risk behavior in chance and crisis situations. Interviews with 230 managers from 20 big firms show that they behave as risk-takers in crisis situations and as risk-averters in chance situations, thus confirming the well known Allais-Paradox. Because of the fact that innovation decisions are closely connected with different risks, this means that they try to innovate if the company faces a crisis and they tend to avoid innovations in chance situations.

A recent paper by Ayres & Mori[6] showed that paradoxical risk return behavior can be explained if it is assumed that managers' time preference functions are dependent on medium-term prospects of profitability from existing business activities. In effect, they argue that at such times, the use of negative discount rates may be justified. The proper interpretation for this behavior is rather complex. In the context of Olson,[7] the behavior of different groups, and their diverging interests in innovations play important roles. On the other hand, most planning and management tools have limited time horizons to such a degree that sudden changes in technology arising from a crisis cannot be forecasted early enough. Also the notorious orientation of management toward short-term operational items excludes risky long-term innovation decisions. Only a careful analysis of the quality of management and the planning tools used in firms with positive correlations compared to the other firms with risk return paradox could clarify this situation. Figure 2 shows the pattern of the crisis-induced innovation process.

3. PROSPECTS OF AN INNOVATION STRATEGY IN THE PRESENT STEEL CRISIS

According to the considerations described above, in the present situation the steel industry should be considering innovative options. Despite the fact that no precise data are available, some information indicates the steel industry worldwide has tended to show the pattern of behavior hypothesized by the risk return paradox. With the exception of Japan, there was no strong interest in R&D in the prosperous years. Actually, in Japan, Federal Republic of Germany, and the U.S., R&D programs supported by state subsidies were started a few years ago.

Regarding the operational sequence of iron-making and steel processing, the main driving force for innovation is the need for process technologies which are low in capital cost, consume less energy, and require less labor than conventional technologies. At the same time, improved product quality should be provided. In the future, steel products will certainly be at the same time very similar to and very different from those of today. The similarity will lie in the basic metallurgy of iron-base alloys. However, the products themselves will be very different in a number of ways. The concept of purity will evolve beyond even the most stringent requirements of today: by this we mean that the chemical composition and the metallurgical structure of steel as well as the nature of the minor phases scattered in it will be controlled to a higher accuracy. The trend today towards ultra-clean steels is certainly pointing in this direction. Steel will also very often be used in conjunction with other materials: this will involve surface coating, plating or ion implantation, as well as composite materials with steel fibers or steel matrices and also so-called "multi-materials."[8, 9, 10]

4. DIRECT STEEL-MAKING

Direct steel-making is potentially attractive because if successful, it offers substantial savings in capital cost (the coke-making facilities are eliminated; iron-making and steel-making are combined).

Overall energy consumption should be reduced because the energy requirements associated with coke-making and sintering (or pelletizing) would be eliminated. Furthermore, no coking coal would be required and the continuous nature of the process would allow a more efficient use of off-gases. Because of the high intensity of reaction, i.e. high processing rate per unit volume (high temperatures and molten, disperse phase contacting), the heat losses should be reduced and fugitive emissions much easier to handle.[11]

The Austrian VÖEST-ALPINE company will have its first reference work on the basis of COREX-process in South Africa by the end of this year. As we have explained, the COREX-process requires lower capital investment and makes use of coke superfluous; moreover, considerable electricity production is made possible. As a result of these facts, the new steel technology embodied in the KVA-process (Klöckner Vöest-Alpine) has remarkably good economic indicators.

5. PLASMA STEEL-MAKING

Plasma steel-making has been under investigation for quite a number of years. This process involves the generation of a stable arc between two electrodes. Because of the very high temperatures attained in this arc, the reactions between the feed materials supplied into the arc are thought to proceed very rapidly.

The earlier ideas embodying plasma arc steel-making suggested feeding a mixture of iron ore and a reductant (natural gas or coal) into the plasma furnace to obtain molten semi-steel.[12] At present, this appears to be a somewhat extravagant use of electric power when applied to the production of ordinary, low-carbon steels because both the endothermic of reaction and the latent and sensible heat requirements would have to be supplied by electric power. Also, it should be noted that the use of fossil fuels tends to become rather less attractive, even from the thermodynamic standpoint, when employed to supply a latent heat requirement at high temperature levels. The threshold temperature is thought to be around 1400-1600°C, above which it may be more efficient to supply energy from electric sources. Within this framework, it appears that plasma technology would be inappropriate for smelting reduction of iron oxides, but plasma processes could well be attractive for melting scrap or reduced iron powders. However, the combination of high temperature requirements and high product value make plasma technology an attractive possibility in the production of molybdenum, titanium, and perhaps aluminum and magnesium.[13]

Plasma steel-making could also be attractive because it would eliminate a major part of the primary steel-making operations. Furthermore, plasma steel-making could be particularly appealing within the context of mini-mill systems, with production rates in the region of 200 to 500,000 tons/annum.[14]

6. CONTINUOUS CASTING: AN EPICENTER OF INNOVATIVE TECHNOLOGY

The finishing end consumes some 35% of the total energy used, is responsible for some 75% of the labor cost and would require some 50% of any new capital investment in green field site plants. It follows that innovative schemes for finishing have an important potential in transforming the conventional iron-making and steel-processing sequence.[14] The epicenter of innovative technologies today lies without any doubt in the field of continuous casting. In the conventional steel-processing sequence, the molten steel is cast into ingots; alternatively slabs or billets are produced using continuous casting. While this latter method offers substantial energy savings due to a higher product yield, in both cases a large number of additional forming operations are required with intervening reheating sequences.

The new continuous casting processes fall under four categories:

* the thin slab caster, for 25-40 mm thick slabs which could then be directly fed into the finishing stands of the hot strip mill;
* the thick sheet caster, for 5-15 mm thick sheets which would need some limited hot rolling, probably for metallurgical reasons;

- the sheet caster, for sheets under 10 mm thickness that could go directly to the cold rolling plant;
- the thin sheet caster that would directly produce a final product equivalent either to the as-rolled sheet or to the cold-rolled sheet, the thickness then would go down to tenths of a millimeter.

Developing these new casting processes means that a number of common and difficult problems will need to be solved:

- Their productivity has to be at least as large as that of one strand of a conventional caster producing the same width in order to avoid the excessive (in terms of investment) multiplication of casting strands. This means that the casting speed has to be increased in inverse proportion to the ratio of thickness. Stationary oscillating molds are certainly unable to allow for such high speeds, and the travelling mold that accompanies the product during its withdrawal is the only solution. Belts and rolls are thus the best candidates for these new technologies.

- Liquid steel has to be introduced into the narrow slit that constitutes the cross-section of the cast slab or sheet, under "satisfactory" conditions. This means that steel should be adequately protected against re-oxidation or re-nitrification by air, and that the feeding should be gentle enough to avoid splashes and phenomena that would lead to poor surface quality. It should be stressed that surface quality ought to be irreproachable, since little conditioning can be envisioned on a thin slab or sheet.

- At the exit of the caster, the enthalpy of the product should be kept high enough to allow subsequent hot rolling when necessary..

- The metallurgy of the whole new casting lines has to be evaluated: the metallurgical structures, precipitate size and distribution, textures, etc. New alloying elements may have to be introduced in the steel composition to compensate for the new effects.

Three categories of technologies are candidates for one type or another of the new casting techniques. The belt caster is aiming at the larger thicknesses. The twin roll caster is meant for the intermediate thicknesses, whereas the very thin ones should be in the league of the single-roll caster. In addition to these are the dominant families of mold caster, which competes in the same class as the belt caster, and the spray deposition process, which should be capable of producing both thin sheets and bi-metallic sheets.[15, 16, 17]

Table 1 gives an overview of published or announced intentions to develop one of these new continuous casting processes.[18]

7. POWDER METALLURGY

Powder metallurgy has been used successfully for producing high quality steel and super alloy components where stringent requirements have to be met regarding mechanical properties. These superior mechanical characteristics are in part attributable to the properties of the powder produced by rapid quenching techniques and by the absence of segregation in the finished products. The price of the steel powder produced from molten steel by atomization was thought to be a critical factor in determining the economic attractiveness of powder metallurgical operations. If it were possible to produce iron powder from the ore directly without proceeding through molten intermediates, such an operation could be extremely attractive from the standpoint of energy conservation, reduced capital cost and hopefully fewer adverse environmental impacts.

It has been suggested that this powder may be directly rolled into high quality strip: thus, the direct production of powder, in conjunction with a powder metallurgical route, could offer rather appealing alternatives to the current iron-making steel-processing sequence. Finally, powder metallurgy could be a logical route toward the manufacture of high quality steel products, viz low inclusion count, minimal segregation, and attractive mechanical properties.[19]

In common with the direct casting of sheet and plasma technology, the powder metallurgical route could be ideally suited for mini-mill type operations producing a limited range of products at a location close to the market.

8. INNOVATION STRATEGY AND ITS RESULTS

Besides these and among others basic innovations not mentioned in this paper, there are many other possibilities for piecemeal innovations which could improve the steel industry's productivity and the quality of its outputs. Many firms were or are still trying to follow this way in the steel crisis.

As to the results of the innovation strategy in the last years of the steel crisis, we have a differentiated picture. Krupp and Mannesmann in the Federal Republic of Germany were successful and showed the possibilities of such innovation management even in crisis situations.

On the other hand, some firms had enormous difficulties in realizing innovation strategies. VÖEST did not have very good experience with diversifications of an innovation character (AMI-electronic project, etc.).

The reasons why innovation strategies fail are obvious. The simultaneous management of crisis and innovation is of tremendous complexity and demands a great deal from the management of the firms. The problems of motivations, organization, corporate identity, etc., in crisis situations could have a negative influence on innovative efforts.

A careful study of the factors influencing the successful realization of innovation strategies could give useful orientation to innovation management. Nonetheless, there is a great need for new effective tools which make a better orientation in innovation decisions possible.

9. THE CONCEPT OF THE INTEGRATED LIFE CYCLE MODEL AS A TOOL IN MANAGEMENT OF INNOVATIONS

Among the instruments of the strategic planning and management, the concept of the Integrated Life Cycle (ILC) seems to have a broader time horizon and therefore some advantages which could be utilized in the planning and realization of innovations in the steel and other industries. Besides the traditional market life cycle, ILC includes also the phases invention, innovation, and --important for senescent industries -- the reorientation (or liquidation) phase. Figure 3 shows the concept of ILC.[20]

With the help of the ILC concept, the future state of the firm could be simulated earlier than by the methods used now, putting management in a position to meet the coming crisis with sufficient time reserves. This means that the firm could start with the innovation or other strategies earlier; management could act, not only react.

In the ILC concept, the phases of invention, innovation, and reorientation are even more important than the traditional market cycle because of the possibilities of influence from the management side.

The limitations of the traditional Product/Market Portfolio can be easily overcome. Special software packages for computing the Technology Portfolio are already available.[21]

One of the greatest advantages of the ILC is the opportunity to structure the demands for information. With the concept of early warning systems, weak signals, and data bases, and with special software, the problem of information can be better managed than in the traditional way.

The IIASA Steel Data Base together with the Event Files represent valuable information with which the ILC pattern could be analyzed and reconstructed for the relevant steel technology. It would be the task of future research to fill the various gaps in data and software and to develop the ILC to an appropriate management tool.

Modern innovation management cannot be effective without the instruments of risk analysis and risk management. An extension of the data base with some software for risk analysis and risk management could improve the results of the efforts. Besides the present files in the data base, an additional risk file could be initiated for the main risk events including product, currency rate, market, foreign country and other risks which had a major influence on the present steel crisis. Klöckner already uses some elements of risk management with relatively good results. The installation of a decision support system for risk analysis in strategic planning could help to implement a functioning risk management in the steel industry.[22]

10. CONCLUSIONS

An empirical analysis of the published accounting data of firms in the West German steel and other industries and interviews with managers show that the classical risk return hypothesis is in most cases a false assumption. Also the announced innovation projects in general confirm the risk return paradox in the steel industry.

Innovation under the conditions of the risk return paradox presents an additional complexity to management which could endanger the existence of the firm. New planning tools extending the time horizon and simulating the coming threats and dangers help to avoid the possible negative consequences of the innovation strategy in crisis situations.

The ILC concept which has already been used to overcome the various shortcomings of the traditional product/market portfolio seems to be a suitable planning and management tool for preparing innovation decision in the steel industry. The present IIASA data base - completed with further events and data sheets with proper software packages - could be developed into a type of decision support system in the context of ILC, making it possible to overcome the risk return paradox in the steel industry.

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Branch : Iron and Steel
Number : 20
Space in Time: 1960–1982

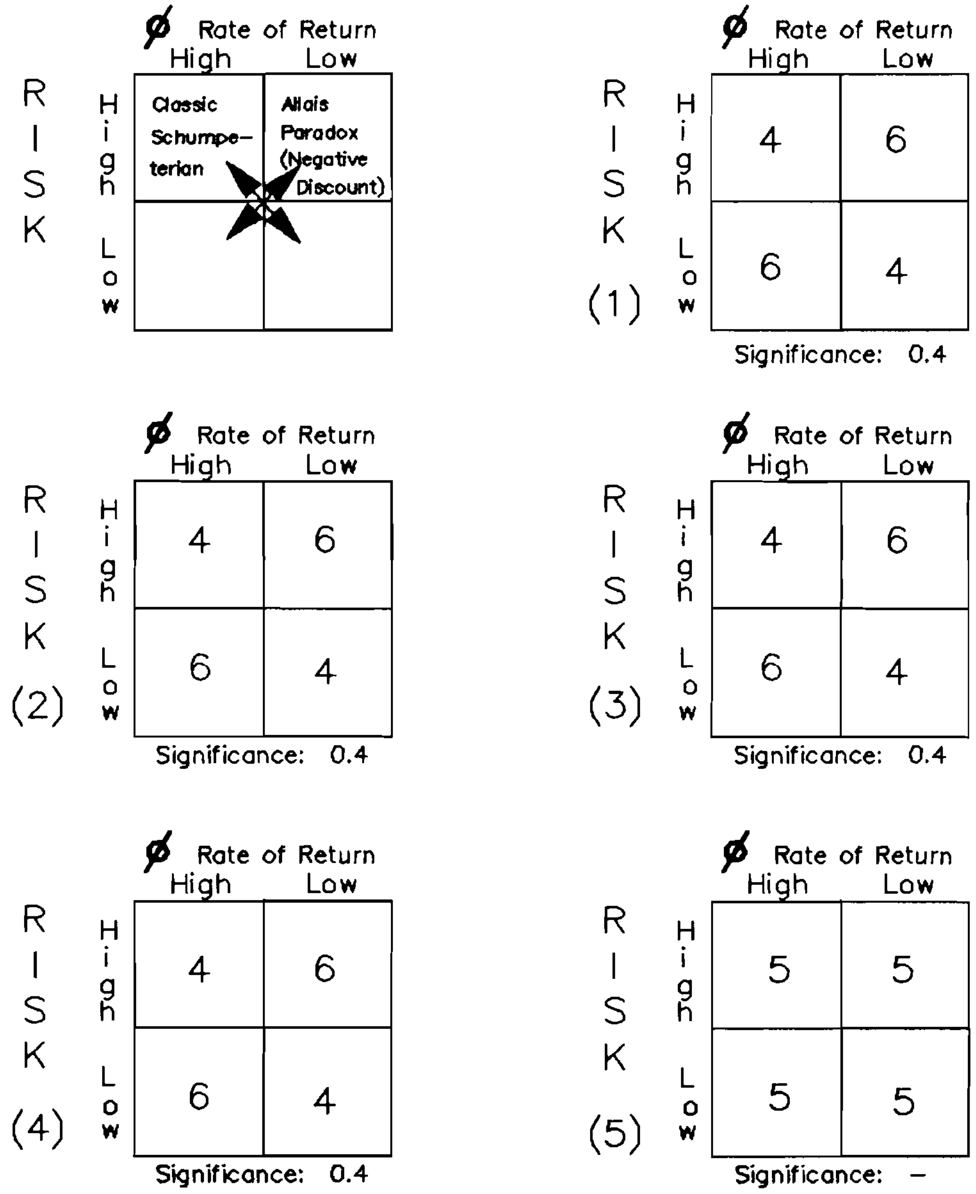

FIGURE 1: Risk/Return Correlations in the Steel Industry of the GFR

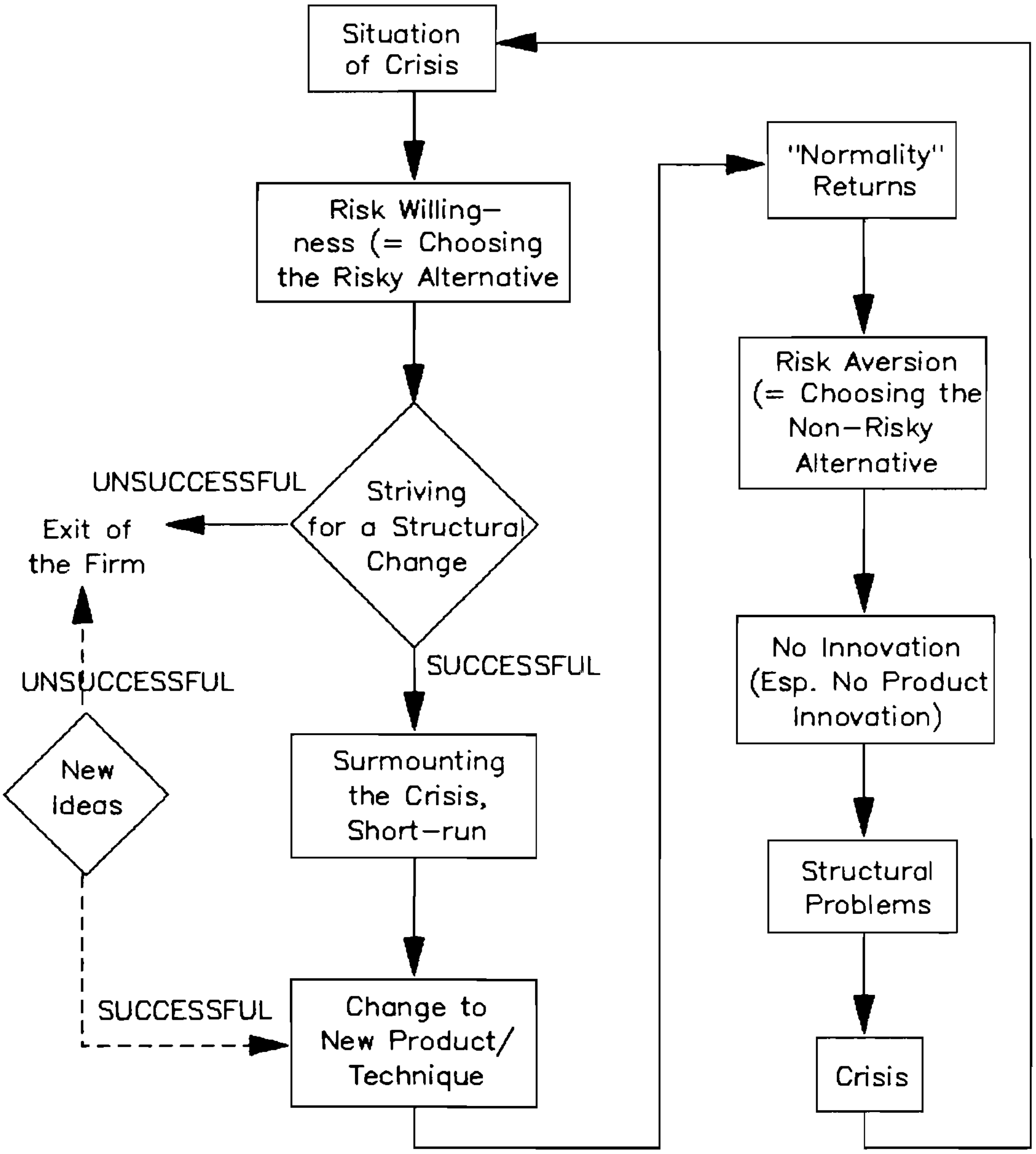

FIGURE 2: Risk/Return Paradox and the Pattern of Innovation Process

TABLE 1: Companies Involved Worldwide in the Development of NCC Processes

COUNTRY	COMPANY	PROCESS
Germany, FR	Krupp	Belt Caster
United Kingdom	BSC	Horizontal Caster
France	IRSID	Twin-Roll Caster
Italy	Danieli	
USA	US-Bethlehem Nucor	Belt Caster
	Alleghany Ludlum Armco National Steel Battelle	Single-roll Caster
Japan	Sumitomo Metals Kawasaki Kobe	Belt Caster
	NKK NSC Kobe Kawasaki Nippon Metals	Twin-Roll Caster
Taiwan		

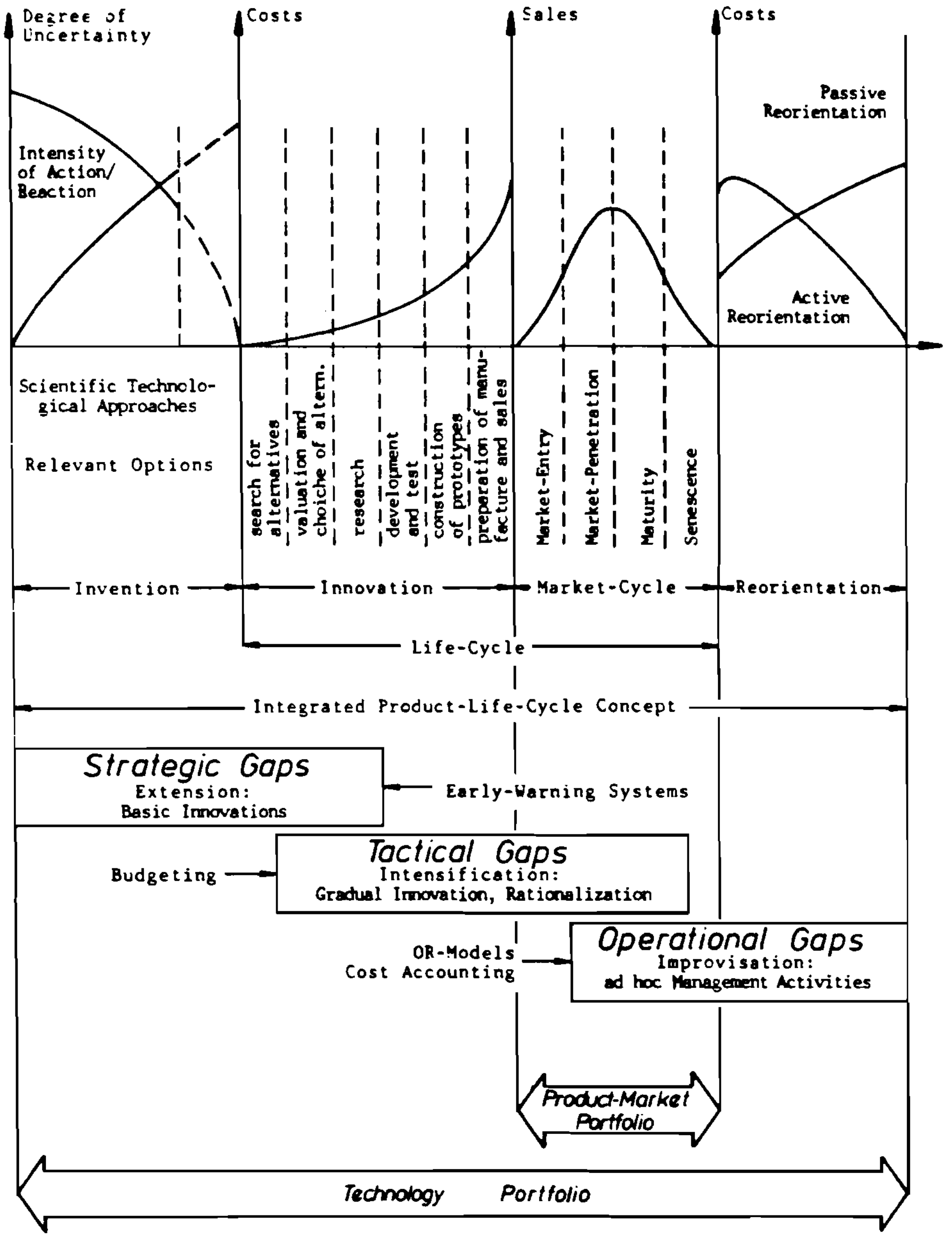

FIGURE 3: Concept of the Integrated Life Cycle

2.4. LABOUR AND SOCIAL EFFECTS OF TECHNOLOGICAL CHANGES IN THE IRON AND STEEL INDUSTRY

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Mr. Chairman, Ladies and Gentlemen,

It gives me great pleasure to address you on behalf of the Director-General of the International Labour Office and to wish the meeting every success.

Important structural changes have taken place in the iron and steel industry world-wide during the past two decades and will most likely continue in the 1980s. There have been major shifts in technology and methods of production, as well as changes in organisation and structure within the industry.

The factors that have shaped the development of the industry can be classified under three main headings: technological factors (technology of various iron- and steel-making processes, and type, quality and preparation of inputs); economic factors (production, consumption, market conditions, access to raw materials and energy, environmental problems, local conditions of development); and social factors (employment, working conditions, training of manpower, occupational safety and health).

The current crisis in the steel industry has to be seen in the context of general economic and social evolution. It is the result not only of cyclical fluctuations but also of significant structural changes and processes, which cannot be put down simply to an imbalance between steel production capacity and consumption. It is quite clear that the measures taken in individual countries or groups of countries to deal with the difficulties facing the iron and steel industry are emergency measures of an exceptional nature. Dealing with these difficulties is not an easy matter. It raises political, economic and social issues. Approaches to these problems vary from country to country, as do forms and methods of industrial organisation and management. This is due to a number of factors, such as differences in economic policy and orientation, system of organisation, technology and scale of production, market conditions and volume of consumption, and the influence of the world market on regional groupings. Differences in tradition, volume of steel production and consumption, availability of raw materials, conditions attending their supply and degree of management decentralisation are reflected in structural and organisational variations within the industry. At the same time, the iron and steel industry in all countries has a number of common structural and organisational features due particularly to its distinctive character as one of the basic branches of industry; these include, among others, its technology, its capital-intensive nature, large-scale output and its dependence on supplies of particular raw materials.

In the development of their iron and steel industries countries usually pass through two basic stages characterised by different patterns of employment growth. In the first stage, the increase in production is achieved by installing "green field" iron and steel plants - i.e. plants built from the ground up in a previously non-industrialised area - and recruiting large groups of new workers. The rates of production and employment growth at this stage of development are, in most cases, comparable.

In the second stage the expansion of production and productivity improvement are achieved mostly by substituting new and more effective technology for the old. Production during this phase rises much more rapidly than employment. This pattern is readily apparent in countries with long steelmaking traditions. In some of these countries a considerable increase in steel output may even be accompanied by a decline in the industry's total labour force.

The measures used to protect jobs or the employment level are of different types; they include in particular direct wage subsidies, subsidies for short-time work programmes, and subsidies to encourage production, the building up of inventories or purchases of goods.

As regards direct wage subsidies, Japan may be cited as an example; in that country the employment subsidy programme has to be seen in relation to the system of life-long employment to which large firms are extensively committed and which is also practised to some extent by medium and small firms.

While the original subsidy programme was conceived primarily as an anti-depression scheme, recently the emphasis has been more on assisting structural change, e.g. the conversion of business activities, and during that process employers are encouraged to keep their employees. The subsidies are also meant to cover the costs of education and training, whether the employees remain with the enterprise or are shifted to other enterprises.

The granting of temporary subsidies in respect of short-time work is a major feature of the system applied in the Federal Republic of Germany, where a public subsidy providing partial compensation for lost earnings associated with short-time work has been incorporated in the Labour Promotion Act. The rate of compensation during the short-time period is 68 per cent of the net wages lost, thus equalling the unemployment benefit rate. The scheme has been applied in cyclical downturns as well as in cases of manpower surpluses resulting from rationalisation and restructuring.

Schemes aimed at ensuring temporary maintenance of employment through short-term subsidies to promote higher output, inventory accumulation or the purchase of goods during periods of slack demand are most advanced in Sweden, which has played a pioneering role in this field. Such schemes constitute elements in an active labour market policy which, together with anti-inflationary policies designed to control aggregate demand and a "solidaristic" union wage policy, compose what has become known as the "Swedish Model".

A number of criticisms have been launched against the various government measures aimed at maintaining workers temporarily on the payroll. One major argument has been that the subsidies have, to a considerable extent, amounted to windfall profits for firms that would have kept the surplus workers on their payroll in any case or would have built up their inventories even in the absence of subsidies. It is also claimed that such subsidies may distort the resource allocation and competition patterns, in particular by favouring the less efficient firms. This alleged misallocation, however, would have to be weighed against the alternative drawback of low-capacity utilisation and mass unemployment. Whatever the merits of these objections and criticisms, they would, at any rate, have to be balanced against the positive impact of the measures taken.

Some of the problems may be traced to lack of administrative experience in implementing such novel schemes. Another criterion for determining the appropriateness of employment-sustaining policies is that of whether the economic changes taking place are cyclical or structural. For cyclical, i.e. short-term changes in the level of economic activity, some form of employment-sustaining policy makes sense to tide the firm or industry over until demand for its products rebounds. However, if the changes are structural short-term measures only postpone the inevitable. It is the realisation that changes taking place in so many industries and countries are in fact structural ones that has often tended to give employment maintenance subsidies a bad name.

Various developments in the technology of iron and steel production have greatly affected the working environment, and in particular the pattern of industrial accidents and occupational disease typically associated with it. In many cases operations involving the handling of hot metal or raw materials are no longer carried out directly by the operatives. Mechanical equipment handles most of the heaviest jobs. Decisions are carried out by electronic equipment instead of human brains. Furnaces, ladles and ingot moulds have a larger capacity, production cycles are shorter, operations are more rapid and more energy is used.

The adoption of quicker and more effective techniques has certainly helped to eliminate accident hazards, the best example being the replacement of manual handling of metal in rolling mills by mechanised systems. The obvious drawback is the stepped-up work pace. With shorter cycles, individual operations have become more frequent and the quantities of materials processed are larger, so that there is greater nervous strain on the worker than there was 10 years ago. Another effect of technological change has been to make the plant more complex. In conjunction with higher working speeds, this means that there are more chances of mistakes in maintenance and repair work.

Traditionally, work in the iron and steel industry has been characterised by physical exertion, stress, heat, noise, dust and exposure to toxic gases. Technological advances have brought about far-reaching changes in the industry, particularly at new plants, in the form of better protection for the workers and lower accident risks. The larger scale on which operations are now carried out and their more rapid pace have called for adaptation on the part of management and employees. While accident risks may have been reduced, the consequences of accidents when they do occur, as well as those of faulty operation and poor maintenance, may now be much greater. Advanced technology also requires a higher level of skills. Problems associated with the working environment are of two main types: those common to many large-scale heavy industries, such as accident risks, heat stress, noise and vibration, and those specific to the iron and steel industry, such as dust and toxic gases.

The right management attitude and good labour-management relations are indispensable in ensuring effective protection of the working environment. It is essential that pollution control equipment be properly designed, maintained and operated so as to cater not only for normal situations but also for peak loads. The processes themselves must be carried out correctly. Proper operation and maintenance call not only for a high degree of management co-ordination and worker co-operation, but also a high standard of training and concern with impressing the importance of environmental protection upon the workforce. All new workers should receive adequate training for their functions as well as medical examinations to determine their fitness for the job, and health education concerning potential hazards at the work place.

In view of its significance for the life and well-being of workers, improvement of occupational safety and health conditions should lie at the heart of any policy to improve working conditions and the working environment, and, over the last decade or so, pressures to improve occupational safety and health standards to that end have indeed been rising, in step with growing concern over the protection of the working environment.

Changes in technologies and methods of work continue to create new hazards, due to the introduction of increasingly complex industrial apparatus and processes, the growing number and quantities of toxic substances used, noisy and polluted working environments, and the creation of new working environments, especially through the development of data processing.
Over the past 20 years awareness of the problems of occupational safety and health has developed considerably in the countries of Europe. This has led to a review of institutional frameworks for prevention and of the methods and roles of the social partners and public authorities in the matter. From this review several lines of approach have emerged.

One of these, based on various experiments made over the years, considers that, in so complex and difficult a task as that of promoting safety-consciousness in industry, the active co-operation of all concerned is indispensable if preventive measures are to succeed. This will inevitably entail gradual changes in the role of the inspectorate, which will have to depend more and more on the plant-level co-operation of representatives of employers and workers.

A second point is that machinery, materials and the working environment are not the only sources of hazards in industry. Others have arisen from developments in structures and working methods and in the organisation of operations. Nervous fatigue and stress have largely taken the place of physical fatigue. The problem is thus one of setting occupational safety and health in a wider context in order to ensure a working environment that will provide workers with complete safety against physical and mental hazards and with a standard of technical protection, occupational hygiene and welfare, corresponding at all times to the technological and social progress of society.

A third point has also emerged: whereas prevention used to be treated as a separate feature added on to the design of a machine, installation, operation or production process. More recently the need for taking account of all aspects of occupational safety and health from the earliest planning stage has received general recognition.

Protection of the health and safety of the workforce is accepted as a primary responsibility by both industry and the public authorities.

The shortening - by stages if necessary - of normal working hours, i.e. the number of hours beyond which work is paid at overtime rates, usually heads the list of demands made by workers' organisations in the iron and steel industry. The International Metalworkers' Federation, for example, in a resolution on reduction of working time adopted by its World Congress, supported the demands for further reductions in daily, weekly or monthly working hours, especially for shift workers or workers performing particularly arduous jobs, and set as targets for their claims the generalisation of the 40-hour, five-day working week and the early introduction of the 35-hour working week in countries where it has already been demanded by trade unions, as well as five instead of four shifts where continuous working is essential for technical reasons. The shortening of the normal working week is, however, the device for reducing working hours that employers oppose most strenuously, while considering it as scarely compatible with strategies to protect jobs.

New forms of work organisation have been a subject of growing interest in recent years. The many varied experiments made in this field, whatever their original motivation, generally have a common purpose: to make work more interesting either by restructuring the tasks of individual workers (for example, through job enrichment or enlargement schemes) or by putting more stress on group or team work.

Improvements in working conditions and the working environment are largely the fruit of experience gained at the workplace by employers, supervisors, workers and their representatives. Policies for the improvement of working conditions and the working environment and for participation by employers and workers thus go hand in hand.

Where occupational health and safety are concerned, the setting up of specialised committees with worker representation is a statutory requirement in most countries, and in some cases has been so for a long time. The past decade has seen a further strengthening in several countries of the role of these committees. They offer a means whereby representatives of management and the workers, together with the safety delegates and, where there is one, the industrial physician, can jointly examine such matters as the problems raised by industrial accidents, pollution, the prevention of occupational diseases, safety and training.

The iron and steel industry is in the process of becoming a "quality industry", offering less "all-purpose" products than products of high value added. This implies high-level skill requirements. The crisis in the industry is thus a matter not only of product quality but of skills, both individual and collective, entailing a need for in-depth transformation. As a result, the extension of the industry to the developing countries cannot be carried out without reference to the most advanced iron and steel industries of the "North", which are now accelerating the rate of their intensive modernisation.

The many technological and operational improvements achieved have transformed skill requirements in the industry. Continuous production processes and the shorter time required for processing ore to iron and iron to steel, and the shaping of steel into its marketable form, have led to a high degree of interdependence between the various production stages. As the plant approaches operation at full capacity, automation and computer controls are introduced to reduce the risks of production imbalances. Generally speaking, transformations of the plant or process and the introduction of new equipment have brought about changes in the workforce by creating new jobs and eliminating others or altering their contents. Although the operation and control of equipment have been simplified and the physical workload reduced, key operators on all shifts must understand the processes and techniques applied, as well as the overall relationship between operations. Technological changes have, in effect, underscored the dependence of the industry on a trained workforce. The new conditions often call for mental rather than physical effort and a capacity to reason in dealing with various situations.

The introduction of new technologies has caused some of the jobs to disappear or to change and new jobs to appear. For example, the introduction of fully automatic conveyor belt charging, electrostatic gas purification and central control stations for gas and hot air blast has eliminated the need for chargers, blast furnace throat supervisors and gas plant attendants. As for the duties of the foreman and assistant foreman in charge of the blast furnace smelting department, they have changed radically. Whereas in the past controls were located at the plant itself, they are now in a central control station. The number of instruments used has increased progressively over the years. Data provided by instrument readings are not taken in isolation, but must be interpreted in a general context so that the necessary action can be taken. The job of keeper is also affected, as he shares responsibility with the foreman for the control of operations. Understanding the information and readings and translating them into action not only is in the interest of production but is essential for the safety of personnel. At the same time, the physical efforts of the keeper's tasks have been lightened. For example, opening and closing the tapping hole have been made easier by the introduction of power assistance. The stove attendant's job has also been transformed: instead of physically checking on the stoves themselves, he operates from a control station. In some cases gauges and remote push-button controls enable scale car drivers to work in a dust-free atmosphere.

Work procedures and supervision have been replanned. On the basis of a programme drawn up by the engineer, operators are now responsible for checking all controls, ensuring that the programme is followed, drawing attention to irregularities and taking emergency action in case of malfunctioning or breakdown. The second charger assists the first, supervises the charge-measuring hoppers and performs such maintenance tasks as eliminating dust in the bunkers and cleaning the weighing apparatus. New processes and techniques have reduced physical labour and have led to the introduction of new skills (e.g. maintenance fitter for hydraulic and pneumatic gear, electronic mechanic for electronic control equipment) and a general broadening of the skills of instrument mechanics.

The main challenge for the iron and steel industry in the future will be to develop a "new" workforce including the training (or retraining) of a sufficient number of skilled workers, technicians, supervisory and professional staff, engineers and managers - and, of course, trainers.

The planning of manpower and training is, therefore, a key element in the establishment and organisation of any industry, including iron and steel. In this regard, some of the principles which have emerged over the years can be summarised as follows:

- Well conceived manpower plans and policies are necessary to ensure that qualified personnel are recruited and trained and made available for each stage in the construction and installation of equipment and, from a long-term point of view, for the smooth and efficient operation of the plant at full capacity.

- The best time for planning training activities is that at which initial plans are being drawn up for the setting up of a new plant or the expansion or modernisation of an old one.

- Adequate plans are required for the timely insertion of manpower at different levels of skill as fresh recruits or as experienced workers.

- Plans for different categories of workers are necessary to meet their legitimate aspirations for advancement and enhance their career prospects.

- Practical and long-range solutions to the many problems related to manpower and training are best sought in close consultation with and between employers' and workers' organisations.

In order to establish manpower plans a definition of the skills required in each section of the plant is needed. Since technology is constantly changing it is not enough to describe jobs by their names: the tasks to be performed must also be specified. This facilitates recruitment, makes for a better matching of available skills to job content, and also makes possible preliminary assessments of training requirements.

Rapid technological change makes it necessary to organise courses for the upgrading of workers aimed at teaching them new skills and expanding their knowledge, in order to increase their versatility and occupational mobility and improve their standard of performance.

The main advantage of in-plant training centres is that they establish an unbroken chain between recruitment, training and employment within the plant. This leads to a closer integration of training with work. Training objectives can be more clearly defined in terms of actual job requirements, and it is comparatively simple to arrange on-the-job and other training within the undertaking.

A major factor in the effectiveness of training provided in institutions or centres is the quality of their teaching staff, who should be sensitive to technological progress and advances in training methods, in particular those concerned with the transfer of skills. Where the centre forms a part of the iron and steel complex, training staff should assist in the identification and training of key workers who will in turn train others.

Long-term training strategies should provide for the replenishment, upgrading and updating of skills to sustain the operation, maintenance and growth of iron and steel plants. Further training is also needed to consolidate the skills and knowledge introduced before and during start-up and running-in, notably through the initial training of workers.

Further training and retraining are vital to the process of plant modernisation, to enable workers to adapt their skill to new equipment and processes. For this kind of training the industry must rely on a combination of its own production facilities (for on-the-job training), training facilities in centres, training facilities at community and national levels, hired specialists and consultants, and training abroad.

Training strategy must be established jointly by the education and training authorities representing governments, employers' and workers' organisations, and other occupational interests concerned within the community. Formal co-ordination is required at two main levels: that of formulation of national training policies to develop the skills required by the iron and steel industry, and that of implementation of training programmes, including curricula, syllabi, examinations and certification.

The whole development process is dependent on the availability of personnel for setting targets, managing operations, implementing programmes and evaluating performance. Much waste can be avoided if development plans, industrial projects and other activities are managed efficiently. Furthermore, enlightened management can do much to promote a safe and satisfying work climate - a major objective everywhere. The training of managerial staff must rely on far more than formal education and training activities undertaken either by institutions or by enterprises. There will inevitably be gaps, particularly as regards ability to solve practical problems of organisation. Knowledge and expertise that are lacking can be made up for in various ways: notably by organising seminars or visits to other enterprises, calling on the services of special consultants, and so on. Many institutions and organisations still see the management development process as merely a series of organised training events, be it in training establishments or within the plant: if more were done to create and expand various types of self-development opportunities, that might reduce the high cost of management training, make training accessible to more managers and make it easier to discover talent that might otherwise remain hidden for many years.

In reviewing the possible development and trends which will affect the training scene in the 1980s, it becomes evident that the task ahead is formidable. Training policies, schemes and programmes have to be reshaped and redesigned in order that millions of people, young and adult, men and women who are looking for ways and means to acquire skills and knowledge may be able to receive training that improves and protects their employability, increases their productivity and incomes, improves their career prospects and generally contributes to better conditions of work and life.

2.5. ASSESSMENT OF THE DEVELOPMENT OF THE TECHNOLOGY AND OF ITS MANAGEMENT: The Bulgarian Case Study on Casting with Counter-pressure

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INTRODUCTION

This paper presents a part of the results obtained during the first stage of the study on the "Management and Technology Life Cycle" carried out in the "Metals Technology" Corporation, on the case of one particular technology -- the Bulgarian technology for casting with counterpressure. The study has been implemented jointly with the work of the "Management and Technology Life Cycle" activity at IIASA. It aims at revealing the regularities of technological development and the interactions between technologies and the development of a system for management.

The pilot technology selected for the first stage of the study was the technology for casting with counterpressure of aluminum alloys, one of the basic application fields of the method.

Elements of the technology are: the machines for casting with counterpressure, the die, and the technological documentation (know-how). The machine is a bearer of the uniqueness of the method, while the die and the technological documentation realize the product technology, and each new type of die is actually a product innovation.

The main goal of the first stage of the study was to trace and analyze the life cycle of the technology; to define its advantages, significance, competitiveness; and to trace the development of the organizational forms of management that have been accompanying the technological development. The study focused on the questions:

- What should management know about technological development in order to orient it correctly and to speed up the process?

- In what way can the theory about the life cycle and innovation processes assist the further improvement of the system of technological management?

DEVELOPMENT OF THE TECHNOLOGY AND ITS MANAGEMENT

The technology for casting with counterpressure consists of the fact that the casting process takes place under gas pressure, i.e. the transportation of fluid metal, the filling of the die, and the crystallization of the casting take place under pressure provided through the compression of air or some other gas.

The competitive technologies of the counterpressure method for casting light alloys are casting under high pressure, casting under low pressure, die casting and vacuum casting. The advantages of casting with counterpressure over its competitors are:

- improved mechanic characteristics of the casting: G_s and G_b are increased by 30%; δ is increased up to three times;
- increased solidity of the casting;
- more economic use of the fluid metal (saving up to 20-30%);
- energy savings of up to 30%;
- increased precision of the casting, which means a reduced need for mechanical processing;
- some ecological advantages, as the process develops in a enclosed space which allows diversion of harmful gases and heat.

The counterpressure method has its area of competitiveness. It is efficient for castings which have to fulfil high requirements for density and strength. In the case of normal aluminum castings, other technologies, such as high pressure casting, are more competitive.

The counterpressure technology has proven to be very vigorous, with possibilities for multiplication. At first it was applied in the casting of aluminum alloys, and later it turned out to be efficient in the casting of non-ferrous alloys, various kinds of steel, and plastic materials. It is also applied in the production of new materials.

The technology is protected with patents and certificates for authorship in 33 countries.

So far, the counterpressure technology has been applied in the electrical industry, in electronics, engine-construction, hydraulics, the car industry, and the aircraft industry.

The concept for this technology emerged in 1956. In 1961, the idea was acknowledged as an invention and was patented. The first laboratory machine was constructed in 1963. In 1966, the first industrial machine was produced. In 1968, the first industrial technology was developed and the large-scale application of the technology in branches of the Bulgarian national economy began.

Different organizational forms existed during the different stages of the development of the technology. In the development stage, a specialized institute for applied research was created as were enterprises for the production of machines and tools. Organizationally, they belonged to one firm. The leading management functions during this stage were the management of investments and the management of technological research.

In the stage of large-scale production, the management functions of marketing and sales developed strongly, because of the need to find efficient areas for applying the technology.

At the present moment, the "Metals Technology" Corporation has an Institute for Fundamental Research which is subordinated also to the Bulgarian Academy of Science. The Institute generates and develops new ideas. The institutes for applied research, using the results from the fundamental research, develop machines with new design and new product strategies. The production units of the corporation produce the machines and the dies for the practical realization of the technology as well as products with this technology. The technological products and the research products are sold by foreign trade and engineering units (See Figure 1).

RESEARCH APPROACH

In order to give management systematic knowledge, it is necessary to study the development of the technologies starting from their creation and continuing with their practical implementation and development. The dynamics of the technology and its characteristics are the objective basis for determining what is general and what is specific in its technological development and what are its stages.

For the purposes of management improvement, it is necessary to test empirically the popular hypothesis, often considered a law, that the management system and its elements change according to the stage of technological development. In this connection, the study was carried out in two directions:

* Analysis of technology dynamics and assessment of the level of the technology;

* Analysis and evaluation of the management of technologies from their creation until their implementation.

The analysis of technology dynamics was based on the concept of the technology life cycle and the stages in its development. Technology assessment aimed at defining the state of the technology compared with its competitors, determining its significance and the extent and directions of its dissemination. The analysis and evaluation of the management of the technology covers the organizational forms, strategic decisions and economic environment.

In accordance with the general concept of the study, the first stage is based on a system of indicators organized into four main groups. These indicators are sources of qualitative and quantitative information about technology dynamics; assessment of the level, competitiveness, prospects, and potential for development of the technology; and identification of the present state and the present problems of the system for management in connection with technology dynamics.

SOME CONCLUSIONS FROM THE STUDY

In studying technology dynamics, the results showed that the technology, in terms of its development within Bulgaria, is in a period of transition to the saturation phases (See Figure 2), having about 20% of the total output of aluminum castings in the country. With regard to its position on the international market, the technology is estimated to be in the transition to the growth phase. This difference in the technology's position domestically and internationally drew the attention of the investigators to more detailed studies on the influence of the scale factor on the life cycle of the technology and its management.

It is obvious that it is not a matter of indifference whether an original technology appears in a large or in a small country. The quantitative assessment of the scales factor in the casting with counterpressure is shown in Figure 3, based on the growth rate of the sales of counterpressure products. The S1 curve shows the development of domestic sales, and the S2 curve shows the sales abroad.

The sales in other countries start with a time lag t from the start of the domestic sales. The t in this technological field is about 7 years.

During these 7 years, about 40-50 new products were developed based on this technology. They have been implemented in all branches of the national economy. The machines and tools for the realization of the technology were improved, experience accumulated, and specialists trained. Production facilities were created for the production of machines and tools and also for the production of products with this technology. The domestic market was developed. At the time of the first sales abroad, the aluminum castings produced with the new technology had already captured about 10% of the domestic market share.

The t, this difference of 7 years between the start of the sales domestically and abroad, is very negative. It slows down the profits from sales on the large international market. What is more, the risk that during this time another competitive technology may appear and reduce the international market for our technology or even capture the entire potential international market for our technology, is very strong.

A more general question can be answered by the life cycle theory: does an original technology, created in a small country, necessarily have to go along the two curves (S1, domestic market curve and S2, international market curve; see Figure 3)?

The purpose of developing a new technology is to obtain maximum profit from the sales of the technology itself or of the products produced with this technology. It is not possible to obtain maximum profit from the domestic market of a small country, because it is limited. Maximum profit can be obtained, however, from the international market. This means that the strategy in the development of a technology and its products must bring them to the international market.

Is it possible to avoid the S1 curve, i.e. to start sales immediately on the international market?

This is difficult because of the fact that the technology itself can hardly be sold there with the expected profit, nor is it possible to find a firm strong enough to invest resources in joint development of the technology, because in the beginning of its development, the technology has not yet proven its high efficiency and competitiveness. Development along the S1 curve, therefore, is necessary, in order for the technology to prove its advantages. We realized that in order to start along the S2 curve, a necessary condition it go some way along the S1 curve.

Then a second question appears: how is it possible to speed up the development of the technology along the S1 curve, i.e. how to make the curve steeper and how to reduce the t?

High rates of development of original and highly efficient technologies, initiated in a small country, can possibly be provided under the following conditions:

* if the state gives priority to these technologies and creates some privileges for their development;

* if the firm which is developing the technology concentrates resources (financial, intellectual, etc) deliberately on

research activities, creation of production facilities, and marketing.

One condition for reducing t is the accelerated development along the S1 curve. The second condition is timely marketing on the international market in order to find potential products which could be implemented and sold on the domestic market.

Important conclusions come also from the analysis of the management system from the appearance of the technology as an scientific invention until the present moment, because a relation between the technology dynamics and the management system is observed. Relating the organizational forms and the stages in the development of the technology, it is possible to make the following observations:

- Different organizational forms existed during the different stages in the development of the technology. Before the stage of large-scale production is reached (i.e. during the development stages), a research establishment, the classic form of managing fundamental research, existed. In the further stages, the organizational forms corresponded to the degree of implementation of the technology and to its market significance.

- The goal throughout all stages has been that each next organizational form should exceed the preceding form in terms of efficiency.

- The organizational forms are more dynamic in the stages which succeed the implementation of the technology in production and its gain of signification market share. They were more dynamic also before the producer worked out a strategy for the development of the technology. During the period of growth, the technology for casting with counterpressure was implemented in a relatively stable organizational form, although its structural elements were developing.

- The organizational forms tend to improve in order to reach a better synchronization within the cycle "research-implementation," and to reduce it. The organizational form which unites science with production assists an accelerated development of the technology and its implementation into practice.

- Some organizational forms must be crated before starting the activities which they will serve.

CONCLUSION

The life cycle concept is an instrument which can assist managers in assessing technological development objectively and tell them what is the present situation of a technology -- in which phase of development the technology is and what its position among competitive technologies is. This is a new method which, along with other methods for analysis and comparison, serves not only to assess the present state, but also to make strategic decisions. In order to create conditions for the speedy development of technologies, it is necessary to know the proper organizational forms that correspond to the different phases of technological development. The match between the process of technological development and the management system creates a favorable environment which stimulates technological innovations.

Figure 1. ORGANISATIONAL DIAGRAM
OF THE DEVELOPMENT AND APPLICATION
OF THE COUNTER-PRESSURE CASTING METHOD

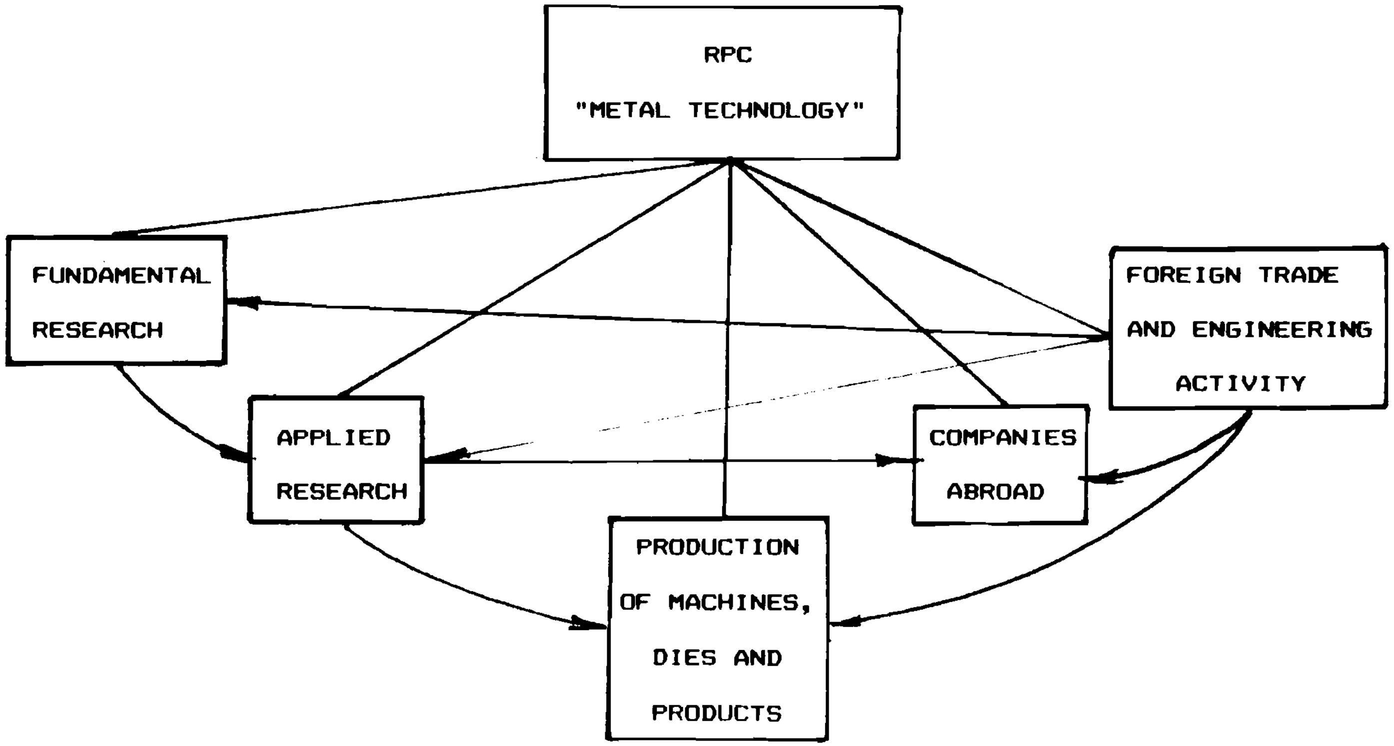


Figure 2. Growth rate of sales

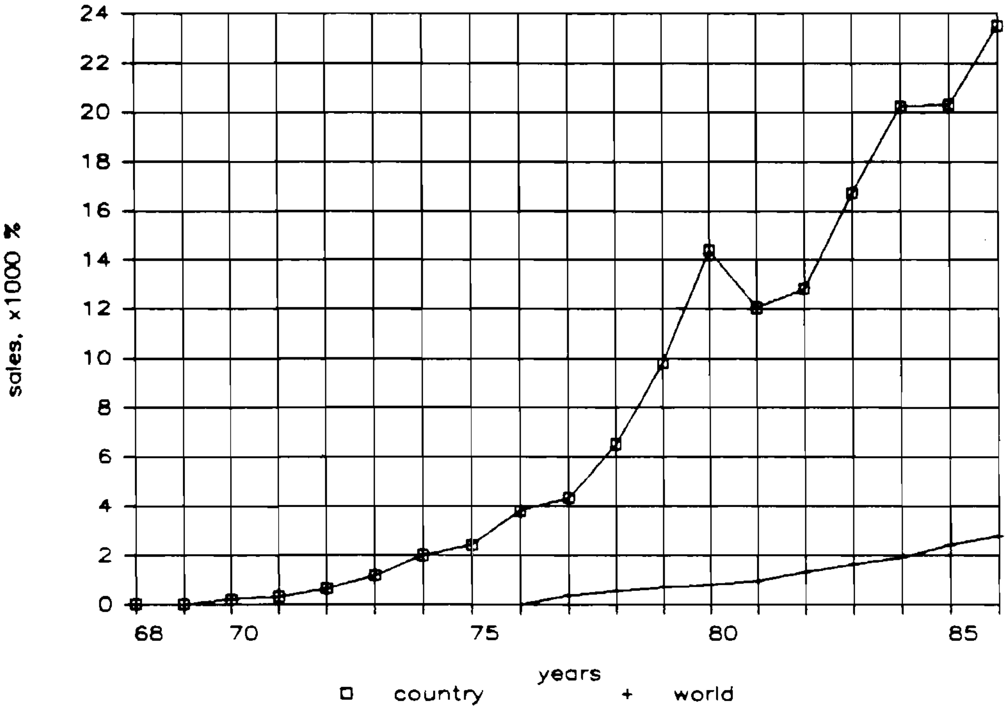
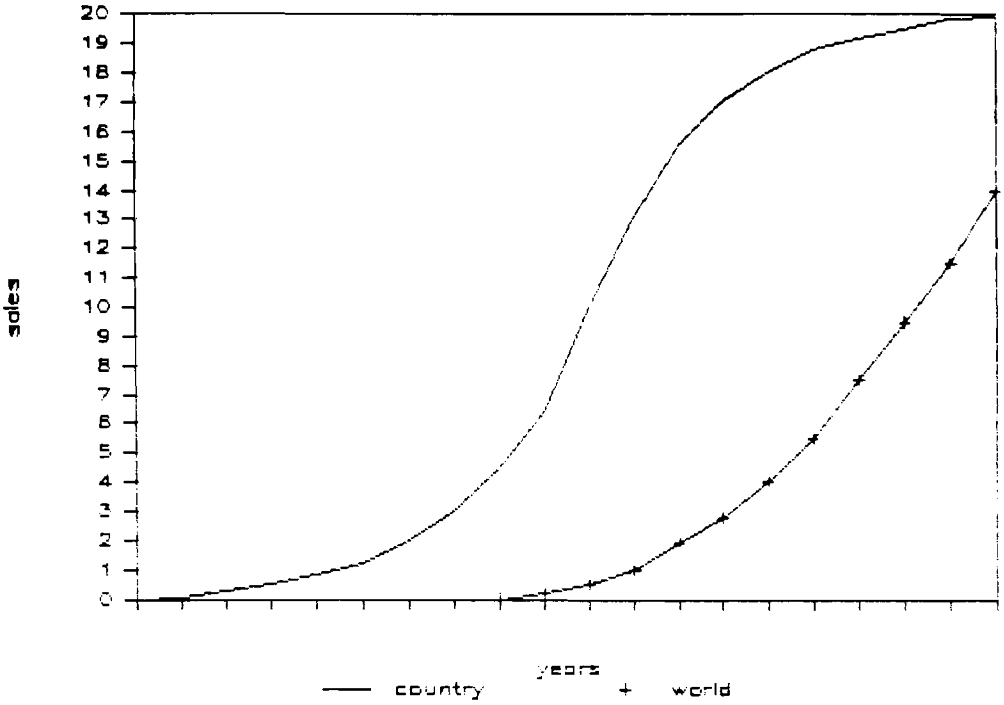


Figure 3.



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+ world

2.6. MANAGEMENT OF TECHNOLOGICAL AND ORGANIZATIONAL DEVELOPMENT IN RESEARCH AND INDUSTRIAL ENTERPRISE "ELECTROTERMIA"

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The world steel production in 1985 was 634 million tons, including 156 million tons electric steel, and a 4% increase over 1984. The forecasts for 1986-90 are to keep the total output stable, but with electric steel increasing annually by 1-1.5%.

Seen against the background of the decreasing or stagnation of total steel output (see Figure 1), the continuous increase of electric steel output and its share of the total is impressive (see Figure 2). This is due to indisputable advantages of the electric arc furnaces regarding production dynamics, capacity to obtain high quality metal, rapid technological development, productivity and level of automatization and computer management, all at the highest level in metallurgy.

The good prospects outlined of electric steel productive give management an opportunity to approach with optimism the planning of development activity aimed at market enlargement for new products and technologies. This is a premise for the technical progress in electric steel production.

Graphite electrode costs are one of the essential elements in the working cost of electric steel. They make up 15-20% of direct operational costs. Their decrease is the long-term goal of our enterprise. An object of this report is the management of this process, its market realization and clarifying the prospects for its development.

The electrode consumption is presented in kilograms of graphite per ton of steel produced. In technological aspects (see Figure 3), it consists of four components:

* tip consumption
* stub loss
* side oxidation
* breakage

The first two are called "technological" by steel producers. They are constant and can be related to the operational parameters of the furnaces. Stub losses and breakages are accidental and to a great extent determined by the skill of the staff and the expertise in choosing electrode quality and diameter. Many researches confirmed that tip consumption is a function of the operational current and normally is fixed in the project for the power performance of the furnace. Side oxidation consumption varies for different furnaces from 30 to 70% of the total. Our investigations showed the side oxidation rate varies along the electrode column from 1.5 to 7.2 kg/m$_2$/h.

In the electric arc furnaces, the electrodes operate at surface temperatures from 1500 to 2100°C.

The technological analysis of every kind of consumption shows that, with the exception of the side oxidation, they are inevitable and it is impossible to influence or reduce them. The side oxidation is useless due to a disadvantage of carbon to oxidize easily over 600°C. That is why 40 years ago, technologists began to look for ways to reduce side oxidation.

In the 1950's, chemists created materials resistant to 1700-2000°C. They conducted many tests with these new materials as protective coating to preserve the electrodes from side oxidation. They used metal powder, calcium carbide, quartz, etc. and tried iron chloride and manganese chloride as well. Because of differences between thermal expansion coefficients of the electrode and the coating, it cracked and fell down. It is proposed to fit a metal net on the electrode and to fill it with a protective material. But all attempts were futile. The statement of Glater, pronounced in 1957 at a congress of electric arc furnaces, is very interesting: "the graphite electrodes consumption demonstrates the importance of the surface losses and gets conclusion that a method of surface oxidation reduction will be very valuable. The researches are performed in laboratories and their end is visible."

What Glater expected was rather optimistic. The protective coating appeared much later and was based on principles very different from those tested.

The three Bulgarian protective coatings were created during the period 1958-1972. In 1972, FOSECO produced non-conductive protective coatings which are deposited under the contact of the electrode column with the current clamp. They have a limited application.

After 40 years of attempts, during the period 1980-1986, many research studies and industrial trials were carried out with so-called combined electrodes, a combination of a water-cooled metal electrode and a graphite one (the last one only is consumable). Such electrodes were developed by the firms CONRADTY and KORF in the Federal Republic of Germany, STELKO in Canada, etc. After many industrial tests, this technology turned out not to be competitive.

The basic reason the coating was rejected by the market was that the researchers had on the way to high melting coatings. As we pointed out, they do not have good prospects due to the great difference of their linear expansion coefficient regarding graphite, which is very low (longitudinal 1.5 x 10^{-6}°C; transverse 2.5 x 10^{-6}°C).

The basic conception of our research group, headed by Prof. Dr. Al. Valchev, is that the coating must have at least one low melting layer (melting point under 700°C), which must smelt before the intensive graphite oxidation and perform its protective functions in a melted state.

During long-term laboratory and industrial research studies, three kinds of coatings were created, representing three stages of development before market realization.

1. Coating of silicon carbide and B_2O_3 (1958-60): It has a perfect impermeability, but low thermal resistance, up to 1500°C. It is also an isolator. But it was used on small furnaces (4 tons) during 1960-62.

2. Coating of SiC and Al: Taking into account the mentioned disadvantages, the low temperature B_2O_3 was shifted by aluminum. The resulting coating increased its resistance up to 1850°C and became current-conductive. In line with good technological qualities, its disadvantage was the complicated operational technology, demanding highly skilled staff. The coating was used in the works where it was created during 1962-64. But this disadvantage banned its market realization, and that is why intensive investigations continued in this direction.

3. Aluminum alloy coating: Based on collected experience and after many laboratory and industrial trials during 1967-70, aluminum alloy was created with Si, SiC, Ti and B, possessing all qualities required for stable industrial operation.

In this stage, the protective coating had gone far beyond the works of its creation. Following this technology in 1970, units for protected electrodes were built up in the Iron and Steel Works L. Breznev, Bulgaria and the British Steel Corporation, United Kingdom.

Regardless of its qualities, this coating finds a limited application. The basic limiting condition is the high investment cost. During 1970-74, a favorable factor appeared in the international conjuncture. The price of graphite electrode rose sharply (as an petroleum product in parallel with oil prices) from 250 pounds/ton in 1972 to 900 pounds/ton in 1977. The graphite price movement is shown in Figure 4. This increase the customers' interest in our product and made a market break-through easy.

In the 1980's, however, unfavorable factors appeared for the market realization of the coating. These included the replacement of part of the refractory for electric arc furnaces with water-cooled panels. The furnace height was reduced, the power schedule changed, so the electrode consumption was greatly reduced. Moreover, electric steel producers turned to two-stage operation as the furnace performed only scrap melting and the refining is realized in a ladle-unit. This changed the rules of electrode consumption with an unfavorable influence on the economic effect of the coating.

To overcome such factors, the enterprise is working in two ways:

1. Perfecting and increasing equipment productivity for producing the coating and
2. Creating new coatings of higher quality.

Our activity on point 1 can be seen from the development of the equipment. In general, the classic scheme from production creation to market break-through is well kept:

* During 1958-70, we operated with primitive equipment demanding low investment and much manual labor.

* During 1970-74, we moved to a conveyor line with every technological operation begin done by a separate machine. Manual labor is minimized, but with increased investment.

* In 1974, research groups, headed by Senior Scientist Vassil Peev, created an universal machine MNE accomplishing all operations with a high level of automatization. During 1975-85, the machine is continuously improved, up to the last model MNE 06M.

* In 1988, we expect to start a computer-managed machine.

On point 2, after long investigations, a new coating has been tested on the furnaces at the Iron and Steel Works L. Breznev. The new product is based on a nickel-iron alloy of aluminum and is expected to appear on the market in the second half of 1987. The new coating ensure a 60% higher effectiveness, and we hope to overcome the market fluctuation of the 1980's.

During the development of the technology to produce protective coatings and the use of protected electrodes, we gathered important experience on some details that were then developed as separate technologies. They are as follows:

1. We utilized the experience from the electric arc treatment to develop direct current heating in metallurgy. This resulted in the creation of a ladle-furnace unit with direct current having important metallurgical applications.

2. Relating to the coating, we accomplished improved construction elements for current contact clamps for electric furnaces. For this, our enterprise has a good market among steel producers.

3. Regarding the normal operation of the contact between protected electrode and contact clamp, we created an "air cushion" sealing device to have the furnace gas exit through electrode holes. This resolves environmental problems in steel plants, and steel producers are very interested in this product. "Electrotermia" has gone on the market.

4. We produce by-products of waste electrodes on a large-scale for the market.

ORGANIZATIONAL FRAMEWORK FOR THE TECHNOLOGICAL DEVELOPMENT OF THE INVENTION

The research work to create protective coating began in 1958. A small laboratory, consisting of one engineer and three technicians and headed by Eng. Al. Valchev, was organized in the Iron and Steel Works Lenin-Pernik. After the first coating was developed, a pilot plant with 4 workers was formed for the experimental production of coatings.

After one successful testing and commissioning, the group enlarged its operation on the frame of the entire steel industry and covered also the foundries in the machine construction industry. For this goal in 1970, a management decision was made to form a "Protective Coating Department" at the Iron and Steel Research Institute, Sofia, consisting of 4 engineers and 8 technicians. A production plant for coated electrodes was built up in the L. Breznev works. Its intention was to cover the entire Bulgarian market and to produce coated electrodes for industrial tests to realize them on the international market. As the department's activities enlarged in many branches (technology, electricity, machine construction, industrial production, and foreign trade), a natural need arose to form an independent organization, and in 1975, the Research and Industrial Enterprise "Electrotermia" was created. It accomplishes:

1. Research activities,
2. Projects for protective coating plants,
3. Projects and production of equipment for protective coatings,
4. Delivery, installation, and start of equipment,
5. Operational staff training,
6. Tests to demonstrate economic efficiency,
7. Training of the staff to serve the coating introduction in steel works,
8. Complementary specialized activities.

The trade activity is performed by a specialized trade organization for license deals on a commission basis. The invention break-through on the international market is being done under conditions of competition with large companies-producers of electrodes. We have to consider our foreign trade policy and technical issues in view of this situation. That is why they both act as a self-formed engineering organization; although formed by two enterprises, it works in common on the specific conditions of the international market.

The invention realization is done principally by license sales of the method and by equipment delivery for protective coatings. Chronologically, the invention has been realized abroad as follows:

1. United Kingdom (1970)
2. Federal Republic of Germany (1975)
3. USSR (1976)
4. Sweden (1977)
5. Czechoslovakia (1978)
6. Canada (1980)
7. Spain (1981)
8. Austria (1982)
9. France (1983)
10. Benelux (1984)
11. USA (start in 1985)
12. Japan (start in 1987)

LIFE CYCLE OF THE METHOD

In our case, it can be described by performance as the Bulgarian production of coated electrodes domestically (see Figure 5) and abroad (Figure 6) as well as by the effectiveness of the market realization (see Figure 7).

It can be seen that in general the market penetration follows the S-curve. If we look at Figure 5 for Bulgarian production, we shall see only the initial trend of the stages "introduction" and "growth." But this is a totally covered market, and every electric steel plant is included immediately as that is determined by the central planning of the national economy.

For the world market (see Figure 6), we expect the aluminum-silicon coating to reach the saturation phase in 1988. Simultaneously, the development of the new iron-nickel-aluminum coating begins. Taking into account its greater efficiency and the well-treated market for coated electrodes, we expect to shorten the phase of rapid growth and to reach saturation in 1996. So we now have a double S-curve for the relative effectiveness, as the second one is forecast for the new product (see Figure 7).

If the expertise establishes that the aluminum matrix has exhausted its potential, we are planning to search for new ways and methods to create products capable of staying on the market.

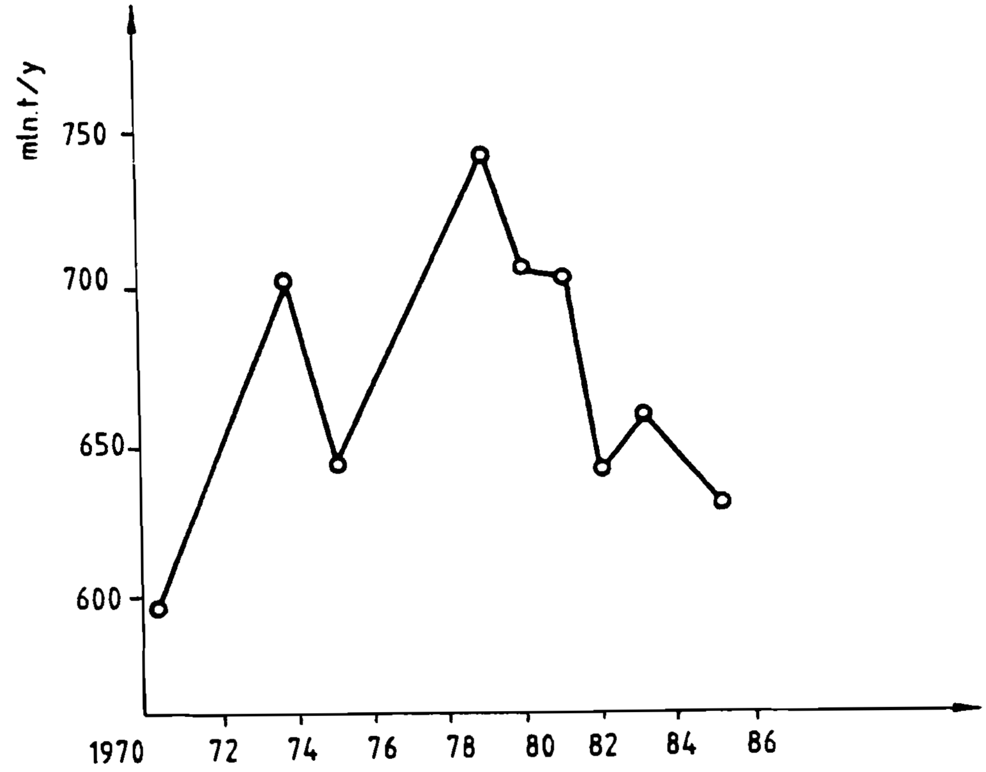

Fig. 1 Total world steel production.

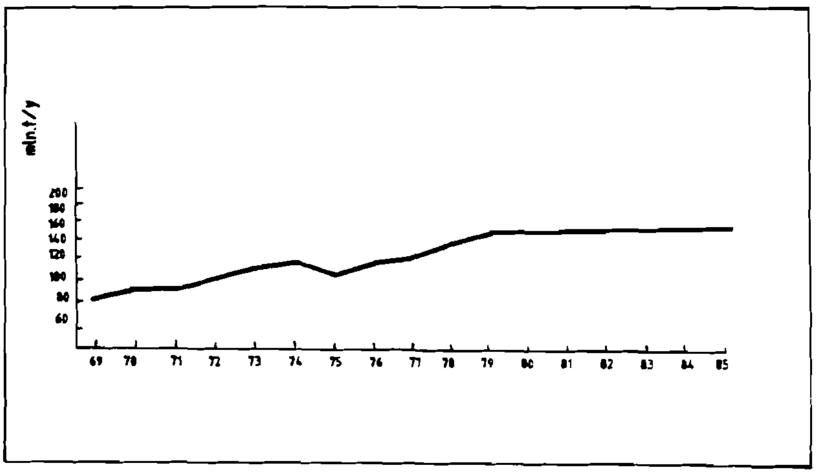

Fig. 2 Electric steel world production

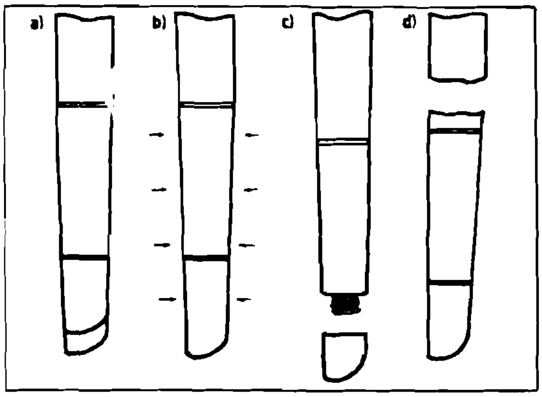

Fig. 3The four most important components of electrode consumption.

a)Tip consumption c)Stub loss
b)Side oxidation d)Top joint breakage

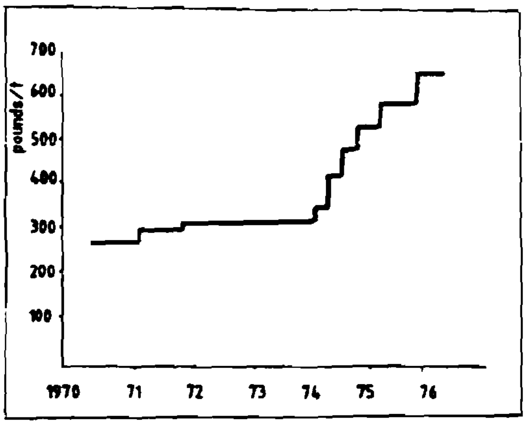

Fig. 4 Graphite electrodes price in english pounds/ton

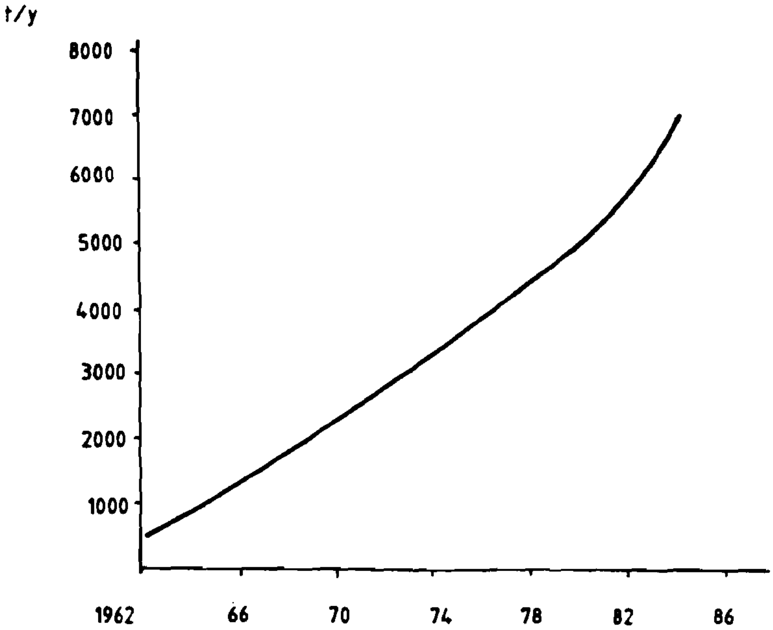

Fig. 5 Coated electrodes production in Bulgaria.

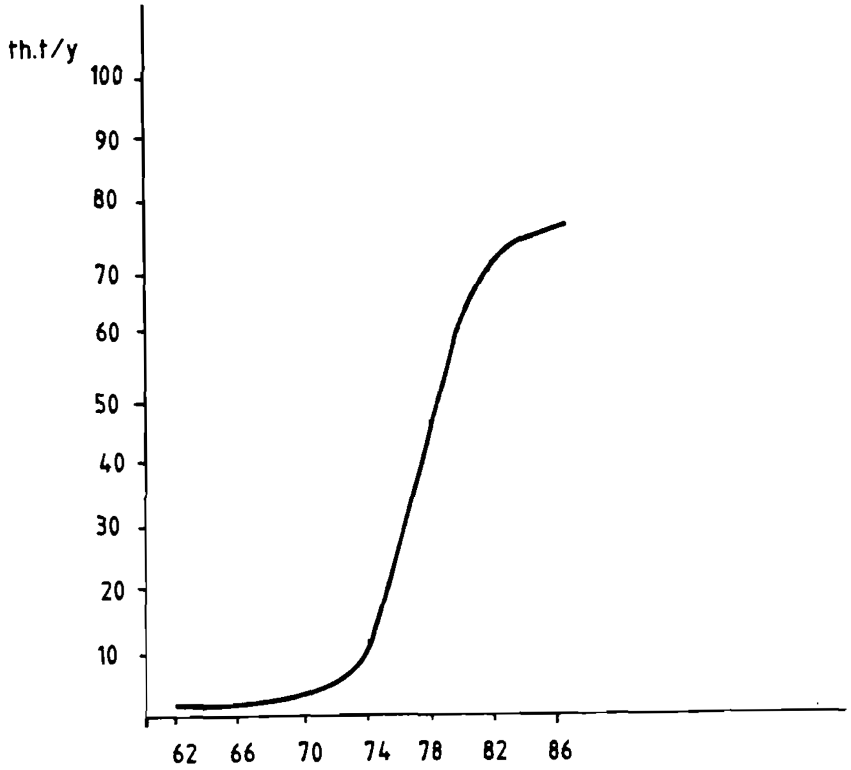

Fig. 6 World production of coated electrodes.

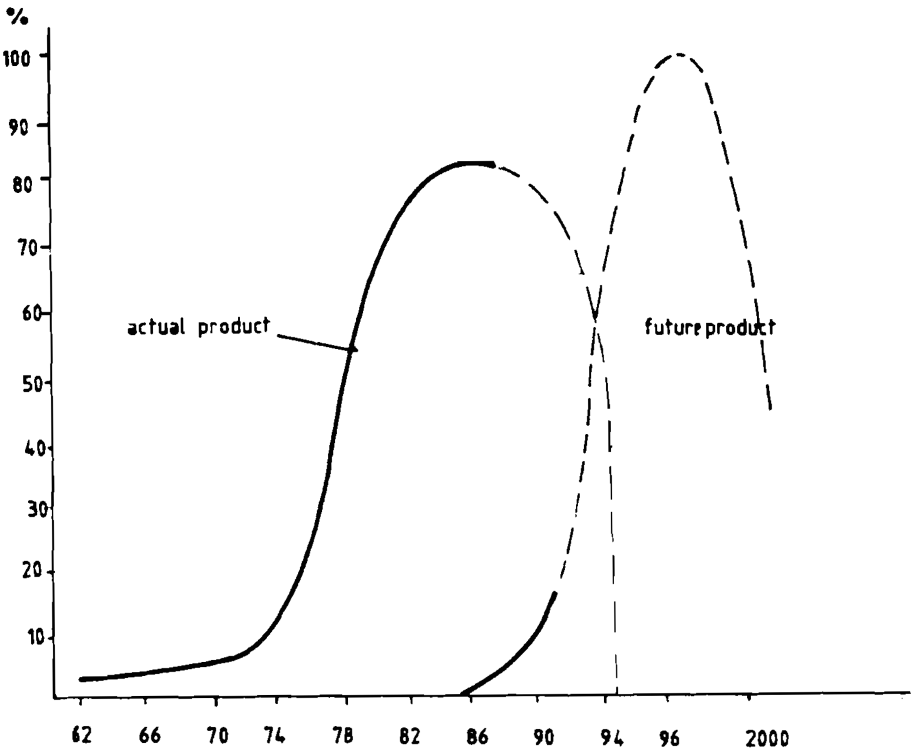

Fig.7 Relative effectiveness of market realization of the protective coating, %

2.7. SESSION TWO DISCUSSION (Excerpts)

Ayres: The latter part of Prof. Goldberg's talk was focusing fairly strongly on the uses of technological forecasting, although he did not use that phrase. I am reminded of the recent book, which perhaps you have seen, called Innovation: The Attacker's Advantage. This book contains many examples of the benefits of guessing right as to when a new technology is ready for adoption and when the old technology is reaching its saturation or its mature phase. However, the methodology of actually determining this is relegated to an appendix and very little is said about it. In the case of the steel industry, are you aware of any formal efforts to forecast steel production technologies, to compile measures of efficiency and forecast them?

Goldberg: Yes, a number of such efforts have been done. Prof. Acs could be most capable in giving you some and as could Dr. Anderson or Prof. Rosegger. There are a certain number of things, for example, many prototypes and developments are being practiced. The GDR has been pioneering, as Sweden has been, with slightly different technologies in plasma steelmaking. In the GDR, there is a plasma steel plant in operation in a Socialist country, which would nullify any prejudice against this type of technology in an old, maturing industry in Socialist countries. In Sweden, there are three different approaches, which means the standard for the industry has not been shaken out yet. But this is definitely one methodology which is forthcoming, and you should not forget the electro as you saw in Dr. Nakicenovic's tables yesterday. The electro steel is not new. but it has undergone many drastic improvements over the last years, and it is the fastest growing new technology which is coming forth.

Anderson: I think your question is really the old exercise. I think the United Nations had years ago a conference in Warsaw where they tried that. We have tried that among the members of the International Iron and Steel Institute, where we ask what they think will be the main processes for steel-making in year 2000, 2050, in a sort of Delphi exercise. It does not work. I find that the steel engineers are perhaps more conservative than others. In fact, if I ask them and I have to make studies on future raw materials requirements, I am entirely dependent on the vision of what the shelf electric furnaces and DRI and blast furnaces will be. Even over the normal planning horizon in the steel industry, which is between 5 and 15 years, depending on the country, I do not get a clear answer. It is very difficult to get some competent people to express a view and really make some technological forecasting in the sense that you are looking for.

Danielsson: I was involved in the development of the Caldo process, and everybody remembers some of this. It is a rotating vessel. As you all know, it was a failure. So why? I was coming to some conclusion that leads into what you said. We had a very good starting point. We had a market demand for better steel. The basic Bessemer, which was dominating at this plant at that time, was not good enough, too much nitrogen, too much phosphates. We needed low cost. We took the liquid steel from one vessel to another. We had a problem with the environment of course. We wanted to use the high phosphorus ore available in that place.

So all of this resulted in the Chief Executive Officer of the company being very interested, the Chief Operating Officer of steel was very positive, and we had a fellow called Calding, who was the inventor of this. "Caldo" stands for Calding and Donner. So we got a process, Calding heated up those rotating things, and we had money. This is important. We had made a lot of preliminary experiments, started on a small scale, and so on, and developed the whole thing. Why did it become then a failure? First of all, the cost was too high. It did not give better steel or gave just as good steel as open-hearth. It was too hot, I would say. Secondly, we did not take a multiple view. If we had investigated what would be the future of iron ore, for example, we could have known at that time that phosphorus ore is out.

Ballance: I was interested in Prof. Goldberg's orientation. I know at least from the U.S. steel industry that the attitude of management until fairly recently has been: "We make the steel, you make the cars, leave us alone and we will do our business." That of course is changing to some extent now, partially because of Japanese ownership as well as the crisis itself. But I think that if we think about it in the context of a life cycle, steel firms have passed through a crisis. In terms of life cycle, the embryonic stage is equally a crisis in any industry. The percentage of failures is going to be very high. Looking at other industries, not being particularly a steel economist, I see that some of the dominant characteristics in the embryonic stage are a large activity of inter-firm collaboration. Vendors may coalesce for an installation in the case of automated equipment and immediately disperse. This type of collaboration is repeated from time to time. The limited literature I have seen on the earlier years of BOF suggest that there might have been similar instances in that case, albeit often personal contacts. When we document or attempt to document the life cycle in other industries, we often look at that.

One question I have is: Is such a procedure practical or would it be relevant in the case of steel, various steel technologies? Could it give us a more definitive history of the life cycle, if practical? Another dimension, I think, is the role of government procurement. At least in the Western European steel industries, state ownership was dominant particularly 15-20 years ago, and remains dominant today. In the industries that UNIDO is looking at today, in the early stages or in the crisis stages, the government is almost always a dominant buyer and also a heavy supporter, albeit not through protectionist measures, mainly because government officials do not know which technologies to protect, but they favor certain ones. Again this could be another characteristic in general that could fit into a documentation of the life cycle.

Well, my main question is are such features relevant coming from an economist who is not a steel economist? One personal query I have, you mentioned that the steel industry is often more labor-intensive than it is capital-intensive. Again, I may be laboring under false assumptions or false limits of measurement, but I come up with the other version when I look at my own figures. Are you thinking for example in the product specific sense, rather than in an industry-wide sense?

Rosegger: I think it would be very useful to distinguish between the notion of capital intensity or labor intensity, which is of course a theoretical notion having to do with factor proportions in a timeless world, and what I would like to think of as factor dominance, which is which input really fits the pace of what goes on in a steel plant. There, of course, quite in contrast to, let's say, an automotive assembly plant or some other manufacturing plant, the pace is clearly not set by the capital equipment, in part because we are dealing with a batch process whose lead and lag times are clearly determined by labor and in part because the very technology embodied in that capital equipment militates against its setting the pace.

The other point I think we very often overlook unless we acquaint ourselves with a given industry is that there is much more flexibility in the amount of labor and the amount of capital that goes into a plant from the very moment when the first hole is being dug in the ground. I have argued that for a long time, particularly with respect to industrial plants in less developed countries where of course the appropriate technology question rears its head again and again. The example also says that even if you have a very modern, apparently very highly capital intensive plant, when it is constructed in a country in which labor is plentiful before you even produce the first product or unit of product, that plant already contains 3, 4 or 5 times as much labor as it would contain if it had been constructed in a country in which labor is very expensive. So there is an awful lot more flexibility there than we economists teach about or talk about when we draw our neat diagrams of factor proportions.

Anderson: I shall draw attention to the differences between different types of economies and between economies in different stages of growth. What I want to do is just briefly speak more about the product, steel. There are many reasons which I have mentioned already that lead to structural change in the economy and the service economy perhaps, and saturation for consumer durables, decline in the investment share, and so forth.

But one other point we should not forget is of course the replacement of steel by other materials. I have over the last 30 years tried to study this subject and find out also for forecasting purposes what is the actual impact, and I have failed each time.

We are now doing another attempt of this sort, where in general terms we want to find out how much higher would steel consumption have been had it not been for the use of plastics, aluminum and other new materials. This time we have tried a trick with the help of some very ingenious engineers where we have taken sector consumption of steel, aluminum, plastics, wood, and cement, and have recalculated the figures from tons onto a strength-weight index and a stiffness-weight index. That means that theoretically you can then add up the total consumption of these materials in a given sector. Then we have compared the development of the material used between two years, 1973 and 1983.

Now if I really had confidence in these figures, which I do not, you could finally calculate how much steel has been replaced by other materials, but I have refrained from doing that because I think it is very misleading. We have looked at the key consumption sectors for steel for countries like Australia, France, Italy, Japan, United Kingdom, United States. As everybody knows, to come by sector consumption data for steel or any other material is already difficult, so there are lots of estimates in there. We have not published this yet; it might still take some time because we have to do a lot of work on it. We have looked at the sectors industrial machinery, electrical machinery, ship building, transport equipment, sometimes we have the automobile industry separately, packaging, household articles, and of course the big construction sector.

For instance, let's take transport equipment. This is the sector where I am really concerned that some new technologies or products could be almost lethal to a great part of the steel industry. Let's look at an important automobile producing country like Italy: the total sector consumption for automobiles is steel, aluminum and plastics (for other countries some timber products as well). In Italy, steel accounted in 1973 for 95% of the total material input, and in 1983, 10 years later, it was still 90%. In Japan, the change went from 87.7% (1973) to 86.3%. Aluminum has increased its share from 3.5% in Japan to 6.6% and plastics from 2.7% to 3.9%. In the United Kingdom, the share of steel has gone down from roughly 78% to about 76%, aluminum has funnily enough decreased in the United Kingdom, but plastics have increased their share from 2.5% to 5.3%.

In the United States, now there I have the whole of the transport sector (we could not get data for the automobile industry separately for all the consumptions). Steel there accounted in 1973 for 80% and in 1983 for 86.5%; plastics have gone up from 2.6% to 4.2%, aluminum from 6.6 to 8%. Now of course in the United States for instance, where one of the main effects on steel use was the down-sizing of the automobile, it is clear that steel (the main material) is more affected because it accounts for 80 or 60 or 70% of the total than another material like plastics or aluminum which accounts for a smaller share of the total.

What I want to say is that although steel is affected very much by the competition from new materials, it still remains the main material in the key sectors like automobile. It will take another product life cycle break-through before it will go away. So far, and I hope at least for my lifetime or the time I will be connected with the industry, steel will hold out for quite a while.

In other sectors like packaging, of course, the share of steel is much smaller. The impact of aluminum, plastics, and glass has been considerable. But there is a constant fight there, and steel is coming back. For instance in Canada, the steel can for beverages has come back because the steel industry has participated in the re-tooling costs of the can-makers and has introduced a connecting system for steel beer cans or other beverage cans as have the aluminum people.

So very often it means that the industry must develop new strategies in order to keep a market share. In other sectors like machinery, steel is unchallenged. Of course, in office machinery, plastics and aluminum are advancing very much, but in any type of heavy machinery, of course, steel is really defending its position very well. If its share, weight-wise being equal, the strength-weight index or stiffness-weight index goes down sometimes, the reason for that is that steel is its worst enemy because weight-wise it increases its service properties very much.

I was surprised to hear Prof. Rosegger say that one of the reasons why his share of hot metal in BOF in the United States was going up was these take-or-pay contracts. Now I am surprised to hear that because the only one I knew for iron ore was the unfortunate involvement of British Steel Corporation Fire Lake. Most of the coal for the US steel industry comes out of their own mines. It is not good enough just to look at what we call direct steel consumption, that is the steel consumption of steel production plus direct imports, minus direct exports. Much better results are obtained, also for the United States, if include indirect trade in steel, that is to say the import of steel-containing manufactured goods, is included. The correlation then becomes much closer.

As GNP has all sorts of odd things in it, if anybody wants to venture again to make forecasts for steel requirements in the future, he had better look, if he can and if he has good data, at the future development of growth fixed capital information.

Goldberg: When preparing Iron and Steel, I asked Volvo, which had just presented its experimental car 2000, the car of the future, if I could use their figures on steel consumption because it would have been a technological forecast of the time. Unfortunately, despite my life cycle involvement in Volvo, they refused so I had to use Mercedes. The then-president of Mercedes said the presentation of the 190 model was the greatest technological achievement in the history of Mercedes. By ordinary production or construction methods, the car would have been 365 kg heavier than it actually was, so it was a quantum leap. This may not be reflected in your figures because the 190 arrived in approximately 1983. In the case of the Volvo car, it of course would be still a more substantial reduction.

This brings me to another example, since you refer to substitution material which I think is very important. Essentially my metaphor for this was to look at the alternatives. One of the most striking examples of life cycles (and not life cycles) is satellites versus cable for message transmission. The satellites had already paid off the cost of reduced transmission costs by 1969. But by 1976, cable had regained its competitive situation. It was breaking even with the satellite transmission, and presently one cable is being placed into the ocean between Europe and United States.

This was something which would have appeared illogical in the satellite development. This is still the old generation, but heavily improved for example by going to digital and reducing the need of amplifiers along the cable. The next generation of cable is almost unbeatable for the satellite. It is optical. It will only need one amplifier station on each side and use the combination of optical and digital technology.

Now I must say something different, in connection with what Prof. Lynn referred to, the Japanese. We are in a kind of collective aging, and he is hoping that the Japanese will be aging collectively. One of the problems of the steel industry in the West has been that the International Iron and Steel Institute has been so excellent in showing the trends of the future, so that the industry has had no reason to look elsewhere.

Anderson: Small companies, these mini-plants or market mills, really only became possible through the development of continuous casting. The great obstacle had been that it was only economic to roll semi's in mills over 1,000,000 or 2,000,000 tons. When the small continuous, the first vertical continuous caster, came with a capacity of 120,000 tons, that was the great break-through for the mini-mill.

Of course, there is a relationship between the size of the plant and the size of the market. For a long while, many mills were in the business of rolling reinforcing rods and bars for a relatively scattered market. It was a niche that they had discovered. They had a limited number of products, and they could produce that in a batch size that was economic. They had, furthermore, the great advantage of having a very small and short command structure. These plants were operated by 60-80 people and were very flexible. They then profited from the general improvement in productivity of the electric arc furnace in the introduction of water-cooled panels and also from the fact that they came into a period where scrap started to become much less expensive than it had been early on. This was because we had been assuming a rapid growth of steel-consuming industries providing prompt industrial scrap and also based on past experience of steel consumption (10, 15 years ago), where through rising living standards more and more steel containing manufacturing goods were scraped and became available for remelting.

Now, of course, the mini-mill is changing. First of all, they have all been growing and that is one of their problems. In fact some have became too big, have also gone into equipment making, and gotten into some financial troubles. But they are all growing. They are growing 1 million tons, 1.5 million tons, and now they are attacking the flat product. Another technological break-through is the casting of thin slabs, which is now starting. That means that they can go on to the flat product sector. But again I believe there is a strict relationship between the scale of operation and the scale of consumption.

The hot-white strip mill was invented because there was a belt conveyor and there was a large-scale press shop in the automobile industry.

Maly: One of the MTL hypotheses is that good management with certain features is one of the main preconditions of high innovativeness of the company. The problem is that if, for instance, Japanese companies had at that time almost similar conditions for the innovativeness in BOF technology, why was a company like Kawasaki with very good management, very young people in top management, with technological backgrounds, and so on, one of the last companies which adopted BOF in Japan. What was the reason why Kawasaki was one of the last companies?

Lynn: I think the case of Kawasaki is very interesting and perhaps instructive. This was one of the fastest growing Japanese steel companies, which picked up in market share during this period. It was headed through most of the years after World War II until the early 1970's by a prize-winning steel engineer, an open hearth engineer in fact. As indicated, this was the last of the major Japanese companies to introduce the basic oxygen furnace. What lesson did I draw from that?

From my interviews, it seemed clear that Kawasaki was almost a one-man company in a sense, despite the size of this enterprise. It was headed by a brilliant open hearth engineer, and at that time Kawasaki may have had the best open hearths around, who saw huge possibilities for improving the open hearth. I think he committed his company to realizing those improvements and perhaps looked down on other technologies. In fact, the people I talked to remember him making very disparaging remarks about the basic oxygen process at the time, that it was sort of a glorified Bessemer convertor and he did not really want to have much to do with it. It strikes me that the bigger lesson from that story relates to where you want technological expertise in an organization.
It seemed to me with the limited number of cases I have looked at that if you have your technical expertise at the very top, there is always a hazard of engineers committing themselves and their firms to the technology they know best. If you have engineers too low, perhaps the company does not make any rational technical choice. At some level in between you perhaps have a management that can draw on the expertise of engineers and perhaps can draw on the expertise of various engineers who have various knowledges.

This had struck me as what happened at the first of the Japanese companies to introduce the basic oxygen process. They had engineers very near the top, but not <u>at</u> the top.

Ayres: What you have just said suggests another interesting aspect of the life cycle which I did not talk about yesterday: the apparent differences in the role of engineers, scientists, pure managers, financial people, lawyers, and so on at different stages. There certainly does seem to be quite a lot of anecdotal evidence that in the early stages of the life cycle of a new innovative product, the managers are likely to be technical people. That is very much the case today in the semi-conductor and the computer industry.

But later on, for various reasons which we might talk about, somehow the role of the engineers and the scientists seems to become diminished and the role of the pure managers, the financial people, the marketing people, and eventually lawyers somehow get involved in the late stages. I find that one of the most interesting characteristics of this life cycle.

Lynn: I would like to make one cautioning comment with respect to the technology we are talking about and those remarks. That is, in steel you have got several different technologies. The basic oxygen process is for steel-making, and there are iron-making technologies and rolling technologies, etc. I am not sure when you have a situation like that with established companies and perhaps some new product life cycles beginning as others may be ending or you may be in different phases of different ones. I am not sure how one would expect the rise of engineers to progress with regard to that, whether the balance of the technologies, whether the technology if you aggregate steel-making, iron-making, and everything becomes important or not. It seems to me it becomes very complicated.

Haustein: A Greek philosopher was the first to look at the world development in cycles instead of a simple linear way of thinking. You spoke about two metrics of time. One was the Newtonian, if I may say so, and the other one was the rather socio-cultural one. But we should be aware also that there exists a third metric, the historical one, a qualitatively different time we should also be aware of.

I have two questions to Dr. De Bresson. The first is the following. I read very carefully your paper, and it was very interesting and helpful for me. You spoke about the proportions and the changes between custom production, batch production, and mass production.

In our country, we had statistics for the metal-working industry. In terms of processing time, there was shown the proportions of batch production, of custom production, and of mass production. Interestingly enough, these proportions did not change over a long time in the past in our country. I suppose that the same was true for other countries. I think the Americans have also such kind of statistics of batch production.

Well, but now the question is the following. What will be in the future? I mean, you have shown that in the microsphere, we will have very fast changes between these modes of production. But what will be on the aggregate level? Will it be the same stability as it was in the past or not? The second question is how do you measure economies of scope?

De Bresson: I was using the concept first of all in reply to Prof. Rosegger of a stock of know-how in relationship to an industry in operation. I think there is no difficulty if you are using the technology to conceive basically that what you learn, you do not forget, and use innovations as indicators of stocks. Because they are sold and continuously on the market, it means that basically you are keeping alive your knowledge.

I just think that it is important to conceive that there are cases when you have people with trade skills that basically humans can forget and individuals move on. But remember that we are animals with memories, we have museums, we have books. Even the mummification techniques, although they are a very delicate combination of skills that the Egyptians had, it seems that we are able to revive at least a pretty approximate substitute of them, although the skill, the basic skill, has eluded us. So I think that if we are going to conceive of know-how either as a flow variable or a stock, we have to clearly put it as a stock. That is the only point I was trying to make.

My example about steel may be wrong, and I prefaced by saying I know nothing of it. It is true that there are examples of a diffusion with the technology not changing much. There are a few in my reading of economic history; they are probably rarer than the ones that change. There are probably factors of diffusion of innovation technologies which are stable, which are the standard economic or other type. Even if my example is wrong, I could find another one which is right.

What I am trying to point is methodologically in a human investigation in the social sciences, you want a theory which you can go from backcasting to forecasting, where you can go from an ex-post argument to an ex-anti argument, where you can have some useful information to try and guide the span of choices.

A way, I think, of going about this is to say ok, we had an oxygen-producing technology, which allows us to try this process. It starts up in 1952, then you have got a number of problems, the pollution, the refractory technique, a number of problems.

Then you can reason strocastically, in other words, condition probability. IF you solve the pollution problem, THEN there are a number of opportunities of adoption possible. So you have a conditional probability model that, having identified the obstacle, the technical constraints, you can say yes, if we solve these problems, we might get to a type of a S-curve. But there are techniques that never take off (and there are many examples in history) because there are blockages, where the sustaining technique is not available and therefore you cannot proceed until much later.

I was interested (this is to reply to the question of custom, batch and line) in Woodward's work in 1959, in her examination of southeast England. She found that 60% of all production was done custom or batch. There are no statistics in the US as to scale of production. There is word going around amongst engineers that 70% of US production is done in runs of less than 100. My hunch is that this is a fairly universal phenomenon, that we have been obsessed with this image of Adam Smith and the pin factory. It seems that there is good reason, if you think of industry as a conflict-cooperation area, that you can have people working in the high margins, custom aspects, but not really in frontal conflict with the line producer, and that you can have people going for a segment of the market, a specialized niche or batch, and there can be co-existence.

I see the custom manufacturer as reaping what has been called economics of specialization. You want something that fits exactly the need of somebody. There is no real cost competition; there is a performance, purely performance, competition. They coexist with people who are trying to reap economies of scope and variations, product variations, and other people who are more specialized in the mass production lines where there are cost reductions.

It would be interesting to rebuild our understanding of equilibrium because it is true that some people react to just price. There are equilibration phenomena in economics with a typology which might extend for much further than these three types, which by the way, I take from Woodward in economic history. I have no idea where it is going to go. My sense is that, and this is just purely speculation, as the part of work which is design-conception increases, the more and more the speed of technical opportunities and innovative opportunities increases, that that would mitigate in favor of getting more flexibility and not locking oneself into line production.

I think this major problem, which is the object of another TES project, is can one combine flexibility and scale economies, can one create this CAD/CAM. There are very few cases of combination of CAD/CAM that I know of as of 1982. I have heard that IIASA's CIM project has gathered quite a few case of computer-integrated manufacturing. But can one ally the flexibility of product variation with economies of scale? If we manage that, it would be extraordinary.

REMARKS (excerpted from Session Two Discussion)

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I would like to say a few words regarding some research I did which seems to bear on the topic of national comparisons. The piece of research I did compared the introduction of the Basic Oxygen Process by the Japanese and the Americans and was based largely on interviews of individuals who were involved in those processes. I think some of the things I encountered relate both to some of the remarks Prof. Goldberg made this morning regarding information scanning and some of the things that management does when it comes searching for solutions or adapting to changes in the environment. I think they relate as well to some of the things Prof. Rosegger mentioned regarding systems and the need to look in a broader sense at the systems in which management may be imbedded as well as the technical systems.

The specific question I was interested in was the one that seems to have been raised as well in the United States, that American managers seem to perform rather less well than the Japanese when it came to identifying the basic oxygen process as a technology that ought to be adopted. One could get into a rather technical discussion of really demonstrating that. But one indicator to me was that in a period in the late 1950's, when there was some reasonable choice apparently, when steel firms around the world were still using open-hearth, that it had not been fully demonstrated that that was not necessarily the best or the worst (or less desirable) way to go. In that period, the American industry was still building a large number of steel plants, as were the Japanese. But in that period in the late 1950's, the Japanese chose the basic oxygen process about two thirds of the time, the Americans about one fourth of the time. So one of the things I was interested in was how does one account for that? Of course there are some economic factors and some adjustments which would be necessary, but this was dealing with plants that were integrated plants, that had blast furnaces, and so some of the obvious reasons were controlled for.

The conclusion I reached was that the Japanese were, partly imbedded in a system and partly because of management styles, much better at reducing some of the uncertainty surrounding the new technology, of coming to a sense that they understood what the problems were and where the solutions might lie. Now some of that relates, as I said before, to the system they were imbedded in, some of it relates to the management itself, as I interpret it. Some of these factors are not necessarily still in place today. Times have changed since the 1950's. But I'd like to just mention some of the institutions involved and then mention some of the management differences that I noted in talking to people.

One fairly obvious starting point in looking at an industry and making national comparisons is the role of government. MITI, the Ministry of International Trade and Industry, has received a lot of attention in the West as a sort of omniscient body watching over industrial policy. In the case of the basic oxygen furnace, this was one instance where MITI did seem to be remarkably perceptive. They were not always so, but in this case, they did seem to be. They had remarkable expertise in-house. Some of the outstanding metallurgical engineers in Japan at the time were in the Ministry of International Trade and Industry. One thing they had then that they don't have now was control over Japanese foreign exchange, which gave them the right to some extent to monitor technologies that were being imported into Japan. Basically, firms that wanted to buy a foreign technology such as the basic oxygen furnace had to go to MITI and get permission. That is where the expertise became very important, because if they had had incompetent people there, it is hard to say what would have happened.

One of the things that MITI did for the industry was that it encouraged the various firms in Japan interested in the new technology to find out everything they could about it, and then when it came to the point when these firms might have been competing against each other and thereby bid up the price to buy the technology, MITI quickly stepped in and said only one firm can go to Austria to purchase the technology. So only one firm would be the conduit, the window as they called it, for this technology. On the other hand, all firms in Japan that wanted to use the technology would be allowed to do so on an almost equal footing, so the advantage of presenting the technology quickly and going to Japan was that one had a little more direct contact with the Austrians and could find out more about it, but no firm in Japan could be kept from using the technology and the price of the technology was the same to all of them, the per-ton royalties that each paid were the same.

The Japanese had a complex arrangement where they paid a lump sum for the technology, $1,000,000 or so, a relatively small sum, and then they divided that up on a lump sum basis, based on how much each of the steel firms had used the technology, so that it cost perhaps half a cent per ton for them to use. So this is one area in which a government institution was involved and facilitated the introduction of the technology and again facilitated the diffusion of the technology within the industry. The result was within 5 years of the first basic oxygen furnace in Japan, all of the integrated steel-makers in Japan had basic oxygen furnaces and were competing, yet were also sharing information in strategic ways.

Another point is related to the suppliers, not so much the customers as was mentioned earlier, but the suppliers. There were some rather interesting differences as well in how the suppliers in the Japanese steel industry helped with the reduction of uncertainty that facilitated decisions to use this new technology. One type of vendor of a sort was the vendors of information, the general trading companies of Japan, which going back to the 1920's had subsidiary companies in Europe, specifically set up to scan a technology, to purchase it, and to bring it back to Japan. Even in the post-war years when they were constrained in their activities, they had metallurgical engineers in Europe watching technological developments. One result was that around two years before the first Alpine BOF was established, the Japanese already had considerable information on the technology, and they had teams coming over to Europe before the technology was actually implemented. So they had very extensive information at an early point from an organization of a sort that does not even exist in the United States, general trading companies.

Another role of suppliers in which the structure was somewhat different concerns the suppliers of refractory brick. In the case of the United States, the suppliers of refractory brick supplied all the firms in the industry and were not trusted by any of the firms for fear that any sharing of information would be conveyed to their competitors. So the American steel-makers who were considering adoption of the BOF had some difficulty running a pilot plant or other experiments, because they did not want the refractory suppliers to know what they were doing. In the case of Japan, the suppliers of refractory brick were closely linked and indeed capitalized by the major steel-makers, and so it was quite easy for them to be invited in to work with the steel-makers to develop brick or to find out indeed if the brick could be developed.

Another key component of the technology was the lamps, the piping that blows the oxygen into the steel. In the case of the Japanese, a joint venture was formed between a major steel company and an engineering company that produced this equipment, so again they were able to experiment with things such as the multi-hole lens, which blew out several streams of oxygen and made it easier to build larger BOF's than had been done in the past. This again is another example. Other things could be mentioned relating to the vessel and other parts of equipment used where the vendors in Japan were more closely linked to the steel companies themselves, and the steel companies themselves did more research on their own than process development, which seems to have facilitated the introduction of the process.

Another kind of systemic organization in Japan which might be mentioned is the trade association. The Japanese received some aid from such organizations as the Japan Iron and Steel Federation and the Japan Iron and Steel Institute. These organizations collected literature from around the world and produced Japanese language abstracts of technical articles, often within weeks of the time they were published. So the Japanese could get articles from "Stahl und Eisen," even people who could not read German or any other foreign language. Engineers could conduct this type of technical research very easily in Japan, and this was not the case in the United States.

Indeed, when I was doing summer research about 10 years ago, I was going to the data rooms of the Japan Iron and Steel Institute just about every day, and at that time they were installing computers and new data sets, whereas when I came back to the United States, I discovered that almost at exactly the same time this was happening, the American Iron and Steel Institute was disassembling its data room in New York. It was selling off the books from their library. So there is this kind of difference in the service provided. Some of it was related to American anti-trust laws, I suppose, in terms of what can collectively be done without some concerns of legal action being taken.

I have mentioned these systemic things that were quite different in the two systems. Some of them have changed. MITI no longer has that kind of centralized control over foreign exchange. Some of these things are not quite the same now, but many of them do continue substantially as before. Within the firm, I think one could go through all the things Prof. Goldberg mentioned. Individual life cycles where the Japanese in the 1950's were quite young executives, division managers in their 30's, something that would be much less true today. One could talk about many other life cycles involved, some of which have changed. But two things struck me as being significant.

One relates again to information collection. Something that was constantly mentioned to me by executives in the American industry where, particularly in the 1950's and 60's, they were just astounded at how the Japanese would come visit their plants, typically in a team of 5 or 6; two things especially impressed them. One was that these Japanese were not vice presidents. The Americans were telling me at the time (this has changed a bit too) that only Americans at the most senior level would get a trip to Japan or Europe because that was considered something of a benefit rather than true information collection. The second thing was that these teams of operating engineers who came through would never repeat the same questions, that somehow there was organizational learning to the extent that if a group asked you something 6 months ago, the next group that came through already knew the answers and did not repeat the question, but asked something new. I've seen reports that were written by Japanese and circulated about their views of various steel plants in the United States or Europe and the comments they made; that information is quite well distributed in Japan.

SECTION 3:

Management Implications, Methodological and Practical Issues

3.1. MANAGEMENT AND TECHNOLOGICAL LIFE CYCLE

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INTRODUCTION

For the successful implementation, development and exploitation of technologies, certain organizational and managerial conditions should be created. How a company can increase its ability to change and how managers are able to manage change, especially technological change, are very important for creating these conditions. The impact of technological change in an organization is usually very broad, complex, and integrative. The more companies are able to cope with this change, the less any inhibiting factors play a role in the process.

The life cycle concept can be useful in explaining technological change. A better understanding of the characteristics of the technology life cycle and of the relation of management systems to different life cycle phases will help to identify the managerial and organizational conditions necessary to manage technological change.

Change can be defined as the introduction or adoption of new conditions or relations within or without an organization. Technological change occurs when a new technology is adopted by a company or when existing technology is improved or modified.

Changes can be radical (revolutionary) or evolutionary. Revolutionary changes occur when basic innovations are introduced; evolutionary changes take place when a technology develops in the course of its exploitation. From this point of view, changes and transition periods between different life cycle phases are evolutionary changes. Technological changes correspond to management and organizational changes. This is of course known to management scientists, but regularities of this correspondence have not yet been deeply studied. How does management change when technology changes, to what extent are changing management features related to different phases of the technological life cycle, and how can this be used as a management tool? These are some of the questions that have not yet been fully answered.

Management and its changes are paramount in this era of technology globalization and internationalization (Razvigorova, 1986). Management can be considered one of the critical success factors in current technological development. Despite protective national strategies and trade restrictions, technologies are today more easily available and more rapidly diffused than two or three decades ago. This is due to rapid scientific diffusion, increased technical collaboration, and new information technologies. The success of today's companies depends to a great extent on the ability of their management systems to select the winning technology at the appropriate time and to create organizational conditions appropriate for its development and diffusion. Many management studies have concentrated on the interrelations among technology, organization and management.

The phases of the early innovation process (i.e., the period in which innovation appears) and the internal laws of innovation development have been studied by Schumpeter, 1939; Abernathy/Utterback, 1975; Mensch, 1979; Marchetti, 1981; Yakovitz, 1984. Innovations usually appear in groups, with a lag between the time of their appearance and that of their implementation (Marchetti, 1981). Some researchers even assume that the discoveries or inventions which develop into basic innovations follow the principle, "first appeared, first served" (Mensch, 1979). Attempts have been made to answer the question to what extent the technology determines the management system and, if this is so, what the regularities are. The relations between structure and technology have been very carefully investigated as well (Woodward, 1958; Walker, 1962; Pugh/Hickson/Hennings, 1969). Their results, however, were very contradictory. At first, a direct relationship between technologies and organizational structures appeared to exist. Later studies proved that this relationship is only indirect and is due to a number of other factors which are less determined by specific technological features. Comparing the structure of companies from one branch (Goncharov/Vasko, 1983), researchers have proven that similar or analogous structures are nevertheless successful (in terms of productivity and efficiency in technology development) to varying degrees.

The organizational structures and forms used by companies to carry out innovation activities to channel a rapid implementation of technologies, or to transfer and develop new technologies have been attracting the attention of managers and researchers for many years. An intensive study of contemporary forms, such as small industries, technological centers, or venture capital divisions, also points to this general interest. To what extent the organization, due to its structural type and flexibility, can cope with changing conditions of technological process and enhance efficiency has not yet been answered. There are indications which show that the organizational and hierarchical structures in current business practice can hardly fulfil contemporary technological requirements. The way to solving organizational problems and creating structures to promote innovation is probably beyond existing traditions and conventional approaches (Miles/Snow, 1986).

Empirically, it has been proven that large companies (Uhlmann, 1977) usually produce basic innovations and that improvements and imitations are due to the activities of smaller companies. In real life, while there are many practical examples of very innovative large companies, there are also examples of large companies which are extremely inflexible and vice versa.

The kinetics of internal conflicts among executives and the influence of leadership style on technology management have proved that dynamic entrepreneurs are risk-takers, consolidators, generalists, risk-adviser controllers or excellent marketing experts who can best serve a company in different situations and phases of technological development.

An accelerating rate of social, political and economic factors are pressuring companies in their technological choices. Faced by the discontinuity of change, it is difficult for many organizations to predict future developments in their environment. The integrative decisions within the company must be able to cope with the integrative impact of external factors. This usually calls for significant collaboration between marketing, production and R&D people and demands that today's manager be a proficient synthesist (Mensch, 1985).

One of the reasons for the greatly varied results of management studies is probably that technology management is usually an object of different concepts. Moreover, it is also usually the subject of separate organizational functions. The problems of managing technology are split between science and its management, R&D (innovation concepts), and production management. In fact, technology management makes it possible to examine and manage the entire technology life existence, from the idea generation to its eventual replacement by a new and more competitive technology. The introduction of the life cycle concept also makes it possible to introduce the concept of technology management.

TECHNOLOGY DYNAMICS -- THE LIFE CYCLE CONCEPT

The study's overall concept is that the development of every technology is a cyclical phenomenon. Technological cycles are regarded as non-deterministic systems driven by causes of a cumulative nature (Sahal, 1981) and can be expressed by cumulative adoption curves, known as S-shaped or logistic curves. Based on the metaphor of biological evolution, the life cycle concept is an economic theory that recognizes similar stages in the evolution of product technologies, industries, organizations, etc. For the purposes of our study, three types of life cycles are relevant: technology, product, and industry life cycles.

The relation between different cycles has been the subject of several studies (Abernathy/Utterback, 1975; Ayres, 1987), resulting in the inter-relations between product and process life cycles as well as organizational and technological life cycles. The technological life cycle is of greatest importance to this investigation. It begins with a technology breakthrough and follows the life cycle of a given technology until it is replaced by a new and better one. The technology life cycle can be investigated on three different levels: world, country, and company (See Figure 1).

TYPE OF LIFE CYCLE	PRODUCT	TECHNOLOGY	INDUSTRY
WORLD LEVEL			
COUNTRY LEVEL			
INDUSTRY LEVEL			

Figure 1.

Technology can have a very broad meaning. For the purpose of this study, technology is regarded as a united set of methods, skills, knowledge, tools, and equipment to produce different goods, services or information. Technologies are recognized as existing in almost all spheres: social, management, marketing, etc., as well as production (hard-, soft- and orgware). Within the production sphere, different types of technologies can be recognized.

Production technologies can be divided into process (generic) and product technologies. For technological development, both are equally important. Process or generic technologies produce completely new products or change, improve or more efficiently produce existing products. New products can also be produced through new combinations of already existing process technologies (See Figure 2).

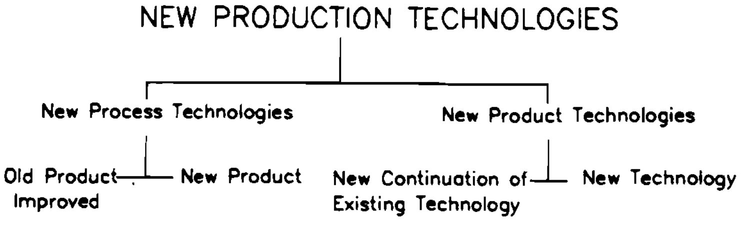

FIGURE 2

Production technologies usually change other technologies such as marketing, logistics, and management. Technological changes are integrative in nature, regardless of the field in which they have been applied.

Technology management should be the main scope of analysis in order to study the complexity of management problems. Technology management takes into account the implications of accelerating technological and economic changes and of organizing technology implementation and exploration. This is a complete cycle which concerns a specific object of management, that of technologies within the system (company or country). Technology management is considered a field linking engineering (and other natural sciences which produce technologies) and management in order to plan, develop, and explore technological capabilities and to help companies achieve their strategic and operational objectives (National Academy of Sciences, Washington, DC, 1987). Within the scope of technology management are different management functions: strategic planning, operational management, control (See Figure 3).

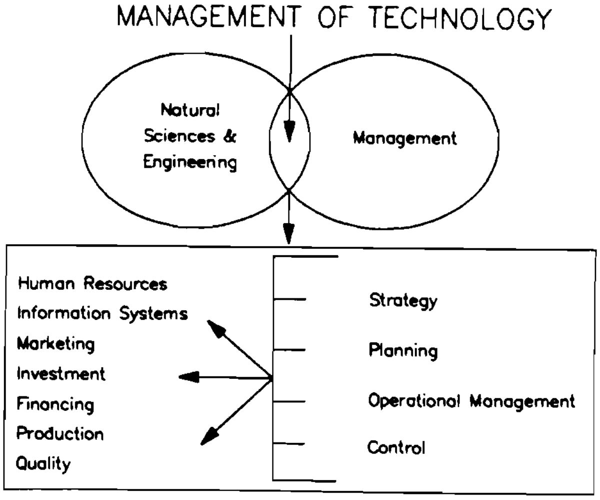

FIGURE 3

Analysis of technology management makes it possible to integrate innovation management and production management during different phases of technology evolution (See Figure 4). Based on the above concepts, the study assumes that economic and performance characteristics change along the technology life cycle as does the management system. Different management characteristics (strategy, structures, control, etc.) should be described in different phases of the life cycle, based on which management changes can be analyzed and defined. Management systems during different phases of technological life cycle, especially during transition periods, can be elaborated as well as differences and similarities.

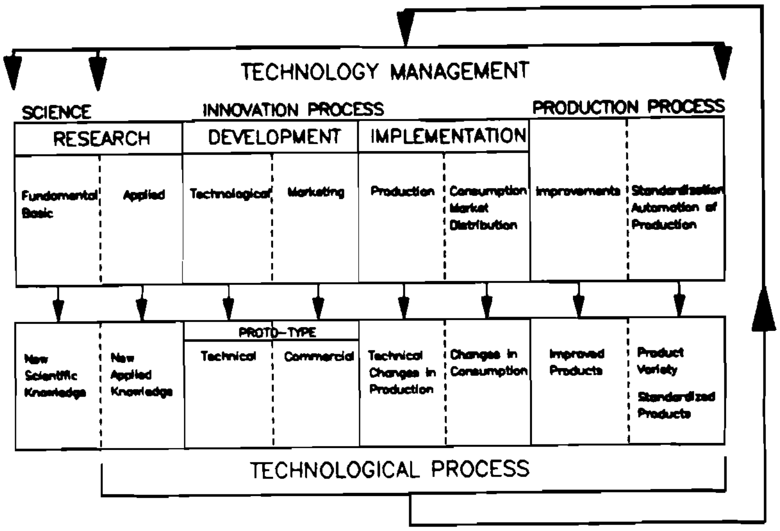

FIGURE 4

To compare management and organizational features and study their dynamics, the S-shaped curve should be divided into phases. Concerning the names, numbers and boundaries of phases, eleven concepts have been taken into consideration. The conclusion is that a lack of statistical data for some phases does not permit an accurate estimation of the phases' boundaries. As a result of the rather poor amount of empirical evidence on distinct technological life cycle phases (DeBresson/Lampel, 1985), only a few indications have been received (Ford/Ryan, 1982; Cleland/King, 1983; Meffert, 1980). Qualitative descriptions should be used for that purpose as well. The number of phases should be rather small. The following phases have been adopted for the study of technology development: implementation, take-off, growth, maturity, and post-maturity (senescence) for some technologies.

The first two phases are very difficult to define. This is especially true at the company level, where there is a marked lack of information about the duration and other economic and technical characteristics of the innovation process. For the purpose of our analysis, the first two phases will be described very broadly, and the life cycle itself will be analyzed in the other four phases.

- **TECHNOLOGY DEVELOPMENT PHASE:**
  - Boundary: Research indicates a potentially valuable technology; decision made for technology-oriented research.
  - Event: First (research) costs occur connected with new technology, decision made to invest in new technology, construction of prototypes, purchase of license.

- **IMPLEMENTATION PHASE:**
  - Boundary: First Output
  - Event: Losses are still accruing from the new technology; construction of an improved model.
- **TAKE-OFF PHASE:**
  - Boundary: Effect of scale of monopoly; many fields for application; sub-market penetration.
  - Event: Losses still possible; high risk investment; stream of parallel inventions or improvements.

- **GROWTH PHASE:**
  - Boundary: First profits accruing, break-even-point passed; first follower on the national market/first buy of license produces output.
  - Event: Imitations; technology penetrates through the market.

- **MATURITY PHASE:**
  - Boundary: Point of inflection of output curve passed; first turnkey deal.
  - Event: Further increase of (national/world) market; large-scale automation.

- **POST-MATURITY PHASE:**
  - Boundary: Maximum of output curve passed; substitution processes; license agreements expire.

TECHNOLOGY MANAGEMENT - THE SYSTEM APPROACH

In the absence of a powerful theory able to incorporate the results of previous studies and information concerning technological development, systems theory and a systems approach can help to synthesize different analytical results and to focus on certain questions or a combination of various aspects to achieve an integrated and broad theoretical view with practical applications about technology and its management. The systems approach permits a step-by-step analysis and study of separate system elements and their relations, while connecting the whole system. Based on that, a simple model of technological development and its management can be built (See Figure 5).

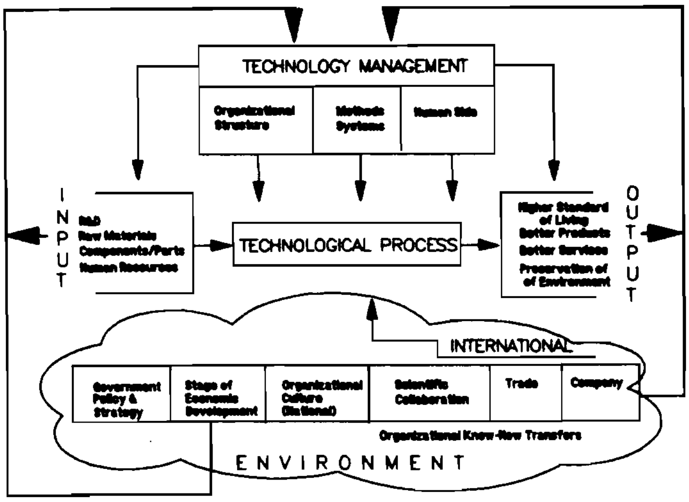

FIGURE 5

In this model, technological process embraces the activities of creation, development, implementation, exploitation and eventually replacement of one technology or group of technologies. The internal structure of this process can be described through different models (life cycle, research-production cycle, etc.). The impacts experienced by the technology selected for our study, during the stages of birth, growth and maturity differ in nature, intensity, and direction. But they can be integrated and expressed (as is shown in the model) in the following way:

Input: the input to the process of technological development (technological process) is defined by the resources necessary to be used in this process as well as by their availability and the ability of the system to spot and use them efficiently. Those resources can be described as R&D efforts or activities, even as the R&D level of the environment (i.e., the ability of the environment to carry out R&D activities through which new technologies in the field can emerge, including the intellectual input to the process). Skills needed in the process to make the new technology work as well as to improve already existing technologies are also considered as an input to the process (i.e., availability of various skilled personnel and organizational settings for their education and training). New raw materials with better quality, easier procurement, and lower cost are essentially important as a main input in the process. Ideas of any kind are also very important.

Output: the output of any technology should be described as a product or service with higher quality and greater value as well as a better standard of living for society, better working conditions, greater environmental protection (in some cases, even its restoration).

Both the output and input of technological processes should be managed by the company. It is important to study to what extent these factors depend on the environment and to what extent the company is able to forecast and manage them.

The environment plays a major role in technology management. The main factors influencing technological development and its management outside the system (company, country, or industry, etc.) can be summarized in the following groups:

- Stage of economic development: characterized by the level of industrial and economic development of a country, region, or economic system which either facilitates or inhibits the technological development of the system under study. A well developed infrastructure and favorable economic conditions can facilitate the introduction, development and exploitation of technology.

- Organizational culture within the environment: can play an accelerating or inhibiting role in the development of technology. This influences the style of the system and individuals working in it through the value system and cultural habits. Society's learning curve for managing big organizations and technologies is also connected with the stage of industrial and economic development (nations with a short industrial history have no accumulated organizational and managerial experience and habits, which in any case does not facilitate technology management itself).

- Government policy and strategy: the participation of government in financing different technological ventures as well as the organizational settings created to facilitate the procurement of various types of inputs to the process has an important impact on the technological process.

- International scientific collaboration, trade and production: results in extensive scientific and technical cooperation between countries and research organizations. Many new technologies are already resulting from the work of specialists in different countries. Therefore, technologies are more easily available to different systems than decades ago.

- International trade through the exchange of goods, operational know-how, services and knowledge: provides easier access to some of the process inputs for companies and countries.

- International cooperation: one of the main reservoirs of new technologies and all types of innovations. Technology transfer between countries as well as between two economic systems is a growing phenomenon despite political and economic difficulties. These conditions advance the problem of transferring managerial and organizational know-how as well.

Based on the above concept and model, the study hypothesizes the following:

Technologies require for their development and exploitation similar conditions and experience similar impacts, not because of their technical nature and characteristics, but because of the stage of their development (rate of novelty) and the source of their procurement (inside or outside the system).

Companies behave similarly during the various phases of the technological life cycle. This makes the life cycle an instrument for company technology management.

The life cycle model is one of several possible models expressing technological development. Its phases can be used not only to study the dynamics of technology, but also to study the dynamics of management and organization.

Management is influenced by both internal and external factors which change the impact of the technological life cycle. Technological life cycles at different levels have different impacts on company technology management.

To check the elaborated hypothesis, a pilot study concentrating on the steel industry was undertaken. The following methodological issues were taken into consideration within the pilot study:

- Specifying the technological life cycle on three different levels (company, national, and world) and the boundaries between the various phases to serve as a base of comparison and analysis of management dynamics.

- Describing technology management, concentrating on strategy, by developing sets of variables.
- Creating an appropriate data base necessary for performing analytical and empirical investigations.
- Elaborating and selecting appropriate methods (mathematical, statistical, and others) which will result in useful findings.

Data to describe management must be selected very carefully because much of it is so-called "soft data" and very difficult to quantify. According to recent research (Sciberras, 1986), all commonly used indicators of R&D activities suffer from severe limitations (in other words, value to wait ratios of finished products, R&D expenditure, number of R&D employees, patents and licenses, rate and direction of technology flow). Furthermore, a reliable understanding of the role of management can be obtained only by combining quantitative data with more qualitative sector-based research. Different studies use a number of different kinds of data or indicators to describe management (e.g. Goncharov, 1982 and 1983; Jamielson, 1980).

The study has developed a set of variables constructed in a way that allows technology management to be described in countries with both centrally planned and market economies (See Appendix).

Two approaches in choosing variables describing management and organization are possible. The first is to choose qualitative variables which reveal organizational behavior. Qualitative variables make it possible to evaluate the relations of the technology development process in a given organization to such tangible factors as management style, methods and environment. The second approach is to choose variables which can be measured quantitatively and mainly indicate company performance, such as economic efficiency of implementing a new technology, resources allocated to R&D or technology change, and so on. The results of each analysis permit us to draw qualitative conclusions about the efficiency of technology management, but it is difficult to draw conclusions about the nature of the organization's behavior towards the environment and the pattern of management itself.

The combination of the two approaches will create a better appraisal of the efficiency and usefulness of the management system in a given organization regarding technology.

Over 50 different variables expressed through various indicators and applied in various combinations are being used most frequently in the field of innovation management and technology management.

Seven groups of variables were chosen to describe the company in general terms, the technology under study, economic performance and results; parameters were selected to describe the functioning of the organization's management system through strategies, structures, and also environment impacts. The list can provide a common framework to study the dynamics of management and organization and changes in both in connection with technology changes. This list is a basis for developing precise parameters for specific research tasks and objectives, specific conditions of different technologies under study, and specific countries participating in the research (i.e., this was the basis for developing a special methodology to investigate new original and license technologies in Bulgaria). The list should be considered as open; other variables and parameters can also be included.

SOME PRELIMINARY EFFECTS AND CONCLUSIONS

A pilot study was designed to check the elaborated methodology. As an object of analysis, the basic oxygen furnace (BOF) steel technology was selected. The reasons for this choice were as follows:

- The steel industry is well documented in many countries (including all IIASA member countries).
- The steel industry is considered to be a mature, even senescent, industry and can be used as an example to demonstrate explicitly the entire range of life cycle phases.
- Several types of steel technologies changed and were diffused through many countries and companies in the last century.
- The data base can be supplemented by much information from literature and previous IIASA studies to save time and personnel resources.
- The BOF technology was first introduced in Austria by Voest-Alpine in 1952. About 30 companies then adopted the technology in its early stages. These "early adopters" are chosen for more in-depth study because we consider them to be companies operating in a favorable environment encouraging the introduction of new technology and under management able to spot and pick up a new technology. The suggested approach of defining the first (take-off) phase of the life cycle was the achievement of a 10% technology diffusion rate (Tchijov, 1987).

Data (quantitative and qualitative parameters) were gathered through company records including annual reports, questionnaires, statistics and literature. The data base has been constructed and is ready to perform cluster analysis through which differences and similarities in company behavior can be elaborated. Qualitative information concerning the type of strategy employed during the period under study (1950-1985) is also available (See Appendix) and will be analyzed based on expert judgement.

The elaborated methodology allows us to draw the following conclusions:

1. The use of the concept of technology management makes it possible to analyze the entire process of technology introduction, development and exploitation. This allows us to study more deeply the integration existing within the system and focuses the attention on management synthesis of that phenomenon. In this way, some of the difficulties and imperfections of branch innovation studies as well as a separate analysis of innovation and production management are overcome.

2. The study of technology management dynamics analyzes the changes occurring in transition from one phase to another as well as the changes due to changing economic conditions and social environment. This can serve as a basis for conclusions about the management of technological change.

3. Cross-country analysis of technology management, despite national cultural and economic differences (or maybe because of them) can provide useful results to facilitate the process of transferring operational experience and organizational and managerial know-how.

4. A systems approach to the study of technology management will permit an analysis of the relations between system elements and an integration of results from other studies. This approach will also permit different objects to be studied and analyzed within the same framework using the same approach and methodology.

The defined changes in organization and management of different groups of technologies can make it possible to foresee changes in management and organization. Such predictions can be used to develop new management paradigms.

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3.2. INNOVATIONS, INVARIANCES AND ANALOGIES: COMMENTS ON THE LIFE CYCLE THEORY AND THE FORECASTING OF FUTURE TRENDS IN FLEXIBLE PRODUCTION AUTOMATION

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1. INTRODUCTION

Modern production automation, including flexible production systems, is (FMS) usually considered as a major ingredient of the solution to many structural problems of the manufacturing industries. It has sometimes had a dramatic influence on production economy: delivery times, lead times, storages, capital use, utilization rate etc. (Bessant et.al., 1985, Horn et.al. 1985).

However, flexible production systems and advanced production automation with computer integrated manufacturing (CIM) have so far been applied mainly by large and/or the most progressive companies. The diffusion of FMS (and CIM) concepts has been rather slow and in fact the flexibility of FMS has not always been as great as expected (Jaikumar 1986). Thus it can be projected that the utilization of FMS, and of production automation in general, depends on the development of the technical properties of FM-systems or on the flexibility offered by the technology itself, and on the other hand to a great extent on how the benefits can be realized during the application design of the production automation system.

Because the realization of the potential benefits of FMS seems to be more a social or an organizational question than a pure technical question, it seems worthwhile to study FMS in context of the innovation management. Furthermore the concept of flexibility has a wider meaning than a production technology - realated intepretation. Flexibility seems to have a central role when an assessment of different company is made. Moreover the technological life cycle concept is interesting to be discussed from the point of the view of FM-systems development.

It is therefore also realistic to relate FM-systems and modern production automation to the concept of production flexibility and also to estimate what kind of technological advances (including organizational innovations) are needed to increase production flexibility and what innovations are necessary to assist realization of the benefits during the design of FM-systems.

The second interesting question is the role of the small and medium scale companies. It seems apparent that the life cycle theory is quite toothless in describing of the technology management in small and medium scale companies.

2. THE LIFE CYCLE MODEL REVISITED

The life cycle model has had a central role in describing the evolution of a product from infancy through growth and maturity to decline. Originally, the model was developed as a framework to support innovation and product management. The model is usually extended also to describe the evolution of an industry or a branch of industry (Porter, 1980).

The different stages or phases of the life cycle model are: conception, introduction, growth, maturity and decline (or conception, infancy, adolescence, maturity and post-maturity according to Ayres (1984)). The essential point is that the product or the industry evolves through these stages and that each stage is characterized not only by the product itself, but also by production technology, marketing technology, research and development activities, etc.

Table 1 summarizes the phases of the life cycle theory (Ayres 1984).

Table 1. Summary of the modified life cycle theory (Ayres, 1984)

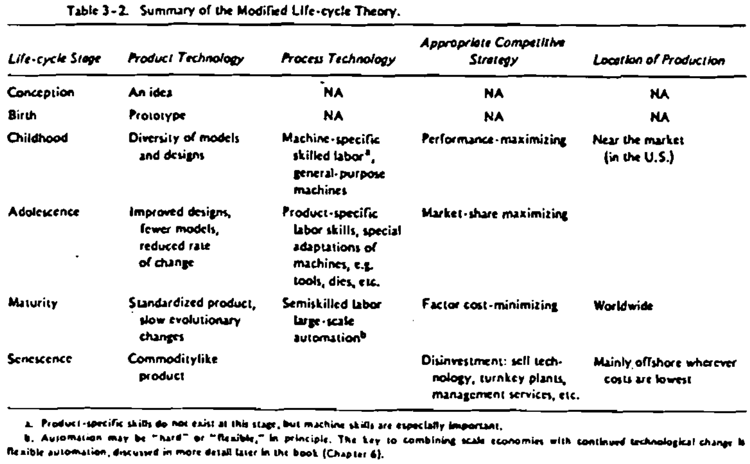

Table 3-2. Summary of the Modified Life-cycle Theory.

Life-cycle Stage	*Product Technology*	*Process Technology*	*Appropriate Competitive Strategy*	*Location of Production*
Conception	An idea	NA	NA	NA
Birth	Prototype	NA	NA	NA
Childhood	Diversity of models and designs	Machine-specific skilled labor[a], general-purpose machines	Performance-maximizing	Near the market (in the U.S.)
Adolescence	Improved designs, fewer models, reduced rate of change	Product-specific labor skills, special adaptations of machines, e.g. tools, dies, etc.	Market-share maximizing	
Maturity	Standardized product, slow evolutionary changes	Semiskilled labor large-scale automation[b]	Factor cost-minimizing	Worldwide
Senescence	Commoditylike product		Disinvestment: sell technology, turnkey plants, management services, etc.	Mainly offshore wherever costs are lowest

a. Product-specific skills do not exist at this stage, but machine skills are especially important.

b. Automation may be "hard" or "flexible," in principle. The key to combining scale economies with continued technological change is flexible automation, discussed in more detail later in the book (Chapter 6).

There seems to be a one-to-one correspondence between the life cycle phase and the production technology (or R + D, marketing). This correspondence is usually used in a straightforward manner as the basis of a strategy formation.

There has been considerable critisism of the one-to-one correspondence between the strategy and the life cycle phase (Dowdy et. al 1986, Olleros, F-J., De Bresson et al., Voss, C.A. 1985, Mac Donald 1985). Mensch et al. (Mensch 1985, Mensch et. al 1986) pointed out that this simple correspondence can lead to wrong policy options emphasized that real life is different from the model: even in mature industries product innovations dominate. There are attempts to make so-called radical product innovations in order to gain real competitive power by a radical improvement in the product (or by a so-called "take-off"). In general, radical innovations - both in the product and the production - are a tool which a mature industry can use to de-mature (see Dowdy et al. 1986). The radical innovations usually lead to significant changes in market dominance.

This raises the question: what is a mature industry or product? Or: do we need different models for industrial evolution and product innovation? Should we talk of product generations, so that each generation has its own life cycle? Can a specific industrial branch or product ever be mature in the sense of the life cycle model?

What we need is a new evolution model, with the aid of which we can search for the invariances and the common logic within the dynamics of product (or industrial) evolution.

Firstly we must note that to each product (or industry) we can relate product technology, production technology, organization and management technology and marketing (or market segmentation) technology. Thus we describe the technology related to a product or an industrial branch as a four dimensional dynamic system. Innovations can be made with respect to each axis of the system: radical innovations on any axis can give competitive power to the innovator.

Secondly the technologies in the different axes have different life cycle phases, making the system interactive and dynamic. This basic property also includes the fact that innovations on any axis open possibilities or create potential for new innovations on the other three axes. Usually the product or industry evolves in a continuum of succeeding innovations in the different dimensions.

One basic problem is that the classical life cycle theory does not take into account the social needs and the social (and economic) context in which the new technology is introduced. This social context sets priorities and goals and modifies the dynamics of the evolution of the technology and has an influence on the different phases of the life cycle; e.g. different organisational innovations are needed in different social contexts. The social context can better be taken into account through organizational and marketing innovations.

2.2. Invariances and analogies

D.T. Jones from the Sience policy research unit of the University of Sussex (Jones 1985) analysed the automobile industry in the foregoing context (as a four dimensional system) and concluded that the industry is by no means a mature industry. The reasons can shortly explained as follows:

The automobile industry reached its maturity in the terms of the life cycle model at an early stage (standardized products, common production technology). After that, Japanese industry made production innovations, organization and management innovations and developed a new, efficient way to produce standard cars and at the same time to guarantee high quality of the products. The Japanese industry was able to create real competition power. The development of production technology opened the way to flexibility, or the economic means to produce different models and versions in small batches. This development opened possibilities of marketing innovations, which together with the incorporation of modern electronics led to product innovations or to a new up-scale segment of the cars, or to a new concept of luxury cars. This development also gave new possibilities to small European manufacturers.

The whole concept of the automobile industry is still in a strong developmental stage and we can expect innovations on each axis, which will lead to further innovations on the other axes. In particular we can expect rapid development of the management and organization technologies, because the flexibility requires a new kind of skills and knowledge on the part of the production workers. (Brödner 1985, Toikka 1986, Hyötyläinen 1986). It is also quite apparent that, at least in Europe, it is difficult to get workers for less qualified tasks and to work in a poor work environment. This social context requires a new kind of approach to work organization.

The development of the semiconductor industry has been rather similar (Ernst, 1983, Bell 1986, Business Week 1986, Dosi 1984). The beginning was characterized by a rapid product innovation phase, until the standard products (microprocessors, memories, standard logic) dominated the markets. After that there was a period of rapid growth of production innovations (Business Week 1986, Guterl 1984), which lead to a new kind of market balance and to a dominance of producers of standard products which could compete by production costs, product quality and high availability. As in the case of the automobile industry the development of production technology (and design methods) opens possibilities for improved flexibility; i.e. for efficient design and production of so-called custom design components. Besides the flexibility marketing innovations are needed for competitive power in the custom design business.

Market segmentation opens possibilities for a new, profitable business, and practice seems to show that, at least in the first stage, there are other producers dominating the custom design business than in the mass market areas. The balance between the USA, Japan and Europe seems to be rather similar to that in the automobile industry. We can also expect new kinds of product innovations because of the better production and design methods (GaAs, optoelectronics etc.).

The above tendencies can also be detected in robotics and NC-machinery. The development and production of standard robots and NC-machines are dominated by companies which can compete with production costs and high quality. Again, there exist possibilities, e.g. special robots, which satisfy the particular needs of certain market segments. It is interesting to note that even in the heavy process industries, such as paper making, the above logic is still apparent: the market (and product) segmentation from standard papers to fine papers and special (coated) printing papers, which has required a lot of production and market innovations, is one evidence of this logic.

What can we conclude?

There seems to be an invariant logic of the product (or industry) evolution, which can be useful in analysing the future trends of flexible manufacturing systems, in estimating market balances and in evaluating new business possibilities. This logic can be described as follows.

> In the first phase the product (or industry) evolution seems to obey the classical life cycle model (conception-introduction- growth-maturity). During this phase the different technological alternatives compete with each other. Before the maturity stage we find the standardization of products and production methods. During the maturity stage a lot of production and organization innovations are made, which usually lead to a new market balance and to a dominance of new producers. Furthermore these production and organization innovations create a new potential for product and market innovations. When the standard products are known, it is easier to recognize the applications where they can be used. Special needs and the means of satisfying them are also more easily recognized. Both market and product innovations lead to market segmentation and product diversification. After that the product-production -organization-market-system evolves as a highly dynamic interactive system. The segmentation process also means that those producers which are able to apply the technology (product, production) to specific customers' needs, or which are able to make product and marketing innovations at the same time, will win a better market share and also make profits. This will lead to a new balance in the markets.

We can describe this basic logic by the following visualisation. (Fig. 1).

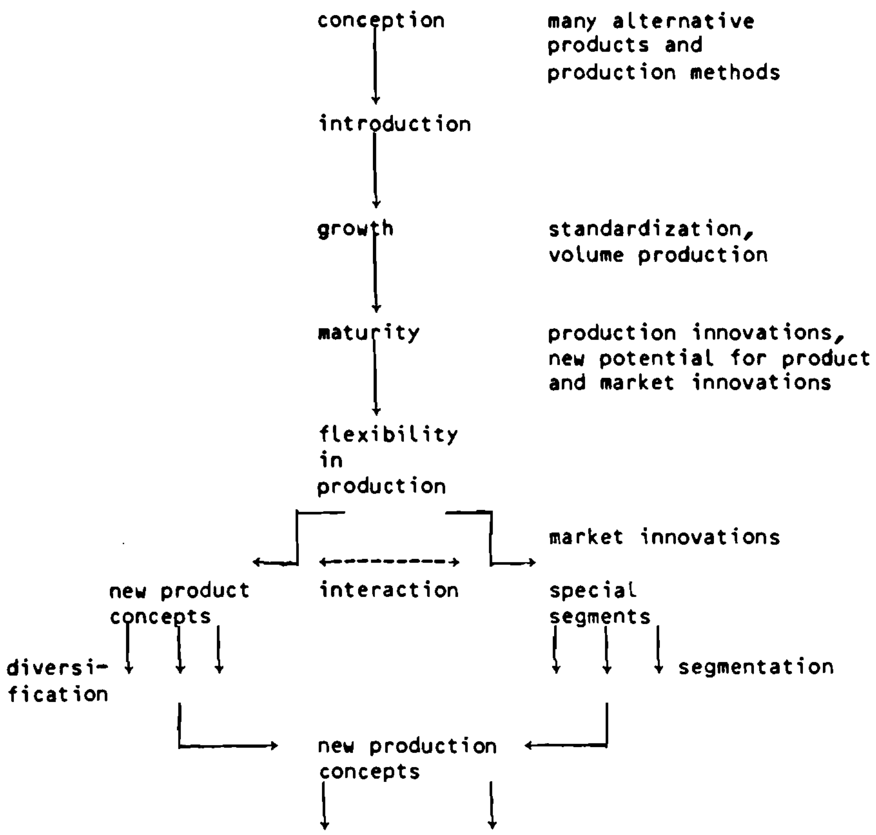

Fig. 1. Interaction of different innovation axes

2.3 Extension of the basic concept

It was stated previously that the life cycle model makes no assumptions about the relationships between technolgy, economy and social context - the evolution of a technolgy through its life cycles occurs independently of the social context. However, it is necessary to widen the concept so that the influence of the social and economic factors can be taken into account.

Perez (1984) and Dosi (1984) used the terms technological style, technological form or technological trajectories to describe the technology - economy (society) pair as a dynamic system. The concept of the technological form or style corresponds to the state concept in the theory of dynamic systems. The state of the system describes the previous history of the system and, together with the external controls and influences, determines the future dynamics.

Originally Perez (1984) and Dosi (1984) attempted to explain the phenomena which in economic terms can be measured as the so-called long cycles. However, what is essential is that the technological form (style) includes not only the basic technolgy but also the utilization forms (products organization, management concepts etc.) and utilization area (products, industrial branches etc.). The basic idea is that certain basic innovations have a great potential to create new economic values, not only in technical and product terms but also in terms of the applications in the widest sense throughout society. The successful application of the ideas and concepts also requires new organizational and managerial concepts, so the diffusion of the new technology clearly means a new technological form or style.

In the basic concept there are several important factors: the motive branches, which produce the key factors and the key technology, and the carrier branches, which are mainly responsible for the utilization of the key factor, the introduction of the key factors into the products, the production, the organization and the management practice. It is interesting to note that the basic idea or the framework is not only applicable in the social and economic context, but also in analysing of the development an industrial branch or a specific technology.

Perez (1984) forecasts that the coming technological form or the next form to come is related to the fexibility (or the flexible production) and information technologies. This means there is a special interest to analyze flexible manufacturing and its future application.

3. FLEXIBLE PRODUCTION AUTOMATION: THE LIFE-CYCLE MODEL AND FUTURE TRENDS

3.1 Flexible production automation: carriers and motive branches

If we apply the basic idea above then we must define the motive branches and the carrier branches.

The carrier branches are basically the manufacturing industries, for example workshops, metal product industries, the automobile industry, wood product industries, the clothing industry, which are all trying to find out new management concepts, to improve delivery times, to shorten lead times, to improve utilization rate - or increase the flexibility. The basic ideas are also introduced to the other branches, such as process industries (paper making, steel industry, fine chemicals etc.)

The motive branches are electronics and information technolgies in general (computers, software engineering, communication).

The ides of the concept can bee seen

- in applying electronics and software in machine controls
- in applying software and computer technologies on the level of manufacturing systems
- in the search for new organizational forms, work content, skill profiles, which are the prereguisites to achieving the benefits of the new production concepts.

3.2 Production automation: the structure and the business

A structurized model of production automation is presented in Figure 2.

	Technology base	Essential knowledge base
Planning methods	Applications	Customized needs, application know-how, project management methods, organization design, impact analysis
Production planning	Planning and engineering Project deliveries	
CAD/CAM	Systems - Flexible manufacturing units (FMU), flexible manufacturing cells (FMC) and systems (FMS) - Factory automation - Software systems - Production control systems	- System engineering - Manufacturing engineering - Software and computer technology - Information technology in general (especially communication)
	Machine automation - NC, robots, automatic storages automatic vehicles etc. - Special production machines	- Mechanical engineering - Electronics and software technology - "Mechatronics" - Control engineering
	Production interfaces - Sensors, transmitters, servomechanisms, switching devices etc - Special devices	- Physics - Mechanical engineering - Electronics - Special methods: signal processing, pattern recognition, image processing

Fig. 2. The levels of production automation

The essential point is that there is no single, well designed production automation technology, but it combines many different technical products and utilizes a high level of integration. It is also essential that software engineering plays a major role on the systems level and that organization innovations and marketing innovations (understanding special needs) are the key factors in the successful design of applications.

This integrated system aspect of the production automation makes it difficult to develop "a life-cycle model" for flexible manufacturing automation. A system concept (CIM or FMS) are still at the emerging stage, but it can utilize mature technologies as components and clearly radical innovations and take-offs in the mature components (robots, NC-machines) can have a major role in future trends.

The FMS or CIM systems can be considered as products and as <u>product innovations</u>. However major difficulties arise when it is noted that FMS and CIM-systems mean <u>production innovations</u> for many industrial branches. The successful application of FMS or CIM or of the concept of flexibility requires <u>major organizational innovation</u> in practice. The FMS and the CIM-system are always special, customized systems designed to fulfil usually very special needs - there exist no unified, standard FMS or CIM-technologies. For this reason application know-how (<u>marketing innovations</u>) is essential in the systems planning and the project deliveries. Again we can conclude that flexible production automation has a very integrating nature and that the future trends and especially the diffusion of FMS- and CIM-technologies will depend on many factors - on many technical components, organizational factors and application design capabilities (Bullinger et al. 1985).

The integrating nature and also the emerging nature of the FMS- and CIM-concepts also reflect the fact that as business areas, FMS and CIM are very diversified: there are specialized vendors for NC-machines, robots, AGV's etc. In addition there is a new emerging business: systems integration and systems engineering, which is software oriented but which requires deep knowledge of a certain application area.

The lack of common standards also provides possibilities of going into business with specialized, interface - and communication oriented software. Furthermore there are considerable possibilities for small, high-tech firms, which are specialized in very narrow technology areas such as special sensors, signal processing, image processing etc. (Bullinger et al. 1985, Bessant et al. 1985, Miller 1985).

Finally it hould be noted that each industrial branch (metal products, electronics, clothing) requires its own special application knowledge which, in general, is not transferable from one branch to another.

3.3 The concept of flexibility

Flexibility is understood in this paper to mean an ability to adapt to changing customer needs (see Ranta 1986, Toikka 1986, Recent trends...1986, Slack 1983, O'Grady et al 1986). The ability to adapt includes both long and short term changes: to adapt to rapid delivery requirements or to adapt to long-term market changes.

In addition to the adaptability, and particularly in the manufacturing industries, the concept of flexibility also includes requirements related to process performance and production economy, such as
- shorter lead times
- decreased storages
- improved utilization rate
- better quality.

Thus as a measure of flexibility we can use on the one hand performance and economical indices and on the other hand "adaptibility power". The latter property is visualized in Figure 3.

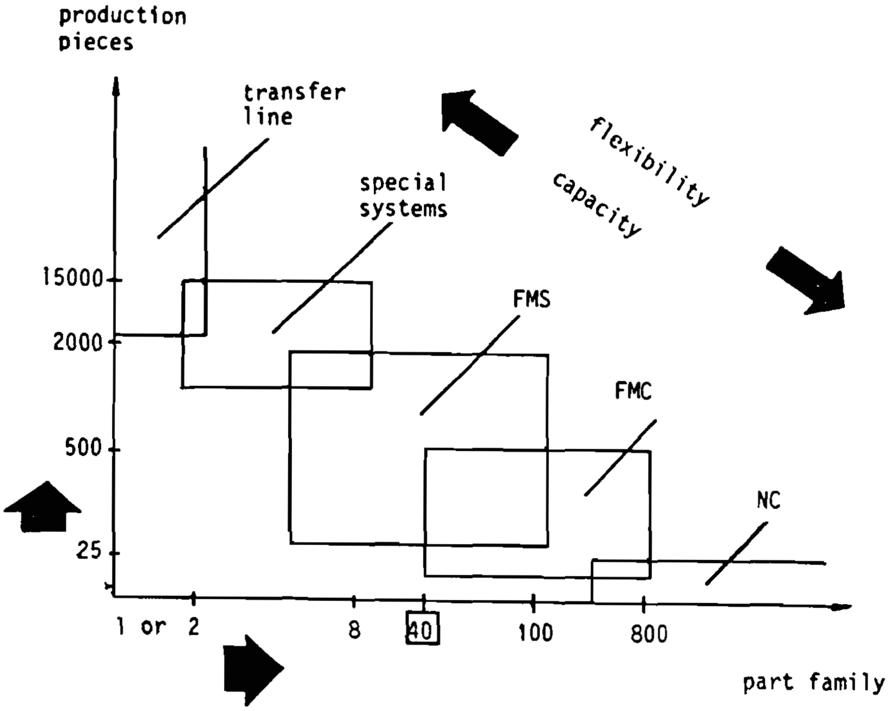

Fig. 3. The batch size and part family size

Thus the essential measures are the production capacity and the part family size. The flexibility, or the adaptability, is clearly increased if the part family can be increased without loss in batch size or production capacity. Moreover, the flexibility or the ability to make different parts also reflects the ability to adapt to future changes in the markets - the greater the flexibility the less is the risk of the investement.

We can therefore measure the development of flexibility and application trends with respect to batch size and part family size (or in more general: production capacity and product mix). This means that in the manufacturing industries one measure of the performance of a production system is the ability to make parts of different shapes and sizes in small batches; or to assemble the parts of different sizes and shapes.

With respect to delivery times and customer needs the ability to adapt to different lead times is one important factor or a measure of offlexibility.

Technical trends, or new characters and abilities of robots, NC-machines etc, can extend the capabilities of a production system and also increase the flexibility. On the other hand, this decreases the economic barriers to the application of FMS and can considerably ease the diffusion of FMS.

3.4 Technological components: trends and possibilities

Software engineering

Software engineering or software systems have a key role in system integration. This has many performance consequences, in particular it has a great impact on the reliability and availability of a system. On the other hand the software systems can also improve the flexibility.

On the software side standards will play an important role. Today, customizing and integration of the systems are carried out with the aid of software. Each system requires - in principle - basic software and communication software modules which must be developed separately for each system. This is nowadays a significant cost factor and is in fact also a major entry barrier for newcomers to the system integration business (FMS and CIM-systems). It also increases also the costs of the specific applications (see also Horn et al 1985). The standard modules - both for communication and basic functions, which could be used in many applications, can remarkably decrease the development costs of a system.

In general it is difficult to identify a life cycle model for software products. But we can say that the standardization of the basic software modules corresponds to the maturity stage of the product life-cycle. The standardization usually means cost decrease and thus opens possibilities for newcomers and specialized systems.

Thus, if e.g. the MAP-development is to succeed, we can expect that in addition to the standardization it will open possibilities or potential for cost effective means to realize specialized systems architectures, or in other words to increase the flexibility in the systems development process itself (as will usually happen at the mature stage). This means that:

- the economic barriers for new entries will decrease,
- the special purpose systems or the subsystems can be economically realized, which means the creation of new business segments and increased diversification of the system products,
- the technology oriented, specialized subsystems or system (signal processing, image processing) can be economically realized as a part of the standard system; this again means new growing market segments,
- in a longer perspective all these trends reflect on the applications of FMS: economic barriers will slowly decrease, application areas will extend and the concept of flexibility will broaden with respect to part families (shapes and sizes).

NC-machines

NC-machines are key components of the FMS for the part manufacturing of metal and wood products. The NC-business has many indications of a mature industry (Horn et al. 1985, EEC 1985): standard products, cost competition and new market balance, in which the winners seem to be efficient producers (with respect to costs and product quality).

However, at the same time there are analogous trends and signs as in the automobile industry: incorporation of electronics, software functions and the flexibility of production processes open a new potential for special purpose machines, which with their high performance satisfy the needs of a special application. After many years there is a growing class of small manufacturers which have built up a competitive power based on special segments and customized machines. Moreover, we can expect that the previously described trends in software engineering will ease the customizing process and open new possibilities for product development.

On the systems level important aspects of NC-machines are: new measurement technologies, fixtures and pallet changers, tool and work pieces changers. The development in all these aspects means an increasing level of flexibility and increasing performance measures of FM-systems.

One radical innovation which could change the whole picture is laser processing. If the technical reliability of lasers increases they could become an effective means of increasing flexibility (milling, drilling and turning by the same tool; no tool maintenance and drift; flexibility of software; applicability to different materials). This could be a real qualitative change from the points of view of both production and the NC-machine business. In general we can claim that optics could, in a wide sense, be the technology which necessiates a new technological form in the material processing and possible also in information processing.

Robotics

Robot manufacturing shows some of the same tendencies as the NC-machine industry: there are indications of a mature industry. The so-called standard robots are an area in which competition is highly cost-oriented. There have been remarkable changes in the market balance: many factories have been closed down and there are only a few strong manufacturers. At the same time new possibilities and potential have been created in specialized robotics for very narrow applications by adding specific technical properties (speed, accuracy, interfaces, signal processing, image processing) with the aid of electronics and software engineering. Specialized robots have also opened possibilities for small manufacturers.

The effects of robots seem to have two major trends. First, there are many stand alone applications of standard robots, such as point and arch welding, painting and other surface finishing tasks etc. The diffusion of robots seems to depend mainly on the costs of standard robots. Thus, because their costs are decreasing and their efficiency is increasing we can expect a steady diffusion of the standard applications. The second main application trend is the use of robots as a part of manufacturing systems (FMU, FMS, FMS, assembly systems etc.). The technical features and the performance of robots are essential for these applications. The capabilities of the robots can have a remarkable influence on the flexibility and the techno-economical performance measures of FMU, FMS and FMS and also of assembly cells and systems. In particular reliability, accuracy, speed, flexible grippers and intelligent interfaces (tactile sensors, vision, other signal processing) play an important role. New achievements in these areas always mean new possibilities on the systems level and also increase the flexibility.

Special machines

In manufacturing areas such as the clothing industry, electronics and also the metal product industry, there are many special machines. They are mainly dominated by the traditional producers. However, signs of diversification are clear. Especially in the clothing sector new possibilities are created by electronics, software engineering and robotics. New entries have occurred and will continue to occur - the production technology will experience radical changes in the near future.

Orgnization, skills, training

The new forms of production organization and training methods seem to be essential for realization of the benefits of modern production automation (Ranta 1986, Hyötyläinen 1986, Brödner 1985, Bessant 1985). New organization and management innovations are required to bring the availability of the system to the accepted level. This can be a remarkable diffusion barrier because of resoursecs which is required.

The results of the comparative studies made by Jaikumar (Jaikumar 1986) clearly show the significance of organization and management practice. Moreover, new training, organization, management solutions have actively to be searched and those which are innovative and not bound with old habits, will win a competitive advantage.

4. THE ROLE OF SMALL AND MEDIUM SCALE INDUSTRIES

The role of small and medium scale enterprises is very interesting - concerning both product innovations and production innovations.

One general hypothesis is that because of their flexibility the small and medium scale industries are able to make radical innovations. In a small country, where the home markets are small, successful product development and product commercialization seem to require a tight specialization and a world-wide operation is usually therefore required. This includes major risks for the small company, which is technology- (or design-) oriented and based on product innovations.

The product development process includes not include only the technical product innovations, but also requires many marketing innovations and later on production innovations. This is true wether the product satisfies a quite new need (or perhaps must even generate new needs) represents a radical innovation in a mature branch, where the market situation is stabilized and dominated by well-known suppliers. In both cases a considerable effort is required to make the product known and accepted. The achievement of a balanced growth, which the technology-marketing-production development requires, can be critical for small- and medium scale enterprises (see Ranta 1986b).

In the application of modern production technology (FMS, CIM) to managing the related organization and management innovations can be great problem for a small company because of resources and skills which are needed to make an assessment. Moreover the modern production system can remarkably increase production capacity which requires new marketing and strategy principles.

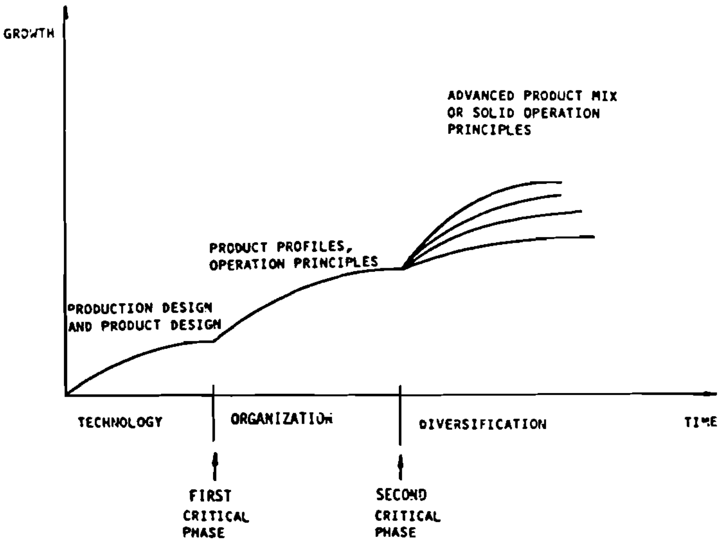

Fig. 4. The stable growth of a technology-oriented enterprise

To put the idea further we divide the small and medium scale enterprises into the following basic categories: product oriented firm, production oriented firm and generalist firm. Each of them requires own type of strategy and moreover a strategy, which differs considerably from the life cycle concept.

Product oriented firm

A small company, which is production oriented, typically manages product technology, i.e. can develop the products and its technology and has a good technological knowledge. Typical examples of this kind of companies are specialized high technology companies or design product companies.

Their problem and strength at the same time are just product orientation. Because of that they have knowledge to make a technological renewal process. Because of limited intellectual and material resources they have usual problems with marketing and manufacturing. Because of specialized product they are operating in a narrow market segment which requires a world wide marketing network. To build up this organization requires much more resources than the technological development work and quite different knowledge and skills. This can be overhelming for a small company.

Quite analogous problem is to develop a manufacturing process which requires financial resources and quite different skills and knowledge than technical product development.

Basically the problem analogous to emerging industry (Olleros 1986), although a product oriented firm can be in a mature business (like ready-made cloth).

A stabile strategy could be as follows:

- specialization and diversification according to the own product imago
- development of the organization and the marketing network

- utilization of a competitive advantage related to product technology to develop production process and to create cost competition - a concept called a design product of long runs
- manage the renewal and growth

Production oriented firm

This kind of a company, typically, manage a certain manufacturing technology, which offers a competitive advantage regarding to cost and quality. This can be a strong base to operate as a high quality part supplier. However, this requires a continuos development of manufacturing technology and clear focusing. The company can be even a high-technology firm - the manufacturing can base on utilization of high technology. A problem can be, as above, marketing and selling capacity. A solid strategy could be as follows:

- defining of operating principles and focusing
- developing of manufacturing and building-up of customer relationships
- renewal of manufacturing and extension of the operation
- managing the marketing and growth; build up of a own selling organization

Generalist firm

A strategy seems to quite indefinite - or "to make all possible". Strategy options are as follows:

- to be a generalist
- to become a product oriented company
- to become a production oriented company

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3.3. TIME, SPACE, INNOVATION MANAGEMENT AND THE LIFE CYCLE CONCEPT

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The relationship between innovation management, its several life cycles, and time is a critical one, yet remains poorly understood. This paper will explore some of the aspects of this relationship concerning the conduct of the management of innovation. It has a bearing not only upon the general theory of the firm, but also upon firms in the steel industry. Because time is such a critical variable in the success of innovation management, it must be appreciated as a fundamental dimension of a philosophy, or methodology, of innovation management. We will include a definition of the concept of time and then examine that definition in the light of the practice of innovation management. First a definition of innovation management.

Innovation management is concerned with the process of innovation in modern industrial and production organizations. Its unifying theme is that complex sequence starting with an invention, or a reinvention, and ending with a product that is manufactured, sold, and eventually used in some way by people. Along the way, original invention may change its form into a usable object, process or technology suitable for marketing and distribution. Innovation is a complex activity which proceeds from the conception of a new idea to a solution of the problem and then to the actual utilization of a new economic or social value. Innovation is not scientific discovery, although relevant discoveries may be incorporated into the innovation. Innovation should also be distinguished from invention, which is the creation of a new product or process or a concept of a means to satisfy a need. Finally, innovation is not the diffusion of technology, which has been defined as "the evolutionary process of replacement of an old technology by a newer one. The period of innovation is assumed to extend over a bounded interval of time, extending from the first realization, to when the first commercially successful embodiment of the innovation entered the market place."[1,2]

This complicated process involves many aspects of organizational life at different levels of an organization at different times, coordinated in time and space to produce a desired result. Consequently, the competent management of time has always been essential in the successful coordination of management and production activity in innovation.

Time is a complex idea that is usually associated with the concept of space, but there has been little historical consensus about it. Einstein, for example, described a four dimensional space-time continuum which includes three space dimensions and one time dimension. Newton thought of time and space as separate dimensions and conceived of time in an absolute as well as a relative sense. He meant by this absolute, true, mathematical time. Time and space are interrelated, but the elements of space possess unique rhythms of evolution and change. Consequently, because of different natural time rhythms, essentially different metrics of time are not only possible, but common. The term "concepts" is used precisely to indicate that it is the idea of time that is important. Measured time is not something inherent in an object or process, but an epiphenomenon -- a metric construct superimposed upon the natural rhythms of events. This metric is illustrated by mechanical devices like clocks which track the rhythms of events and processes.

So, there can be many metrics of time to describe natural rhythms of development, evolution and change in natural processes and events. This is a highly relativistic concept of time, subject to biological and physical variation as well as to psychological, sociological and cultural differences. This has consequences also for the social coordination of production because any product or process is the result of different rhythms and streams of activity. If they do not coordinate, there will be no product. This rather obvious idea of coordination of events through time, while reflecting the inherent rhythm and pattern of activity required by the events, is true of the simplest biological tasks in humans and animals and the most complex industrial systems. Yet though this seems self-evident, so-called scientific management seemed to have disregarded this fact by using a single metric of production time to organize a work force and production procedure. The result has often been asynchronous dislocation and eventual systemic breakdown. More will be said about this later on.

Historically speaking, the most basic time metric is the solar day based on the daily revolution of the earth. The rotation of the earth is said to be quite close to an ideal time standard. Also, so-called sidereal time based on the stars was the dominant concept of time long before clocks were invented. Calendars throughout history also reflect a cultural variety of concepts of metrics of time. Chinese and other Asian peoples distribute calendar days into cycles of sixty days each. The early Egyptians began with a lunar calendar as did the Hindus. The Greek calendar used a combination of the rhythm of the sun and moon as does the Jewish calendar. The Hejira or Muslim calendar was also based on lunar motion. The question as to which metric is the better one is probably not so important. One would have to specify important for what end? The point is that within these and other systems there was much variety as to metric units of time such as days, months and years, even though common natural rhythms of the sun and moon were used.

The Perception and Experience of "Time"

For human beings and all other forms of life, a space-time orientation is essential to adaptation and survival. Orientation in time and space is one of the fundamental adaptive requirements and conditions of existence. It is so basic, obvious and commonplace that it is often overlooked and taken for granted, and so often in the management of complex systems this fundamental reality is ignored. We know, for example, that information and feedback is an essential functional component of a time-space orientation. However, in many organizations, this basic communication requirement for successful adaptation may be ignored, and thus managers may fail to provide opportunities for workers to utilize their basic time-space orientation fully. A deeper meaning of "participative management" recognizes this basic need in people, because it assures that people will have some individual control over time and space in their lives on the job.

Other Issues

In the past, errors in perception, assessment and application of certain concepts of time have resulted in serious asynchronous (mismatched) outcomes: Taylorism (scientific management), the rationalization of work procedures, is an early example. It presumed that an ordering of events according to rigid time sequences, to which the individual was "fitted," would result in both efficiency and effectiveness. Perhaps it was less Frederick Taylor's design error initially than an interpretive error by those who later interpreted his work. The general case is illustrated below in Figures 1 and 2:

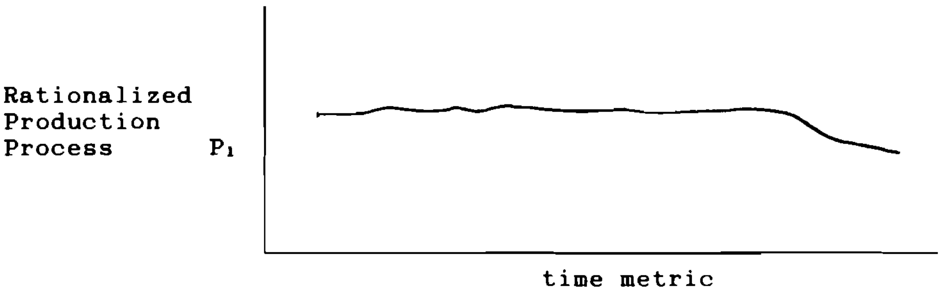


Fig. 1
Innovation and Time

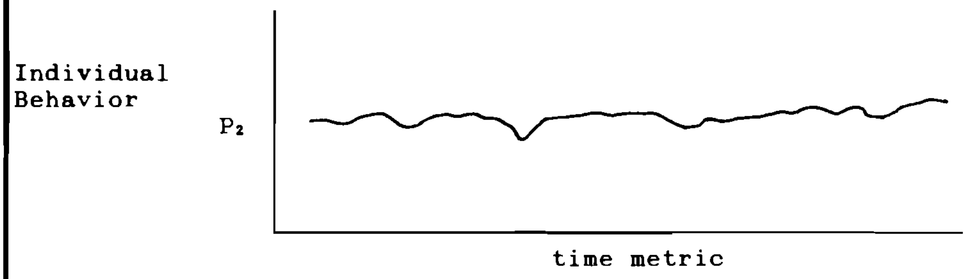


Fig. 2
Individual Behavior and Time

Coordination or matching of the two rhythms is necessary to reduce costs due to the conflict between human and machine rhythms. Creation of the conditions for this type of conflict is an historical error not at all limited to the industrial revolution and thereafter. Given the over-determined commitment to rationalism during and after the Enlightenment, it is not hard to see the basis for this error in practice. Figure 3 illustrates the combined person-product relationship to productivity and time. We would assume an eventual decline in productivity would eventually occur, which is certainly the historical experience and a factor in the formation of such societal responses to conflict.

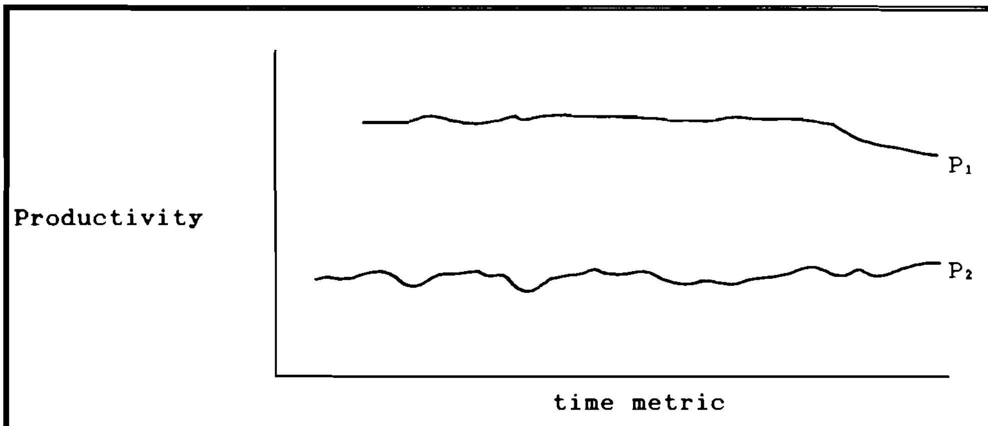


Fig. 3
Asynchronous Time/Space Relations
and Productivity

The modern socio-technical solution to this problem has been to create and to manage a convergence of human and machine rhythms, illustrated in Figure 4.

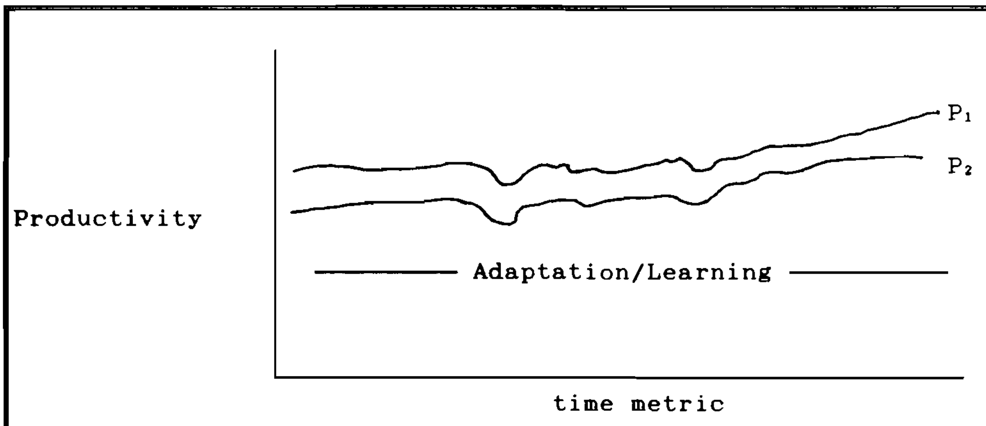


Fig. 4
Synchronous Time/Space Relations
and Productivity

Following a period of successful adapting and learning, the usual pattern has been to show an increase in productivity. A case example may illustrate some unwanted outcomes of asynchronicity. Over three decades ago, a very large corporation constructed a new assembly plant for cars in Ohio, USA. The production line was exceptionally well designed using the latest technology. But, the rhythmic fit between people and the assembly line was poor. One factor that contributed to a major strike and shut down the plant was changing the speed of the assembly line (timing) beyond human ability to respond. A public sector example of asynchronicity involving a production line was the U.S. Post Office in an earlier day. The inability of workers to speed up their response rhythms and still meet basic human needs became apparent. The problems were the familiar outcomes of productivity decline, absenteeism, turnover, and costly errors.

The recent solutions to the problem of asynchronicity have largely been socio-technical in nature as illustrated by the Swedish example at Volvo's Kalmar plant, in the new Honda integrated automobile plant in Ohio and a Ford stamping plant in northern Ohio. All three have been reasonably successful solutions to meeting human needs while reaching requirements in production logic and manufacturing. As a matter of fact, the longer run effects of time rhythm sychronicity are usually salutary and overcome the long run adverse effects of asynchronicity which eventually arise. The price paid for historical blindness toward the dangers of rhythmic discontinuities has been very high in human suffering ranging from labor unrest to accidents and the longer term effects of work stress, not to mention poor productivity quality. One regularly told anecdote is in the form of a warning never to purchase cars built on Monday or Friday because rhythmic asynchronicity is highest at these times in many cases. Flexible times for working has been one solution to this difficulty.

The perception of time is a critical factor in productivity, quality control, work satisfaction, and overall performance quality. Reference to cultural differences has been made earlier. It is easy to see that the perception of time will affect the natural conduct of production. If employees cannot maintain schedules, get to work on time, or coordinate with others because of different time perceptions, serious production discontinuities will arise.

Paul Fraisse has said that"Rhythmic induction, or the occurrence of organic periodicities which synchronize with periodicities in nature, constitutes a form of adaptation to the temporal conditions of existence. The general biological and psychological significance of this statement for adaptation is obvious. Rhythmic induction permits living creatures to turn reflex reactions into reactions of anticipation... The existence of organic rhythms induced by periodic variations in the environment has particularly important consequences for man. They provide him with an internal clock..."[2] My point is that because this internal "clock" will vary from person to person, from group to group and from culture to culture, the design of any production system may also have to vary. Modern "flexitime" policies for employees recognize this fact in contrast to earlier production and management systems which rigidly superimposed an arbitrary metric of time for everyone and to which everyone was regimented, regardless of individual differences and needs which was illustrated in Taylorism.

There are not only variations in the perception of time, but evidence also that differences in attitudes and motivation can have the effect of changing the perception and response to time duration. It will affect our subjective evaluation of time duration where such an evaluation may lead to important changes in behavior. An over-consciousness of time, for example, may be related to boredom on the job. Time seems to pass more quickly when there is high motivation and interest in the work than where not. In an interesting discussion of time perspectives, Gonzalez and Zimbardo illustrate the relativity of time and show how it relates to such variables as age, gender and income, for example.[3] Levine and Wolf explain how time is also culturally defined and determined.[4]

This evidence suggests that the initial strategic design of the organization requires careful attention to how measured time is conceived and integrated into the overall rhythm of production. Modern socio-technical management recognizes the need to accommodate in some appropriate way the separate individual behavioral rhythms of employees with the overall production rhythms of the organization whether it be a factory or an office.

Time Perceptions and Rhythms

Consider the interesting side effects of different perceptions and rhythms of time as they might also affect communication between people. Assuming a single metric like a clock is the standard of comparison, then it is not uncommon for different cultures and individuals to interpret that metric either very loosely or very stringently with point interpretations in between these two extremes. Some people are punctual, others not. For some, the interpretation of time with reference to this metric standard is always quite precise. To others, personal rhythms as shaped and affected by personal needs and wants predominantly seem to influence the perception of time.

For example, during the industrial revolution in England and the United States, punctuality became an enforced standard to fit people to machines to assure maximum productivity efficiency. Consequently, indigenous peoples in less developed areas, where the use of the time metric and standard to enforce national procedures in production is employed, would undoubtedly function less well in an assembly line system until they have adapted their sense of time. Their sense of time might better fit custom and batch mode of production. According to Max Weber's definition of bureaucracy, enforcement of a uniform time standard is an underlying characteristic of the "routinization of charisma" and regularization and rationalization of organizational behavior common during and after the industrial revolution in the West.

However, rigid standardization of the time metric by clocks is now being reinterpreted in modern organizations in such a way that the needs and wants of employees are given greater recognition in the new industrial and organizational environment. The rapprochement between the formal organization and the individual is the result of a compromise which is based on a recognition that if the clock standard is interpreted less rigidly, productivity may actually increase because life styles and production styles can become mutually supporting rhythms.

Consider below in Figure 5 the hypothesized implications of a variable perception of the standard of time in five cultures.

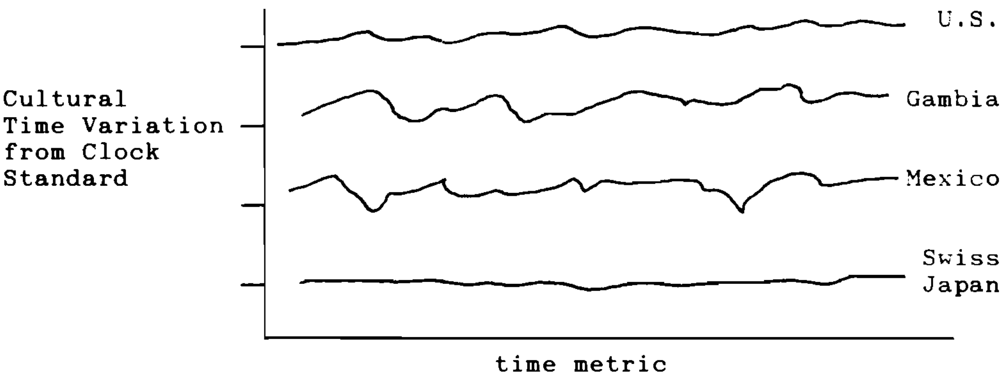


Fig. 5
Process/Rhythm in One Day

The obvious conclusion is that the personal "metric" for time is highly varied as is the cultural norm. Person/machine coordination is more difficult in cultures when there is greater variation.

Socio-Technical Leadership: An Example of Time Responsiveness

Chosen here because of its relative comprehensiveness, Likert's "System 4" management approach seems implicitly to encompass these socio-technical time requirements for effective innovation management. For example, when providing leadership and supervision, "System 4" managers act in supportive ways towards employees by providing praise and positive feedback to them about their work. In addition to the obvious motivational value of rewarding behavior, an incentive in itself, it also encourages a positive space-time orientation, especially toward important people in the work environment who have power and control over their environment. Consequently, this may reduce the level of anxiety associated with work stress, especially that coming from a powerful other who may be seen as a source of threat to one's ability to cope effectively and to survive in that environment.[5]

An emphasis on effective team development and team behavior provides a second important aspect of leadership. To the extent that effective work teams flourish, different individual rhythms of productive behavior are coordinated through group process in more effective ways. The satisfaction of personal needs in groups complement individual productive behavior so that individual "time" frames and group "time" frames are more synergistic. Complex jobs are made easier if people are friendly and help one another. For example, the production team approach in the Volvo Kalmar plant in Sweden is a case in point, as are the Honda system and other new socio-technical approaches in the General Motors and Ford corporations. Team members are able to adapt their time orientations to their work roles and responsibilities as personal and group needs require to reach overall production goals.

A third aspect of such leadership concerns the provision of technical support and other useful job related information by managers, including necessary tools with which to work. Some of this technical support may be educational over a long period of time, a common example being employee development programs. Again, this addresses the issue of time management and space-time orientation through effective information and task related technology. Obvious as it may seem, this is still an area of major problems in management. Employees often do not know what they are doing or what they are supposed to do all the time, especially where job related systems undergo change. An individual's knowledge base may not be up-to-date or functional and timely, nor are they always given proper tools with which to work.

A fourth aspect is concerned with future time orientation about productivity goals. Expectations about future events, especially those which bring rewards and success, are very important motivators and integrating factors in behavior. Expecting the highest possible reasonable standards of work goals from everyone is essential to developing a high level of work satisfaction and a sense of team and organizational loyalty and pride. Lack of a suitable orientation for work energy dissipates that energy, often in non-productive ways.

The fifth aspect involves enlarging the sense of ownership through encouraging greater participation in all relevant facets of the production system. Participation, therefore, encourages, through the sense of ownership of a part of the life of the organization, a blending of the pattern of an individual's concept of the future with that of the organization. One is more likely to accommodate one's personal rhythms more readily to what one owns than to what is seen as foreign to one's needs, expectations, aspirations and other personal goals. Lateness and absenteeism, physically or psychologically, are important problems in time management, and would seem to be correlated with the extent to which there is less personal involvement in the organization's activity by employees.

Other important aspects include the timing of interpersonal communications within and among employees and work groups; the rhythm of tactfulness, awareness and propriety reflecting a basic attitude of respect for others' psychological "life space." These leadership characteristics form a basis for improved time-space consciousness in management closely related to higher productivity, lower error, and lower absenteeism and lateness.[6]

Strategic Organizational Time-Space Considerations

Time and the rhythm of choice in strategic decision making is critical in innovation. This concerns pacing innovations from the initial invention to final diffusion of a product in a market, encompassing the critical steps of research and development, raising venture capital where needed, and marketing. A most difficult aspect of innovation management is forecasting future need. For the most part, forecasting technology is poor at best. Sensing when to invest is still a difficult art. Timing is still less frequently successful when based on formal analysis, than on experience and intuition. It is more of an art than a science, and holistic and intuitive.

Marketing, management science and organizational behavior contribute to understanding decision making and choice under uncertainty which can be applied to problems of innovation management. Along with everything else, innovation management at this level, including strategic planning, requires highly effective information systems that help organizations to locate their time-space focus in the innovation management cycle from invention (R&D) to product diffusion. Readiness to innovate will depend, in part, on information about the past, present and future human needs and wants. If there is a match between those needs and wants and the particular product innovation offered to the market, the innovation may succeed. Timing once again is critical at all phases of a life cycle.

Marketing technology, much of it borrowed from the social sciences, has become very effective by including survey research, among other techniques. Measurement of consumer preferences (consumer behavior), in a tradition started years ago at The University of Michigan's Survey Research Center economic behavior program by the late George Katona, is still one of the most effective methodologies for this purpose. Yet consumer preferences may not always reflect certain reported needs and wants at a given moment. One may like to own an innovative car, but one may not either need or want one at that moment in time. Complex individual and group circumstances may transcend the statistical regularities of a given survey of preferences no matter how extensive the population sample. So even though it is important to include this kind of data in one's information menu for decision making, it is necessary to do so with a certain amount of careful analysis of the situation at the moment.

Just when we think we may have captured the essence of consumer attitudes toward a product we can be surprised to find it is different because the rhythm of behavior has moved beyond our time boundaries. Leon Festinger once pointed out that in measuring attitudes one had to keep in mind the distinction between thinking and doing -- between thought and action. While one may like a particular product for some reason or other, one might never go out and buy it for entirely different reasons, some of which may include not having enough money, peer pressure, and so on; as aspects of timing, attitude measurement and timing are closely related and are far from simple. Yet apart from these limitations, such "decision support systems" are necessary in effective innovation management.

Planned obsolescence and other strategic choices are not unusual in innovation management. Information about consumer wants and needs often is ignored for strategic and tactical reasons that have nothing at all to do with consumer needs and wants. Innovations are often held back to control the rate of diffusion so that greater market control is attained along with greater profits for a longer period of time. Sometimes it may take the form of planned obsolescence. If innovations are dribbled out a few at a time, the possibilities for increased market control are greater, although sometimes public clamor for something new and better will be so great that a manufacturer cannot ignore it. It is far from clear if consumer readiness to buy is more intrinsic or extrinsic, and whether advertising always works as it should.

Other organizational time-space considerations include overall management of research and development as a source of invention and innovation. The patterns of R&D management are numerous, ranging from the earlier creative forms used by the E.I. DuPont Company, which led to the discovery of the polymer called Nylon. Without the creative R&D environment, almost like what one might find in basic research in a university, perhaps Wallace Carothers, the discoverer of Nylon would never have done so. The impact of this discovery and all the innovation and inventions it spawned is an industrial legend.[7] Other forms of R&D innovation management can be more focused on immediate results that have a market value in the short term. It is also not hard to create a management environment in which the rewards are such that scientists, engineers and others in product development work for short term results and "bottom line" goals if that is the strategic objective. But this may come at different stages in the "life cycle" of a product.

The interesting and perplexing question is again one of how to think about time and space. Where should strategic management's focus be located? Upon short time horizons or upon longer time horizons, or combinations of the two in strategically opportune ways? Notwithstanding the limits of most, if not all, forecasting, we do need to have a greater sensitivity toward the future since it is often true that what will develop spontaneously within a longer period will be quite surprising. Innovation management requires a creative combination of time series, time horizons and a sense for both long and short rhythms of events. Moreover, the words long and short are, as a rule, not very descriptive or precise forms of language to use in this case. A more precise and flexible metric of time is needed to identify length of time and place. For example, when we speak of short and long term, do we mean minutes, days, months, years and so on? Quarters are widely used.

The rhythmic free style of some music is a good analogy and example of the creative use of meter to reach certain novel effects of variation and contrast similar to nature. In natural settings, rhythms change, often rapidly. Compare the rhythmic variations in the classical symphony form with those of a Stravinsky and one has an idea of how important variations in meter can be to express the ideas of time and space in music. In the production systems of the future, the meter and rhythm of work may be highly variable. Perhaps an analogy with some of the better forms of modern music is not inaccurate. Instead of the block form of classical rhythms with its regular meter, modern forms change often from bar to bar, but the overall effect is a meaningful pattern which makes sense. It is interesting that pre-classical forms often displayed a high degree of rhythm variation, thus reflecting more natural rhythms.

Time is an arrow and never a boomerang and as a measured rhythm always has a forward thrust and is in reality non-repetitive. Even in so-called cycles when some events seem to recur again and again, they recur differently. No cycle or pattern is a true repetition. Consideration of time, therefore, is developmental, evolutionary and unique. Clocks and engines, as well as people, wear out eventually. Trees may bear different qualities and quantities of fruit each season. The cycle of a given innovation may differ each time so that it loses its value or gains new value.

Other Spaces, Other Considerations

Innovation management often requires other forms of coordinated institutional management which may involve externalities such as public policy and government. For example, 1978 and 1979 seemed to be bumper years for commentaries on this theme. The Committee for Economic Development (CED) published a report on stimulating technological progress and explored such agendas as tax policy, technology transfer, and federal support of R&D. The U.S. National Academy of Engineering and National Research Council in 1978, 1979, and 1980 completed monographs based on studies of trade and related economic issues among other things. The Carter Administration's Advisory Committee on Industrial Innovation issued its final report in 1979 with reports on economic and trade policy, environmental, health and safety regulation, industry structure and competition, patent and information policy and procurement and direct federal support of R&D.[8,9]

Recurring agendas seem to include recommendations about economic and tax policy, federal R&D support, regulation, patents and information policy, antitrust regulation and so on. The time coordination of such multiple agendas of such orders of organizational and societal complexity raise a spate of questions concerning "industrial policy" and when and how government is to play a role in the encouragement of innovation, new ventures and economic development in general. When to intervene in any given economic situation is, for those who guide public policy in market or planned economies, an interesting strategic question. The painful failures due to misplaced innovations in the Third World due to poorly time, and planned, investment and aid are well known. Often in the past, the timing for a particular form of support for innovation is wrong or misplaced because a culture's concept of time is not well enough understood. Also government support in the U.S. does not take a concerted form as in Japan where coordination between public and private sectors is close. Because of the structure of the American government, unilateral decisions of an economic nature are usually not possible without Congressional approval if they are far reaching and important.

This discussion so far is not intended to be exhaustive, but to show that the time and space attributes of innovation management are critical. Time is ubiquitous and underlies all analyses of management systems and procedures. To oversimplify it is a serious mistake because the rhythms of measured time are so strategically important in resource allocation. We not only need a more varied definition of time, but a more creative attitude towards its definition and use.

Reflections on Time and the Learning Curve

To illustrate how errors in estimation and judgments can occur because of under specification of time in theory, consider the following example of the familiar learning curve concept from economics. The economic definition of a "learning curve" can take this form.

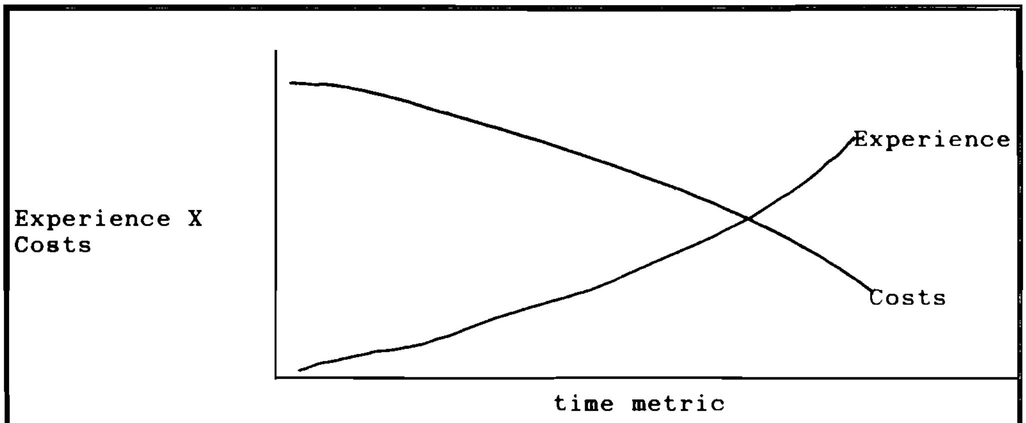
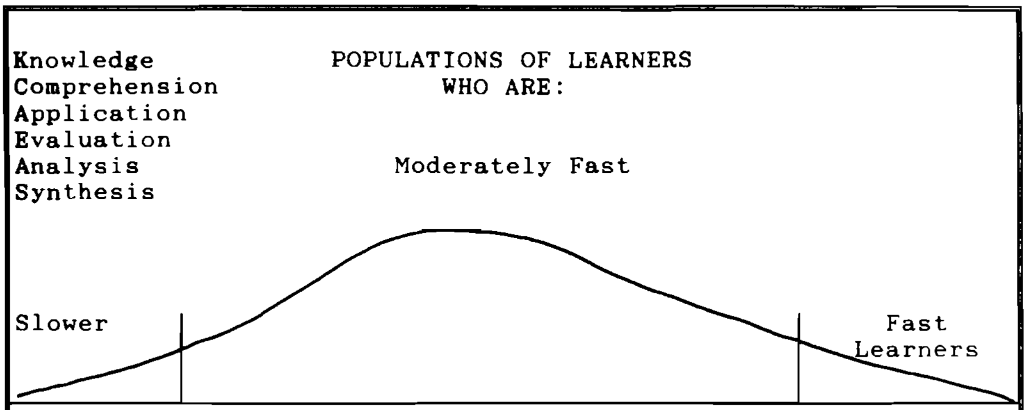


Fig. 6

The assumption is that as "experience increases (ceteris parabis), costs should decrease and productivity increase. but the term "experience" is an under-specification of the actual human learning process. Learning is much more than just "experience;" it is a highly complex cognitive process and a way in which the mind adapts to a new situation. There are, of course, numerous ways to think about the learning process. However, for the purposes of this example, a taxonomy, created by B. S. Bloom, that identifies six fundamental mental processes in learning as an "experience" will be used to make this point.

Learning involves knowledge (data) and comprehension, but equally important are the complex mental processes and cognitive behaviors called evaluation, application, analysis and synthesis. Evaluation, for example, is complex because this cognitive process involves using a value system to judge and assess a product and process. Consequently, the manner in which an individual a) acquires (learns) values, whether by conditioning, imitation or insight, and b) judges something using them is necessary to know if one is estimating the time it takes people to progress along the learning curve.

The same may be said for such mental processes as application, analysis, and synthesis. Especially where new tools are put to use, application is central. Whether given in training sessions or in the form of written manuals, the steps from an explanation of how something works to its internalization by an employee, and then to its subsequent expression in performance, not only takes time, but also reflects the fact that people will differ in the time it takes to learn to apply (see Figure 7). Ignoring such individual differences in learning rates only adds to under and overestimation and serious error in design and management.

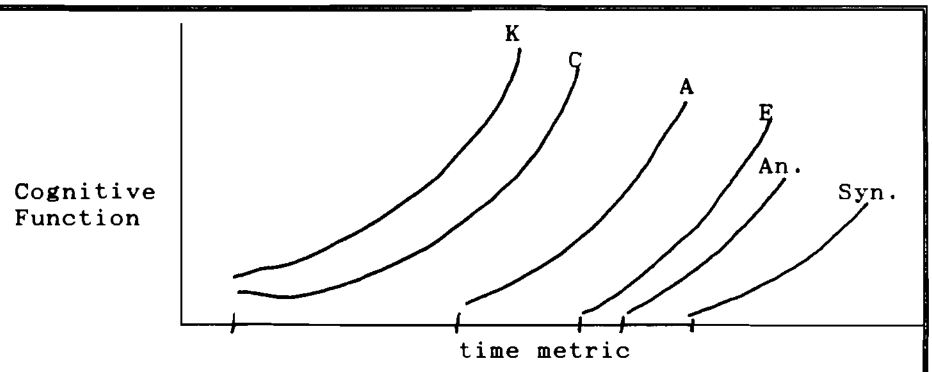


Individual Differences in Measured Rate of Learning
Fig. 7

This last point is, of course, an invitation to learn something about the psychology and sociology of human learning, one of the most critical and least understood aspects of organizational and economic change.

Learning itself, that is, the manner in which these cognitive processes are acquired, is highly complex as well as open to several kinds of interpretation. Learning theorists such as B. F. Skinner and others follow a conditioning model. Gestalt theorists like Koffka and Kohler follow a "systems-gestalt" model of learning. Edward Tolman, on the other hand, tried to combine the two in his "sign-gestalt" learning theory. So time in the learning process will be interpreted differently depending upon which of those points of views one holds.

Note Figure 8 which is intended to illustrate the point that a gross, undifferentiated measure of learning can lead to under and overestimation of the time it takes a group to learn data, theory and facts, to comprehend them and then to apply, evaluate, analyze, or synthesize them.



Learning: **Change** in Cognitive Functions
Knowledge
Comprehension
Application
Evaluation
Analysis
Synthesis

Fig. 8

Ecological Changes

All Human systems are ecological in nature. That is to say, they are ecological because they are affected by resources and competition for them, and always are subject to changes due to a process called succession -- the process by which one phase or stage is followed by another ending with a so-called "climax community." In this way, time maps the ecological changes due to changes in residents in a system including not only plants and animals, but also the influence of technology. The number of residents in an ecological system at any given time is critical. Who drops out and who survives is also important because those who remain may either be generative bringing new life, or degeneratove bringing decline in the eco-system. To the extent that the world is seen as a eco-system, we may now seriously question whether the human race as a planet occupant is sufficiently regenerative ecologically given our destruction of the global ecology. This way of thinking about time emphasizes the configurational changes over time in both structure and process, bearing in mind that it is the underlying processes undergoing change and not the time metric. Note the progression in Figure 9.

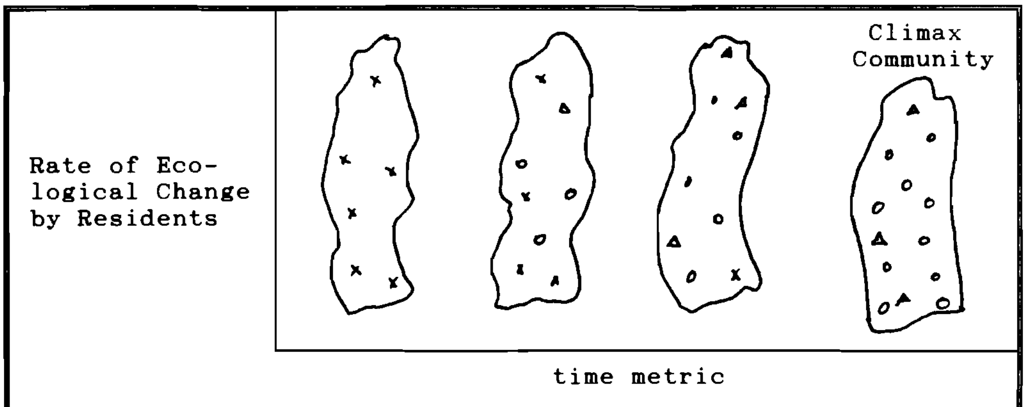


Fig. 9
Ecological Change

Final Remarks

Consider finally the important distinction between the terms "cycle" and "evolution" and why it is necessary to make a distinction between the two. The Oxford Dictionary defines a cycle as a recurring series, while an evolution is defined as an "opening out" or "development" over time. The natural rhythm of time in a regular cycle, such as the rising and setting of the sun and moon, is a stable recurring event that itself has been the standard of the metric of time. Or consider as another example sidereal cycles or the measures of time using observations of successive apparent movements of certain stars.

It is quite obvious that in highly routinized forms of manufacturing, the basis of volume production and economies of scale is to create small cycles of activity. Custom and batch production is much more evolutionary in the sense that the product may be individualized and changed as it is made. The former emphasizes regularity of production and efficiency; the latter does so less often.

As previously noted, it would seem that in some cultures the assembly line process may present difficulties of fit between people and machines where the space-time concept is rather loosely defined. Moreover, to utilize a cycle concept of recurring events where evolution is required may create a basis for serious errors in planning.

Consider, therefore, Figure 10, which associates the standard time metric with the level of strategic analysis. It is important to know whether events are truly cyclic or evolutionary. Each would require quite different strategies. For example, in economic development, evolutionary trends are very important because one is looking for improvements in agriculture, manufacturing and eventually the quality of life. A mistaken interpretation of the weather as a cycle could, therefore, be a serious mistake for a farmer when so much weather behavior has an evolutionary character and is not strictly recurrent and cyclic. This affects one's view of the future and determines expectations and thus allocation of scarce resources.

Even the so-called "long wave" theory may not be a long cycle as the theory suggests, but an evolutionary phenomenon. So the beginning of the wave is not the same as the end of it. How we view the future as well as the past is shaped significantly by the degree to which we expect events roughly to be the same or different than before. Of course, strictly speaking, nothing is every the same as before since clocks run down, the sun's radiation will change, stars burn out and die, and so on. Yet relative recurrence is important to distinguish for obvious reasons because we depend on cycles for our existence and welfare, as we depend on evolutionary trends. Please consider Figure 10. Figure 10 suggests how we may profitably view the range of levels of analysis in strategic planning for any system about which knowledge of cyclic or evolutionary activity is required.

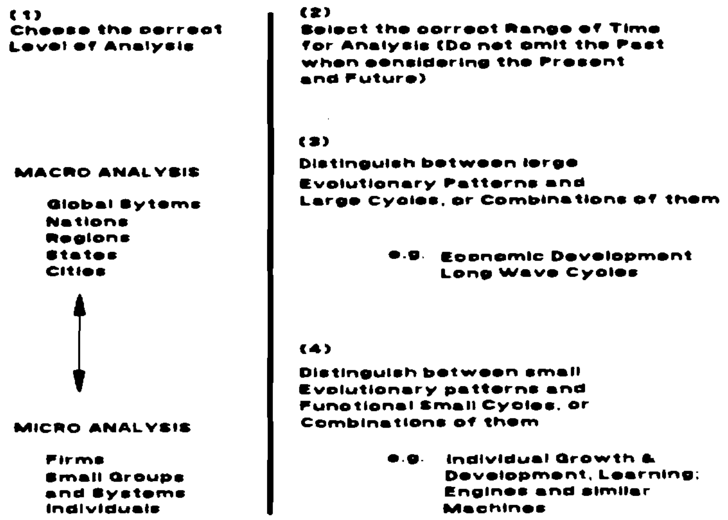


Fig. 10
Levels of Analysis

NOTES

1. This definition comes from the Battelle Columbus Laboratories report "Interactions of Science and Technology in the Innovative Process: Some Case Studies," as reported in: Sven B. Lundstedt and E. William Colglazier (Eds.), *Managing Innovation: The Social Dimensions of Creativity, Invention and Technology*, New York: Pergamon Press, 1982, pp. xxi-xxii.

2. Paul Fraisse, *The Psychology of Time*, New York: Harper and Row, 1983, pp. 40-41.

3. Alexander Gonzalez and Philip G. Zimbardo, "Time in Perspective" in *Pyschology Today*, March, 1985, pp. 21-26.

4. Robert Levine and Ellen Wolff, "Social Time: The Heart Beat of Culture," *Psychology Today*, March 1985, pp. 28-35.

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8. National Academy of Engineering, *Industrial Innovation and Public Policy Options: Report of a Colloquium*, Washington, D.C.: National Academy Press, 1980.

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3.4. A SYSTEM-APPROACH TO INNOVATION AND THE INTER-RELATIONSHIP OF BRANCHES OF SCIENCE

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ABSTRACT

The main objective of the investigation was to find the way leading to the construction of a consistent theory of innovation. The methodology applied was that of brief reviews of specific approaches to the phenomenon of innovation used by the various branches of science and their inter-relationship. On the basis of a cybernetic model, the system character of the process of innovation is explored. Blocks of findings from economics, engineering sciences, sociology, and other branches of science are used to show the applicability of the system approach to innovation. It is found that innovation is rather a surplus effect of the functioning of a so-called technological system. Therefore, the technological system, i.e. labor organized into a system, from the point of view of the resources of the national economy, can be seen as a primary system, while innovation can be considered as a tool or means of economic development.

INTRODUCTION

Innovation is a complex phenomenon which cannot be kept within the bounds of any discipline today. It has generally been accepted that in the long-run innovation is the primary drive of economic development. Let us have a quick glance at the various branches of science to see their specific features and characteristics, when studying and analyzing innovation as a phenomenon.

BRANCHES OF SCIENCE AND INNOVATION

It is a paradoxical fact that economics is the one branch of science which has overlooked the primary effect of innovation for a long time. Economics used to consider innovation as a supplementary activity of organization, necessary to satisfy social needs, that is, requirements of supply and demand. Some economists looked at it as a separate, specific economic system which could be placed somewhere between the forces and relations of production, while others thought of it as a process separate from the material sphere, independent of production, mostly preceding production itself. The generated technological knowledge and its utilization were judged on the basis of hierarchy, in a linear way, stage by stage, "the existing and useful novelty is first put into production, then marketed."

Inventions were considered rather as isolated phenomena, and the role played by the knowledge of engineering within economics was neglected, despite the fact that from the technical point of view innovation is a kind of activity which can never be carried out in one step. It is a series of steps; it is a continuous, uninterrupted creative work of engineering.

Sociology is a younger branch of science than economics. It is in the sphere of gravitation created by the continuous interaction between the "hard" social sciences and our current system of values. In the case of innovation, however, both the dynamic changes of this process and its basic social functions have been overlooked by sociology for a long time. Sociology has also underestimated the fact that innovation also means a process on the micro-level (taking place within the community) and undergoes a long, tiresome and painful period of shaping, development, and revision, before resulting in a product.

The study of groups and social structures are in accord with political science when innovation is analyzed through the behavior and relationships of various groups of society. Here special emphasis is placed on the relationship between companies and authorities, the attitude and behavior of managers, the centralization (or decentralization) of organizations and management, the proportion of state intervention and company independence.

While political science focuses only on the external conditions and relations of innovation, psychology, and within this socio-psychology, concentrates on and limits its attention to the study and analysis of the innermost drives of innovation, that is, individual human behavior. It is extremely difficult, however, to reveal the stimulus of creative thinking within the process of innovation by relying on human psychical behavior alone.

Within the sphere of social sciences, jurisprudence can be characterized by its pragmatic attitude. The registration of priority means moral appreciation for the inventor and a basis for his financial recognition on the one hand, while indicating a certain amount of market protection and economic contribution to the use of the novelty, on the other. Through the collaboration of engineering and jurisprudence, the applied science of protecting industrial property came into existence, and the contradictions of its own existence were almost immediately recognized: the newness and the protection of the novelty seemed to be endangered by continuous development, by the ceaseless process of innovation which had created the novelty itself.

From the aspect of innovation, the most significant achievements have been brought about by the philosophical-methodological sciences flourishing on the basis of recognizing the specific impact of complex systems and by the various branches of engineering connected thereto.

The sign of development along this line was the appearance of system-cybernetic research and the separation of the concepts of simple and complex. Complex (non-physical) systems cannot be adequately characterized by their complexity alone; they can be described more accurately by such factors as the interdependence and reciprocal effects of components, teleological character, decision-making, impact of subjectivity, conflicts and uncertainty, insufficient information, the impossibility of comparing indicators, self-regulation, and the fact that the total effect of the complex system is generally greater than the total effects of the individual components. The engineering way of thinking has been gaining new ground because complex systems cannot only be studied and analyzed, they can be designed and created as well. At the same time, the one-sidedness of engineering with regard to innovation is shown by the fact that it considers organizations as tools and people as elements of the process, and thinks in terms of physical measurements and actual efficiency.

THE FUNCTION OF THE SYSTEM

To illustrate the principle of the complexity approach, let us see the application of the interdisciplinary approach when setting up one of the possible models of the innovation process.

The Closed Circle of Innovation, which is often called the cybernetic model of the process of innovation, describes the initial concept for every related branch of science. It expresses the unity of the social process of innovation, its system character.

The application of the philosophical-methodological principles of complexity on innovation means that we can speak about a complex system, sizing up alternatives, striving for purposeful decision-making, even when sufficient information is lacking. It is a self-generating system, made up of several components, but flexible at the same time, not only setting tasks for itself, but ceaselessly searching for the information necessary for the most expedient solution as well.

Applying the engineering approach, the model recognized the function of the system as a uniform process of generating and processing information. Thus, it is not a privilege of R&D to feed information into the system, as this can be done by the subsystems of marketing or production, too. To illustrate the hierarchical structure of the model in a simpler way, the economics approach can be applied. In keeping with this, research, development, production, and marketing are sub-systems of the process, but their function does not only involve the processing of information, but also the generation of new information. The engineering approach is reflected in the recognition that the process is not linear. Its phases overlap both in chronologically and logically. There are several feed-backs to the preceding phases, and thereby, in an ideal situation, self-regulation of the system is achieved.

As one can see, marketing is a component of the process of innovation and, as its sub-system, takes part in the generating and processing of information. At the same time, however, it fulfills the function of controlling the system as well. Verifying values through the market mechanism also serves as a social control or regulation of the whole technological processing of information and facilitates coordination with social needs. This is how the theory of information links up with the theory of economic value-creation. While the technological system as a whole, representing a conglomeration of the elements of the innovation process, considers the generation of information to be its function, striving to produce the highest value, the checking, verifying mechanism of the market is meant to establish harmony between this change and the needs of society.

A non-empirical, but purely cognitive, model of the Closed Circle of Innovation is unsuitable for providing a more differentiated illustration of relations or a thorough study of the infrastructure of innovation. It can, however, be used as a filter of thoughts when thinking within a framework or within the context of structures or processes in the course of decision-making.

From among the general principles of complexity, the following can be pointed out, as being relevant also for innovation.

* The principle of teleology says that in order to achieve a goal several ways are possible. Therefore, we cannot speak about an optimum technology from the aspect of the scientific-technological progress.

* The principle of minimum stipulation states that the "man-machine" type of socio-technological system continuously changes in time. Therefore, in order to fulfill its function, the organization must have a satisfactory degree of freedom and independence in decision-making. Only some essential limiting regulations can be tolerated.

* Efficiency is a feature of complex systems, actually a synonym for the accessibility of the goal. Therefore, efficiency is defined as the probability of achieving the goal in the case of a system laid down and functioning within the firm's medium. Since in the case of innovation the goal itself

cannot be considered as flexible and the system and its media are mobile factors, efficiency can only be a relative factor. When referring to a technological system, it is right to speak about technical, political, and cultural efficiency, and productivity can be mentioned, too, in the context of economic aspects. The principle of joint optimization, however, indicated that there are correlations among these factors on a mutual basis and that in the course of innovation productivity reaches its maximum value as and when permitted by the joint mobility of the technical, social, and other components of efficiency.

CONCLUSION

The work organized in a system is considered as a technological system; the utilization of new knowledge produced by the technological system is regarded as innovation. The author of this paper has formed the opinion that technology as a system, from the point of view of the resources of the national economy, can be characterized as a primary system, while innovation can be considered as the tool or means of economic development. Innovation has been raised to the level of primary economic concepts through the recognition of its significance within the economy itself. Having recognized its social and economic role, there is an urgent need to work out a consistent theory of innovation as well.

3.5. COMPANY SIZE AND INNOVATION ACTIVITY IN THE STEEL INDUSTRY

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1. INTRODUCTION

This paper analyzes the role of company size as an important organizational attribute in the area of strategic management, especially innovation management. The main objective of our current study is to specify the role of company size as a factor of time, where time is represented by the phases of the technological life cycle. The new elements in this study are the global worldwide viewpoint and the usage of the technological life cycle concept. Moreover, a new methodological access for dividing companies into groups has been developed.

There is a general impression among the public that small, young companies are more innovative than larger, older ones. The number of researchers studying the relationship between company size and innovation ability is very high.[1]

The notion that small, young companies are more innovative is far from unambiguous, but many authors are in agreement on the subject. On the other hand, many authors cite examples where large companies seem more innovative.

A further third group of researchers feel the problem of determining which size of firm (small, medium or large) is most innovative is much more difficult to resolve.

2. METHODOLOGY

At the workshop, "Size and Productive Efficiency: The Wider Implications," held at IIASA in June, 1979, one of the major topics of discussion was the relationship between scale and innovation, in particular the way in which the development and adoption of innovations are influenced by the size of the firm. One result was that an optimum organization size exists for major process innovations: not so small that a diversity of managerial experience is lacking and not so large that there is rigid bureaucracy and lack of common purpose.

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[1] For more details, see Maly, 1987.

The above mentioned facts demonstrate a wide diversity of opinion among researchers. We hypothesize that the optimal company size from the point of view of innovative activity depends on many factors (industry, technological life cycle phase, country size, country's industrial structure, etc.) and changes according to these factors. From this viewpoint, we cannot speak of an optimal size in general, but only of an optimal size under specified conditions. We must consider the fact that the optimal size is changing over time in conjunction with the changing critical factors.

Company (or enterprise or other organizational unit) size is measured by many different criteria, as one comprehensive criterion to specify size has not yet been agreed upon. These criteria can be divided into 3 main groups:

- company's material substance,
- company input,
- company output.

Material substance measurements would usually include the number of employees, the value of capital goods, and total capital. Input is expressed mainly by the consumption of raw materials or energy, and output by number of units/tons produced, gross output, etc.

Using any one of these criteria has both strong and weak aspects. For example, the most wide-spread criterion is probably the number of employees, but difficulties arise with this in the case of automated production. Each criterion conveys different aspects of size. From that point of view, it is necessary when conducting a concrete analysis to select the criterion most appropriate for fulfilling the objectives of the analysis, in an effort to eliminate inconclusive results.

The object of our study is the steel industry, namely BOF technology. The most significant and comparable criterion in this case is the capacity of raw steel production per year. This criterion is usually used to indicate the size not only of a steel-mill plant, but of the entire integrated steel company as well. Moreover, the criterion is widely used in literature, statistics and reports as well as in articles and research papers. It is furthermore used in both planned and market economy countries.

Using the number of company employees is not acceptable, because of differences in production profiles, mainly of the rolling-mills, which greatly influence productivity and the required number of employees involved. Other material substance criteria, such as the value of capital goods or total capital, could be used, but are less suitable when taking into account not only Western, but also Eastern companies (where this data is not available). Input criteria, such as consumption of raw materials or energy, are also not available in many cases. Output criteria, for instance total volume of raw steel production per year, is influenced by the level of capacity utilization.

The second methodological issue is specifying the boundaries between groups of company size. Three groups are usually distinguished in literature, official statistics and reports as small, medium and large companies. Authors, however, use different boundaries for the three groups. These boundaries depend on the object of the study under question: an entire industry, different branches of industry, or other branches of national economies (agriculture, transport, service, etc.).

Statistics covering the steel industry usually use the following divisions: up to 500,000 tons of raw steel capacity per year for small companies, 500,000 to 1,500,000 tons for medium, and over 1,500,000 tons for large. This division is also used in literature. If we examine this more deeply, we must state that so far these boundaries have been established most subjectively and are hardly suitable for a detailed analysis. Our idea is to create more natural and homogeneous groups by means of suitable mathematical methods, in order to derive more statistically significant results. Figure 1 shows us the example of Swedish steel companies divided by the customary boundaries. At once, it is clearly visible that these boundaries do not create any natural, homogeneous groups.

SWEDEN - SIZE OF STEEL COMPANY - CRUDE STEEL OUTPUT

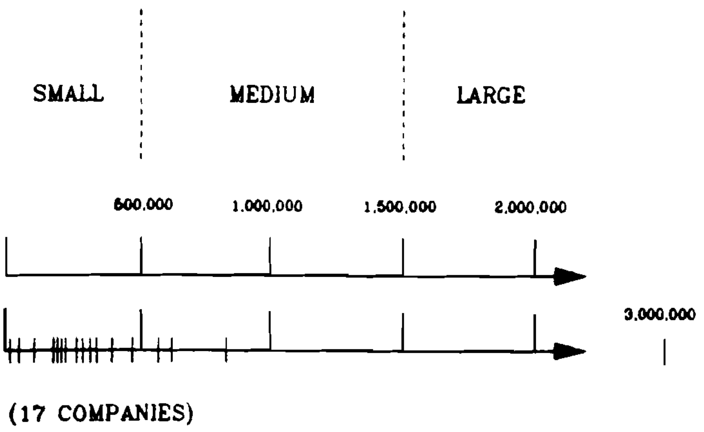

Figure 1

In our case, we used a new method for clustering points located on the line of real numbers, combining cluster analysis and histogram as developed by S. Miyamoto.[2]

After clustering the companies into more homogeneous groups, we come to the very difficult methodological problem of how to distinguish the more innovative companies from the others. We are aware of the difficulties this task presents, but it is possible, however, to formulate the hypothesis that the more innovative companies are those who adopted a new technology or product in the early period following its first adoption globally. The next methodological question arises immediately: how to specify the "early period following its first adoption globally."

To answer this question, we start from the premise that specifying such a period is possible by means of the theory of the technological life cycle. This particular theory has been developed mainly by Abernathy and Utterback (1975). Empirical evidence demonstrate that product and process technologies show a rather predictable pattern of dynamic behavior.

The typical S-shaped function is designed usually by means of the degree of penetration of technology as measured by market share, percentage of adoption, etc., expressed usually by annual capacity or output. We suggest designing the S-shaped curve by means of the share of the BOF early adopters to the total number of integrated steel companies in the world. This is because we want to recognize the early adopters, the firms which adopted BOF during the early (i.e. take-off) phase of the technological life cycle. We try to eliminate the cases when these same firms adopted BOF later on at other plants.

For calculation, we used the simple Fisher and Pry model:[3]

Equation 1.

$$\ln \frac{f(t)}{1 - f(t)} = c + bt$$

The curve is symmetrical, $b(t) = b =$ constant, and point of inflection $f*(t) = 0.5$; $f(t)$ is the share of the early adopters of BOF to the total number of inegrated steel companies worldwide and c, b are the parameters defining the S-shape.

So far, we have not developed a exact method to help us define the boundaries between the consecutive phases of the technological life cycle. The literature regarding this particular problem is not very helpful. The only possibility at the moment

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[2] For more details, see Attachment 1 in Maly, 1987.

[3] Fisher/Pry, 1971/

is to specify the boundaries from some technological and economic indicators. The take-off phase measures the period during which the early adopters started to produce steel using BOF technology.

The last, but perhaps the most important, issue is to what extent do we require a data base to resolve the issues. We must take into account not only our specific task, but also the availability of data. Because the steel industry is well documented in statistics and literature, we have decided to gather information from many countries around the world, bearing in mind that not all steel companies can adopt BOF. BOF technology can be adopted only by companies with certain technological prerequisites. This implies that we must restrict our attention to integrated steel plants (i.e., those with blast furnaces, steel mills, and rolling mills), and moreover exclude those integrated steel plants producing only special grades of steel. In these instances, only electric furnaces, not open hearth or BOF, would be preferred.

The next question to arise is what year to take as a basis for the analysis of quantitative data. We suggested taking the year of BOF's first commercial adoption as the basis for our analysis.

3. FINDINGS

The first commercial adoption of BOF technology was in 1952, when the first convertor came into operation at Voest, in Austria. From that point on, other steel companies had to include the option of adopting BOF into their strategic planning.

The main source for our data base is Cordero's survey of Iron and Steel Works of the World for 1952. This book includes all major producers of iron, raw steel and rolled steel products as well as many other producers of re-rollers, tubes, iron powder, etc. Hundreds of companies were analyzed from this book in order to select the integrated steel companies, excluding those concentrating their production exclusively on special grades of steel.

The list of 123 companies (see Attachment 1) includes practically all integrated steel companies worldwide. The only exceptions are the United Kingdom and some less important countries for which complete data was not available. By our estimation, about 140 integrated companies existed in the world in 1952, so our sample contains almost 90% of the total.

We shall start our analysis using the standard classification of company size, i.e. up to 500,000 tons raw steel capacity per year for small; 500,000 to 1,500,000 for medium; and over 1,500,000 for large. Using these standard classifications, we obtain a division of integrated companies into groups shown in Table 1.

Table 1

	Small	Medium	Large	Total
Number	44	58	21	123
Percentage	36	47	17	100

The main sources for identifying the early adopters were Lynn (1982) and Stone (1966). The number of new firms adopting BOF worldwide by year from 1952-1970 is portrayed in Figure 2.

NUMBER OF NEW FIRMS WORLDWIDE
ADOPTING THE BOF BY YEAR,
1952 - 1970

YEAR	NUMBER OF FIRMS	CUMULATIVE NUMBER	YEAR	NUMBER OF FIRMS	CUMULATIVE NUMBER
			1961	3	21
1952	1	1	1962	8	29
1953	1	2	1963	9	38
1954	2	4	1964	13	51
1955	0	4	1965	6	57
1956	0	4	1966	10	67
1957	5	10	1967	5	72
1958	5	14	1968	7	79
1959	1	15	1969	2	81
1960	3	18	1970	3	84

Source: L. Lynn (1982); J. K. Stone, (1966)

Figure 2

From that data base, the life cycle curve was created by means of the cumulative number of firms adopting BOF every year.

The estimated result of Equation 1 is as follows:

$$\ln \frac{f(t)}{1 - f(t)} = \underset{(25.0)}{.292} * (\text{year} - 1952) - \underset{(-35.4)}{4.35}$$

$$R^2 = .974 \qquad \bar{R}^2 = .972$$

$$\text{D.W.} = 0.83$$

where the values in the parenthesis are t-values.

Figure 3 shows the typical S-curve as a result of that sample.

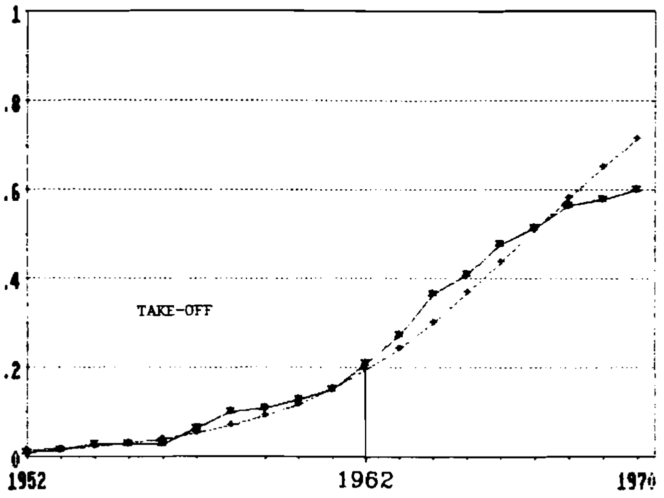

Figure 3
Total Integrated Firms = 140 (saturation point)

The take-off phase (containing the early adopters) starts in 1952 with the first commercial adoption of BOF and finishes in 1962 as specified from certain technological and economic indicators. Such a specification is supported by technological and economic indicators from literature. Meyer and Herregat (1974) came to the conclusion that by 1961 or 1962 all purely technological problems in adopting BOF had been solved and that all countries and firms were facing a homogeneous technology. Tchijov (1987) concluded that the boundary between the take-off phase and growth phase of different technological life cycles in the case of steel production might be defined as 9-10% of total production. BOF technology reached this ratio in 1962-1963 (Rösch, 1979). - During that period (1952-1962), 29 firms adopted BOF.

Figure 4 contains a list of the early adopters of BOF.

FIRMS ADOPTING THE BOF,
1952 - 1962

FIRM	COUNTRY	DATE	FIRM	COUNTRY	DATE
Voest	Austria	11/52	Hindustani	India	1/60
Alpine	Austria	5/53	Amagasaki	Japan	8/60
Dofasco	Canada	10/54	Fuji	Japan	10/60
McLouth	U.S.	12/54	Sumitomo	Japan	5/61
Yawata	Japan	9/57	C.F.& I.	U.S.	7/61
Bochumer	W. Germany	9/57	S.A.R.L.	Portugal	-/61
Belgo Mineir	Brazil	10/57	Kobe	Japan	11/61
J&L	U.S.	11/57	Kawasaki	Japan	4/62
Petrovski	U.S.S.R.	-/57	ATH	W. Germany	6/62
Koninklijke	Netherlands	1/58	Norsk	Norway	-/62
Nippon Kokan	Japan	1/58	USINOR	France	-/62
Algoma	Canada	11/58	Richard Thomas	U.K.	-/62
Kaiser	U.S.	12/58	National	U.S.	9/62
Krivoh Rog	U.S.S.R.	-/58	Broken Hill	Australia	12/62
Acme	U.S.	1/59			

Source: L. Lynn (1982); J. K. Stone (1966)

Figure 4

Using the standard classifications, we can divide the early adopters into groups as well. The only difficulty is that data on the size of all early adopters are not available. For that reason, we were able to consider only 22 companies (76%). The division of these companies is depicted in Table 2.

Table 2

	Small	Medium	Large	Total
Number	8	8	6	22
Percentage	36	36	28	100

When we compare the results from Tables 1 and 2, we can state that in the group of small companies the percentage (36%) is exactly the same, in the medium group slightly lower (36 versus 47%), and in the large group, on the contrary, slightly higher (28% versus 17%). We can conclude that large companies were more innovative than the medium and small companies.

Studying the process of adopting BOF, we see that at the stage of early adoption, it is very easy to distinguish two main waves. The first lasted from 1952 to 1954, during which 4 companies adopted BOF. After that, there was a 2-year pause and then the second wave from 1957-1962, during which 25 companies adopted this technology. The percentage of companies by size during these two waves is shown in Table 3.

Table 3

	Small	Medium	Large	Total
# All E.A.	8	8	6	22
Percentage	36	36	28	100
# 1st Wave	2	2	0	4
Percentage	50	50	0	100
# 2nd Wave	6	6	6	18
Percentage	33.3	33.3	33.3	100

From the results, we can see that the small and medium companies began adopting at the same rate (50%) in the first wave, and then were followed by all three groups at even rates.

In the second step of our analysis, we shall use as an alternative solution the method for clustering points located on the line of real numbers combining histogram and cluster analysis.

The computerized results depicted in Attachment 1 show us the clusters of companies by size. We have 20 clusters and from that can distinguish the differences in production capacity between them. Attachment 2, the histogram, gives us illustrative information about the density and breadth of the "valleys." Combining the results of both the cluster analysis and the histogram allows us to specify four main clusters (groups) of companies by size. Using round figures for particular zones, the boundaries of these groups are as follows:

small:	up to 999,999 tons
medium:	1,000,000 to 2,999,999 tons
large:	3,000,000 to 5,999,999 tons
mammoth:	6,000,000 tons and over

We have to add that no exact mathematical method exists for specifying the boundaries, but combining the cluster analysis with the histogram creates the scientific framework for rational expert specification of the boundaries. The first main factor is the breadth of the "valleys" (histogram); the magnitude of the differences between clusters is the second important factor.

The reason why the breadth is more important than the differences in production capacity stems from the results of the cluster analysis. We see that the first clusters (1, 2, 3) with the greatest distances (16,700; 5900; 3499) each contain only one "mammoth" company. Such results are of no use to our analysis. The distance (breadth) between the mammoth size companies and the group of large companies is so large (8,600,000 to 5,101,000 tons) that this in itself implies a homogeneous and natural grouping, without a non-practical division into groups of one isolated mammoth company each. We specified the round figure of 6,000,000 tons as the boundary between mammoth and large companies.

The next largest distance (breadth) is between 2,505,000 and 3,750,000 tons (Cluster No. 4), and the round figure of 3,000,000 tons creates the boundary between the large and medium groups.

Within the small/medium zone (1,000,000 - 2,999,999 tons), determining the boundary between the small and medium groups is the most complicated. We cannot use the breadth, because in that case we isolate groups with only 2 or 4 companies (2,500,000 or 2,000,000 tons). In the considered interval (1,000,000 to 2,999,999 tons), we then have only one other round figure of 1,000,000 tons. Fortunately, Cluster No. 14 is situated on that boundary and can be used. Other previous clusters under considration are difficult to use from a logical point of view. Clusters 6, 7, 8 and 9 are in the other area; Clusters 5, 10, and 11 create uneven groups; Clusters 12 and 13 have only a small number of items; and so any round figure cannot be used.

After specifying the boundaries of the groups, we can continue as in the first step, using the standard boundary classifications. The division of the 123 companies by size and of the 20 early adopters is depicted on Table 4.

Table 4

SIZE	Small	Medium	Large	Mammoth	Total
Number	79	36	5	3	123
Percentage	65	29	4	2	100
# of E.A.	11	8	3	0	22
% of E.A.	50	36	14	0	100

The results of Table 4 show us more distinctly that the group of large companies is over three times as innovative as the groups of small and medium companies. On the other hand, the group of mammoth companies is completely non-innovative.

Analyzing the two main waves in the period of early adoption, we obtain the results depicted in Table 5.

Table 5

SIZE	Small	Medium	Large	Mammoth	Total
All comp.	79	36	5	3	123
Percentage	65	29	4	2	100
# 1st Wave	4	0	0	0	4
Percentage	100	0	0	0	100
# 2nd Wave	7	8	3	0	18
Percentage	39	44	17	0	100

From the results of Table 5, we can again see more distinctly that the small companies started the adoption of BOF only later to be followed by medium and especially large companies, where the share was four times higher than the rate of the number of companies (17 versus 4%).

From the results of this analysis, mainly from its second step, we conclude that from a global point of view all size groups, except mammoth, took part in the early process of adopting BOF. The relatively higher share was that of the large companies, but the process began with the small companies.

4. CONCLUSIONS

At the outset, it is necessary to stress that the results achieved have been acquired from a very narrow sample of one innovation in steel-making technology, albeit one of the most significant and decisive industrial events during the last 35 years. It is necessary to evaluate the outcomes, bearing this in mind. All these facts should be considered prior to drawing concrete conclusions from the results. Furthermore, the relatively narrow data base also does not permit broad generalizations in formulating our conclusions.

The main aim of this study was to verify the different hypotheses regarding the relationship between company size and innovative activity. Our research aimed to investigate the possible concrete implications of the results on management decision-making, especially in the area of strategic management, as well. The idea was, in conjunction with the aims of the MTL activity and other recommendations, e.g. directions for further research done by Buzacott (1980), to analyze the optimal company size closely with regard to innovative activity.

The aim of such findings is clear. These results can pave the way for better strategic decisions, not only on the company level. To specify the role of company size could be important, for example, for governmental policy, bank intervention, as well as for a company's own investment strategy and strategic management of innovation technology. Government as well as bank policy can differentiate their support of companies using, among others, the criteria of size. Governmental bodies and banks can use differentiating instruments such as direct R&D funding, conditional repayment loans, cooperative research programs, pricing (in planned economies), high-risk loans, patent policies, tax deductions, standards and regulations; education/training/re-training funding, and export credits in favor of those companies whose probability of innovative activity is higher.

An analysis of the results of our study, a comparison of the results of the first and second steps (Tables 2 and 4), and especially the results of the second step show most clearly that the most innovative group in the case of BOF adoption was the group of large companies, three times as high as the groups of small and medium companies. The results partially prove Wilson's theory and the conclusions of the IIASA workshop (1979) "Size and Productive Efficiency: The Wider Implications" in that the optimal size lies somewhere between the two outer extremes. But in our case, it is very important to recognize that the take-off phase of the technological life cycle was started by the small companies. On the other hand, we also see the complete lack of early innovativeness on the part of the mammoth companies. These are the facts which must be taken into consideration in strategic decision-making.

A further fact must also be considered. The above mentioned conclusions are made up for the take-off phase of the technological life cycle. In the following phases, the situation could be (and most probably is) very different. So government, bank and company strategic policy must take into account size as a factor of time (the different phases of the technological life cycle) as well.

A basic questions could be raised in conclusion. When a technology is in the maturity or post-maturity phase (as is BOF at present) are these results applicable? The answer follows: this study carries primarily a methodological significance which can be applied not only in the steel industry to other technologies (i.e., continuous casting), but in other industries as well.

Moreover, the adoption of BOF technology has not yet been completed. We have many examples, not just in developing countries, but in developed countries both East and West as well

(France, Czechoslovakia, FRG, Portugal, USSR) in which BOF has been adopted since 1981.

As a suggestion for further research in this area, it would be of great value to continue the research through the other phases of the technological life cycle (growth, maturity, and post-maturity) and compare the results with our findings. It is now, of course, a question of obtaining data for these phases.

In order to generalize the results of our study, it would be necessary to test the achieved results not only for other innovation technologies in the steel industry (e.g. continuous casting), but for innovation technologies in other industries as well (e.g. CIM in mechanical engineering, adoption of IR, etc.).

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ATTACHMENT 1
CLUSTER ANALYSIS

Column 1:
Production Capacity

Column 2:
Distance between
Production Capacities

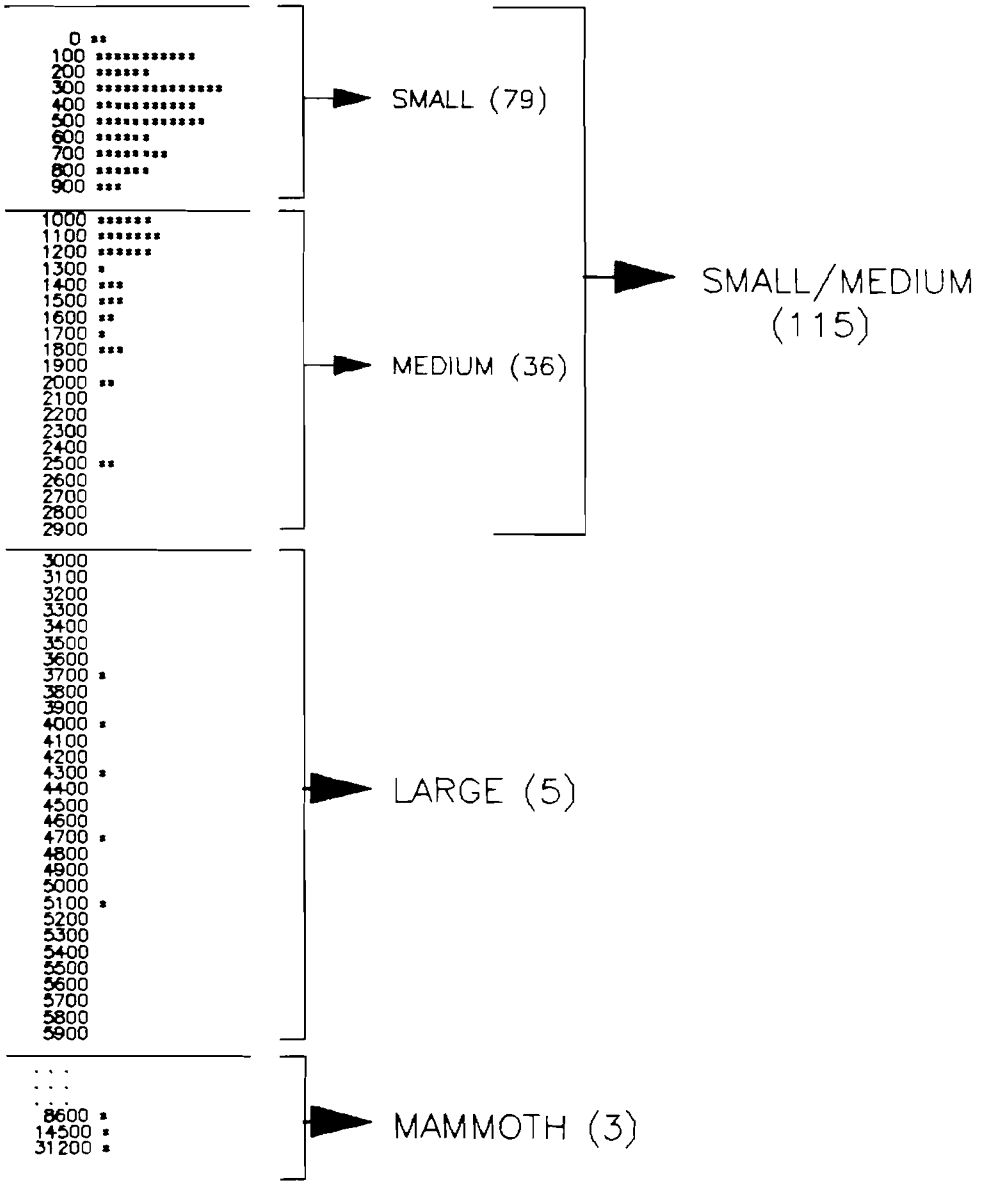
Brazil	Braziliera	39	17
Sweden	Hellefors	56	61
FRD	62-August	117	0
China	Tai-Yuan	117	29
Brazil	59-S.B.N.	146	4
Spain	Duro-Felquera	150	0
USSR	Labaikalski	150	5
Turkey	Demir	155	5
Sweden	S.K.F.	160	10
Mexico	A.H.M.	170	4
FRD	Sudwestfallen	174	3
Japan	Nakayama	177	0
Columbia	Empresa	177	23
USSR	Lysva	200	25
Mexico	Cia	225	0
UK	Shelton	225	15
GDR	Marx-hutte	240	20
Chile	De Accro	260	21
UK	Workington	281	19
USSR	Chusovoye	300	0
USSR	Vovoshilov Iron	300	20
UK	Skinningrove	320	5
UK	Parkgate	325	3
Japan	61-Kobe	328	12
UK	Scotland	340	10
Sweden	Norrbottens	350	0
Belgium	Hainant	350	0
France	Chatillon	350	8
France	Sevell-Mauberge	358	2
Belgium	Boel	360	0
Poland	Czenslochowa	360	30
Austria	Voest	390	6
FRD	Niedertheinische	396	4
Luxembourg	Miniere	400	0
Norway	62-A/S	400	0
Netherlands	58 K.W.	400	0
Belgium	D'Esperanze	400	0
France	Normandie	400	0
France	Forneaux	400	20
USA	54-McLouth	420	0
Hungary	O.Z.D.	420	30
Brazil	Siderurgica	450	30
Belgium	Forges	480	0
Belgium	S.A.M.S.M.	480	20
Sweden	Domnarfvets	500	0
France	Sollac	500	0
USSR	Voroshilovsk	500	0
USSR	Serov	500	35
France	S. A. des Hauts	535	6
Italy	ILVA	541	9
Canada	Dofasco	550	0
USSR	Trans-Kaukasus	550	20
Austria	Alpine	570	5
Spain	Altos-Hornos	575	5
SAAR	Anonyme Forges	580	17
Japan	Kawasaki	597	3
UK	Consett	600	0
Argentina	Mixto	600	0
USSR	Amurstal	600	13
Spain	Empresa	613	4
UK	Baldwins	617	33
USA	Detroit	650	50
***********17	************		
UK	Stewart	700	0
USSR	Stalin Works	700	0
USSR	Stalin Metal Works	700	4
USA	Newport	704	16
USA	Granite	720	0
SAAR	Neunkirchen	720	10
France	Acieries	730	47
FRD	Mannesmann	777	23
Hungary	Diosgyor	800	0
USSR	Dzberzinski	800	0
USSR	57-Petrovski	800	0
USSR	Yanekievo	800	40
Canada	Dosco	840	35
SAAR	Forges	865	25
USA	Int'l Harvestor	900	0
Luxembourg	Hadir	900	20
Belgium	Tubes	920	80
***********14	************		

SMALL

ATTACHMENT 1
CLUSTER ANALYSIS
(con't)

USSR	Novomoskovsk	1000	0	MEDIUM
USSR	Orsk-Khalikovo	1000	0	
USSR	Kirov	1000	0	
USSR	Azorstal Steel	1000	72	
***********15	***********			
USA	Pittsburgh	1072	23	
USA	Crucible	1095	5	
USA	58-Kaiser	1100	0	
Luxembourg	Arbed	1100	0	
USSR	58-Krivoj Rog	1100	0	
USSR	Kuilyshev	1100	10	
France	Usinor	1110	6	
India	Tabe Iron	1116	54	
Africa S.	South Africa	1170	30	
Belgium	S. A. Laminoirs	1200	0	
Belgium	S. A. John	1200	34	
Japan	NKK	1234	11	
Canada	Algoma	1245	1	
Canada	Stelco	1246	39	
FRD	Oberhausen	1285	45	
***********19	***********			
France	Wendel	1330	111	
USA	Sharon Steel	1441	9	
FRD	Rheinhausen	1450	28	
USA	Ford	1478	22	
UK	Wales	1500	18	
UK	Colvilles	1518	42	
***********20	***********			
USA	61-Colorado	1560	96	
***********13	***********			
FRD	Neiderich	1656	31	
Japan	Fuji	1687	13	
USSR	Bakal	1700	155	
***********10	***********			
FRD	Dortmund	1855	5	
USA	Wheeling Steel	1860	10	
Australia	62-B.H.P.	1870	130	
***********11	***********			
USSR	Zaporozhstal	2000	0	
USSR	Kuznetsk	2000	500	
***********5*	***********			
USSR	Stalin	2500	5	
Japan	57-Yawata	2505	1245	
***********4*	***********			
USA	Inland Steel	3750	250	LARGE
***********9*	***********			
USA	Armco	4000	350	
***********8*	***********			
USA	Youngtown	4350	400	
***********6*	***********			
USA	62-National	4750	351	
***********7*	***********			
USA	J and L	5101	3499	
***********3*	***********			
USA	Republic	8600	5900	MAMMOTH
***********2*	***********			
USA	Bethlehem	14500	16700	
***********1*	***********			
USA	US Steel	31200	0	

ATTACHMENT 2
HISTOGRAM



3.6. LEADERSHIP IN DIFFERENT PHASES OF THE LIFE CYCLE: CASE STUDIES OF U.K. STEEL MANAGERS

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The construction of data bases on managers has been made possible by analyzing new biographical dictionaries of business leaders. Extensive material is available for detailed studies of key decisions in the history of the steel industry over the past hundred years from the British Dictionary of Business Biography (5 volumes, Butterworth, 1980-1985). The Dictionary and its accompanying data base contain 73 entries of managers who were recognized as outstandingly successful in the British steel industry. They range in time from early iron-masters to people involved in the recent reshaping of the British economy during the postwar periods of nationalization and denationalization. The collection also includes key individuals such as Henry Bessemer (1818-1898), inventor and development of the Bessemer process; George Clark (1809-1898), manager of the Dowlais Iron Co., which encouraged Henry Bessemer and adopted improvements to his process; Sir David Dale (1829-1906), who was managing director and chairman of the Consett Iron Co. and sponsored numerous technical innovations, and Thomas Vickers (1933-1915), who developed and installed numerous innovations, including steel casting improvements which helped to keep Vickers Co. in the lead against major international competition. Recent leaders included are Raymond Brookes (1909-), who persuaded GKN to install modern drop forges after the Second World War; Edward Judge (1908-), who supervised the relocation and modernization of Dorman Long after the Second World War, and Julian Mond (1925-1973), who in the last years of his life presided over the re-organization and expansion of the British Steel Corporation.

The collection as a whole is well distributed by period, with especial strength in the nineteenth center history of steelmaking. Thirty-six of the biographies deal with people who were most active in the last century, while 23 deal with men who were influential between 1900-1935. The other 16 deal with more recent figures. More contemporary information will be available about these men, especially those who are still alive. But there should be no problem in identifying more recent people of importance and interviewing them for this project.

Sources for these biographies come largely from archives, many of which are extensive and will yield detailed information about the management of companies, including evidence of complex decision-making processes. Fifty-three of these archives are held in public repositories and will be easily accessible, while thirteen are in the possession of companies or other private owners, some of which will nevertheless be available for our research. Forty-one biographies used company histories as sources, and we have an additional bibliography for the history of the steel industry in Britain of over 200 references for further background research. Further information about these steel men is available from their published writings, which are most revealing about their attitudes towards change and management, of which 34 are available. There is no question that there is sufficient material available for detailed studies of most of these managers and their companies.

U.K. Steel History

The key issues for the history of the British steel industry have change significantly over the past hundred years, but follow a pattern of decision-making which provides continuity for our study. One hundred years ago, discussions about the future of the industry centered around questions about siting and scale efficiency in terms of the relationship between sources of raw materials and transport to markets. Traditionally, steel-making needed to be near forests (for access to charcoal) or coal fields. The Bessemer process implied less of a need because, by removing the need for most of the fuel used in iron pudding, Bessemer reduced the advantages of a coal field location for the finishing trades. At the same time, it favored bigger units capable of dealing with the output of its highly productive operations. The decision-makers of the time had to deal not only with the prospect of a major relocation of plant, and not only with the adjustments necessary for new melting technologies, but also with the loss of direct managerial control which growth and innovation imply. On the whole, they adjusted rather poorly, confronting their decisions late and adopting reactive, rather than decisive, stances. The exceptions, as well as the norm, will tell us a great deal about the context of decision-making and the kinds of people who go against main trends.

Around the turn of the century the pressures for integration in order to reach large size was strengthened by the introduction of blast furnaces. By the years before the First World War, it had already become clear that rebuilding would be unavoidable, and the critical decisions centered on the timing of the necessary investments. Small adjustments to changing circumstances were essential, but the firms which made a series of successful adaptions tended eventually to fail to see the need for more fundamental changes, which their previously less successful rivals had to face. The steady application of minor technological changes took place most readily in a setting of growing demand, especially when coupled with changes in the type of product required or, apparently less radical, when an industry faced severe competition. Extreme cases of the first are the introduction of bulk steel-making associated with railway demand or, in the sheet and tin plate business, the arrival of the wide strip mill. The related instances of the second include the attempt to introduce mechanical puddling to meet the challenge of Bessemer's process, and the various devices introduced into the sheet mills when quality sheet was first demanded in bulk in the twenties, and when the strip mill was also becoming a potential supplier.

Significant resistance to technological changes was still apparent, despite the recognition of superior large-scale practices. Between 1913 and 1928/9, products, techniques, markets, company organization and the national framework within which individual company decisions were made were all changing at an accelerating rate. The influence of reports about American strip mill practices played a major part in the industry from around the First World War. Discussions about the feasibility of introducing such plants to Britain continued through the inter-war period, with various conflicting assessments being produced to account for contradictory estimates of the potential markets for different kinds of steel in various quantities.

The key decisions of the Second World period and its immediate aftermath concerned the construction of the largest sheet and tin plate complex in Britain, leading to the formation of the Steel Company of Wales and new works at Port Talbot and elsewhere. This concern so preoccupied the planning of the early 1950's that the oxygen steel process (L.D., as it was referred to in Britain) was not given sufficient chance to change the minds of planners. Leaders of the industry remained unconvinced, and in mid-1956, Richard Thomas & Baldwin planned a new melting shop using open-hearth technology. Ten year later, the Steel Company was forced to replace all its existing steel-making plants with two large L.D. vessels, capable of 3.25 million tons per year.

This summary history of key decision-making situations in Britain over the past hundred years is only intended as a guide to the careers of the steel producers whose biographies are being collected and analyzed. By combining a careful assessment of critical periods in the local industry with detailed analysis of the individuals, we can learn a great deal about the importance of the utilization of information in specific decision-making situations.

Applications of the Data Base

The purpose of this work, in conjunction with that of Dr. Razvigorova and the IIASA team, is initially to develop a methodology for looking at managerial decision-making about technology, which makes use of IIASA's unique opportunities for research and dissemination. I also hope that my contribution will show how the Management of Technological Life Cycle project can be directed to firm-level analyses more effectively and address questions about managerial techniques and managerial decision-making. The work in general intends to contribute to a variety of topical issues now exercising the minds of management theorists. Many of these ideas are explicitly historical in character, and I think therefore that it is not inappropriate for me to apply historical methods. Learning curves, business cycles, questions about catching up behavior are explicitly historical, but I think would benefit from the kind of empirical work which historians are used to doing. Questions about the flow of information, about the composition of groups of decision-makers, corporate boards, and questions about risk management in crisis situations, and in particular about how understandings of particular problems in the past can influence managers to change their behavior and give us some hope that if they can change their behavior by their mistakes, we might be able to influence and change their behavior by telling them about the mistakes of others.

Using firm-level material, we can address a number of issues quite straightforwardly. Considering the structure of corporations and the problems that those structures create in the flow of information and the management of technology, we can analyze, for example, the place of technical decision-making within corporate structures. We want to know a great deal about not only the information available to managers and also how information which is available to managers is used by them. For that we need to know a great deal about their background, the capacity to analyze various kinds of information, and what they then really do with it.

By analyzing the organizational charts of a number of large corporations, we can see a great deal about what they imagine themselves to be and what public image they intend to present. What might be revealing, for example, is the relationship between company laboratories and top management. We can see, for example, in the structures of a number of large American companies, that there is a direct relationship between the chief executive and the director of laboratories. The opportunities this relationship provides, even if it is an imagined relationship, are likely to be greater than a top management which presents itself as more distant from the source of technical change. This can be seen graphically, for example, in the difference between the organizational chart used by the American electrical products company, RCA, in contrast to the chart used to express the structure of the British chemicals products company, Imperial Chemical Industries. The British company, typically, shows a far more complex structure, especially considering the effort taken to simplify the flow chart. In particular, we see that the access afforded the technical people in the company is far less direct to the real decision-makers in the corporation, reflecting the fact that, despite the fact that this is a highly science-oriented company, technologists do not have opportunities to wield a great deal of direct power. Indirectly they might do so, but the corporate structure is not designed to promote that.

My hypothesis is a simple one about the relationship between the management of technology and relative success. I think it is also generalizable and therefore provides the hypothesis or set of working hypotheses for comparative methodology. The factors affecting good decisions are the interests and abilities of top managers vis a vis technology and their relation to the information about technology which their organization is capable of providing. The interests and abilities of a technical manager, I believe, can be assessed through contextual analyses, by graphical analyses. Information can be assessed by looking at both the structure of the organization and the mechanisms in place to provide standard quality information.

Consider the variety of types of information available to managers: Background, including facilities, competitive position, etc.; financial information at various levels and to varying degrees of quality; personnel, including knowledge about the extent, distribution and quality of workers; and market information about both products and production technologies. These are presented in the form of: financial statements (which are rarely objective); personnel lists (usually internal, rarely considering the state of the labor market); market surveys (usually about purchasers and rarely about ultimate users where manufacturers are making intermediate products); R&D laboratory summaries, usually of a non-technical nature; and cost estimates for production equipment. This summarizes many of the types of information with which I am familiar from company archives.

So what this data base can provide, in addition to the analyses drawn from the kind of corporate information generally available to researchers, is the generation of new analyses on technical decision-makers as individuals and their industrial and corporate context. It can provide us with comparisons with other business leaders, both of technical and non-technical backgrounds. It can show us the differences in decision-making conditions of those different groups, and it provides us with an opportunity to put our data in the form which other researchers can use to assess other groups of leaders, so we can contrast what makes a highly successful technical businessman different from other achievers. It also gives us a great deal of detail about decision-making situations, the information, the time frames, the interests of individuals, and the interests of their organizations.

Let me give you some illustrations. A data base of about 1200 biographies of business leaders who were active and successful (successful vaguely defined) in Britain during the 100-year period between 1880-1980 is available and can be used to produce case studies such as we have developed on Vickers ("Vickers:

Technical Innovation in a Family Firm") and British Steel Corporation ("Julian Mont, Lord Melchett -- Investment Strategy in a Nationalised Industry").[1] Similar data bases for other countries' business leaders are also rapidly becoming available (e.g., United States). Our date base of British business leaders does not include Scottish business leaders, a data base for which has only just recently become available.

For a specific example of what can be done with the kind of information provided by these data bases, let us look more closely these 1200 British business leaders. They are broken down with over half in manufacturing, just over 10% in finance, and the other third distributed among other industries with a high proportion of that third in mining. I must note that this reflects historians' biases and available evidence, and not a sociological technique.

What is regarded as important for British leaders is their social background (for those of you who know something about Great Britain, this appears to be relatively important in the U.K., where perhaps it is spoken about more than in other countries). For our group of 1200, we can break down the social background to 60% for social group 1 (in sociological terms referring to people from professional and land-owning classes) and 20% from social group 2 (skilled workers). There are also social groups 3, 4, and 5. So 80% come from the top two social groups, using a standard sociological characterization of British society.

Our preliminary results already show interesting things which contradict assumptions about what makes up great business leaders in Britain. Immigrants were not over-represented. Consistent with this result, the social group 1 is highly represented. Private education is over-represented; only less than one third (around 30%) attended any further education; half of those at Oxford or Cambridge. It also was found that there was an interesting symmetry in the breakdown comparing founders, inheritors, and managers of British business. The high proportion of inheritors is very important in Britain. We have also statistics on what happens to families two and three generations later when the firms fall out of family hands.

How we can apply this specifically to the case of British steel and the kind of information which will provide a methodology for comparative analysis? The data base of British steel men consists of 73 leaders for which we can do the kind of analysis just described. The general level of education of the steel men is rather higher than that of the general sample. A slightly

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[1] These case studies, developed especially for the MTL study, can supplement the analyses given above.

smaller proportion have had only an elementary education, 6% as opposed to 9%, while a higher percentage has had some formal further education, 40% as opposed to 29%. For the time being, there is no real explanation for this; I do not know that steel was a more demanding industry than the industries in the rest of the data base.

It is by now a common-place assumption (as has been mentioned) that businessmen in Britain have come from backgrounds that were comfortable, if not actually wealthy. This generalization holds true for the steel men, only 4% of whom had fathers who were clerks or foremen. The fathers of our steel men are distributed as follows: 38% were themselves industrialists, 16% were engaged in non-manufacturing business activities, 21% were members of the professions, and 10% were landowners and farmers. When the fathers' occupations are classified according to the 1968 standard industrialized classification categories, it emerges that most of those fathers who were industrialists were themselves engaged in metal manufacturing (as were 22% of the whole group) or the manufacture of metal goods, including ships and vehicles (as were a further 12%).

It is possible to analyze the biographical information to find out the proportion of people who were inventors as opposed to those who made technical advances in their companies by being dependent on outside technologies. This is an interesting finding, not just because of the fact that the proportion of inventors is under 10%. But it is the kind of finding which, if we approach our statistics modestly, I think we can compare internationally to find out things such as this, that in the case of Britain, the early steel managers were significantly more innovative than later steel managers. It fits a kind of pattern about the people who lead new industries tending to be more technically interested in those industries, which are passed over to non-technical managers later on. I am not generalizing very far, but this particular finding does fit that pattern.

We find overall that the British steel men made their contribution to the industry by being general or financial managers in the industry. Just over 90% were general or financial managers, of which around 26% had some engineering training, and those who had some engineering training (not surprisingly) were twice as likely to be innovators. That is the kind of information that also provokes very interesting comparative analysis.

Information about their background in the firm can also be drawn. Very few innovators joined the family firm as managers, but non-university men were more likely to be innovators in Britain. This of course is something which will contrast very strongly with other countries, but something which is perhaps consistent with our prejudice towards what Oxford and Cambridge do to potentially very innovative people.

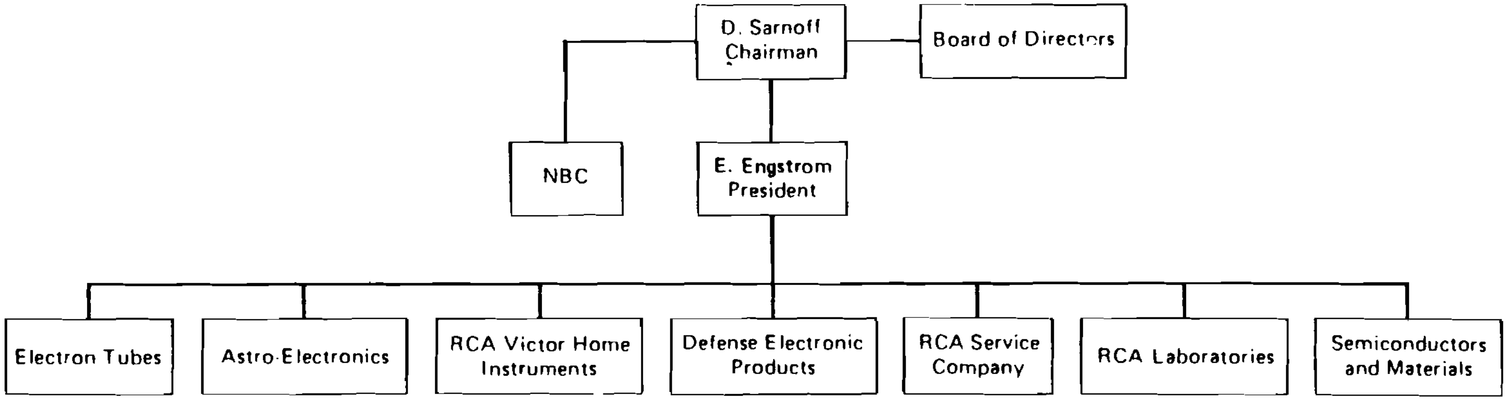
Given the opportunities these data bases offer and the types of analyses shown in the two case studies mentioned, what I propose is an ambitious project for the MTL project at IIASA. We have here a large set of very straightforward information which provides opportunities for technical comparisons, industrial comparisons, and international comparisons. For the development of this project, we still have to answer the questions: which technologies? which industries? and which countries? It is, however, not impossible to expand this methodology to answer very interesting questions about the conditions of managerial decision-making. I propose to extend it through extensive interviewing techniques, in additional to archival work. It is important to know both the documents that people have available to them and their attitudes about their positions and their perception of their power. This must then be correlated as much as possible with the quantitative data which is now available.

Let me sum up some of the advantages of the proposed methodology. First of all, it is highly reliable because the quality of information we use and have at hand is very good; we do not extrapolate. Second, it is easily communicable because, in addition to statistical and theoretical analyses, it can provide easily comprehensible descriptions of real behavior and can be interpreted for practical cautionary tales or other kinds of informative anecdotes. Third, it also takes advantage of IIASA's unique conditions and opportunities in providing access to numerous top managers and analysts from different countries.

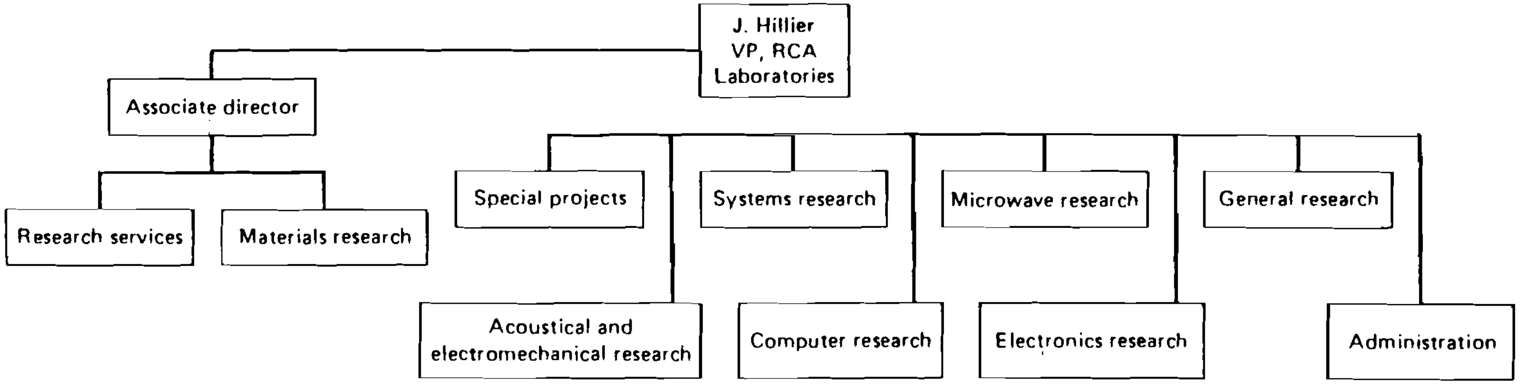
The users of the results of this type of study could be influential governmental policy-makers who must identify and then shift resources to encourage certain kinds of people to do certain kinds of activities. The results could influence business leaders perhaps to recognize that people in other places dealing with a particular kind of decision-making problem have relied on different factors (more financial information, other types of technical information) and modified their approach to the problem. A study like this could also be directed to influence management trainers at business schools.

Most importantly, this kind of information can be used to assess the flow of information within organizations, and it can give indicators of where the most effective decision-making has been done and under what conditions.

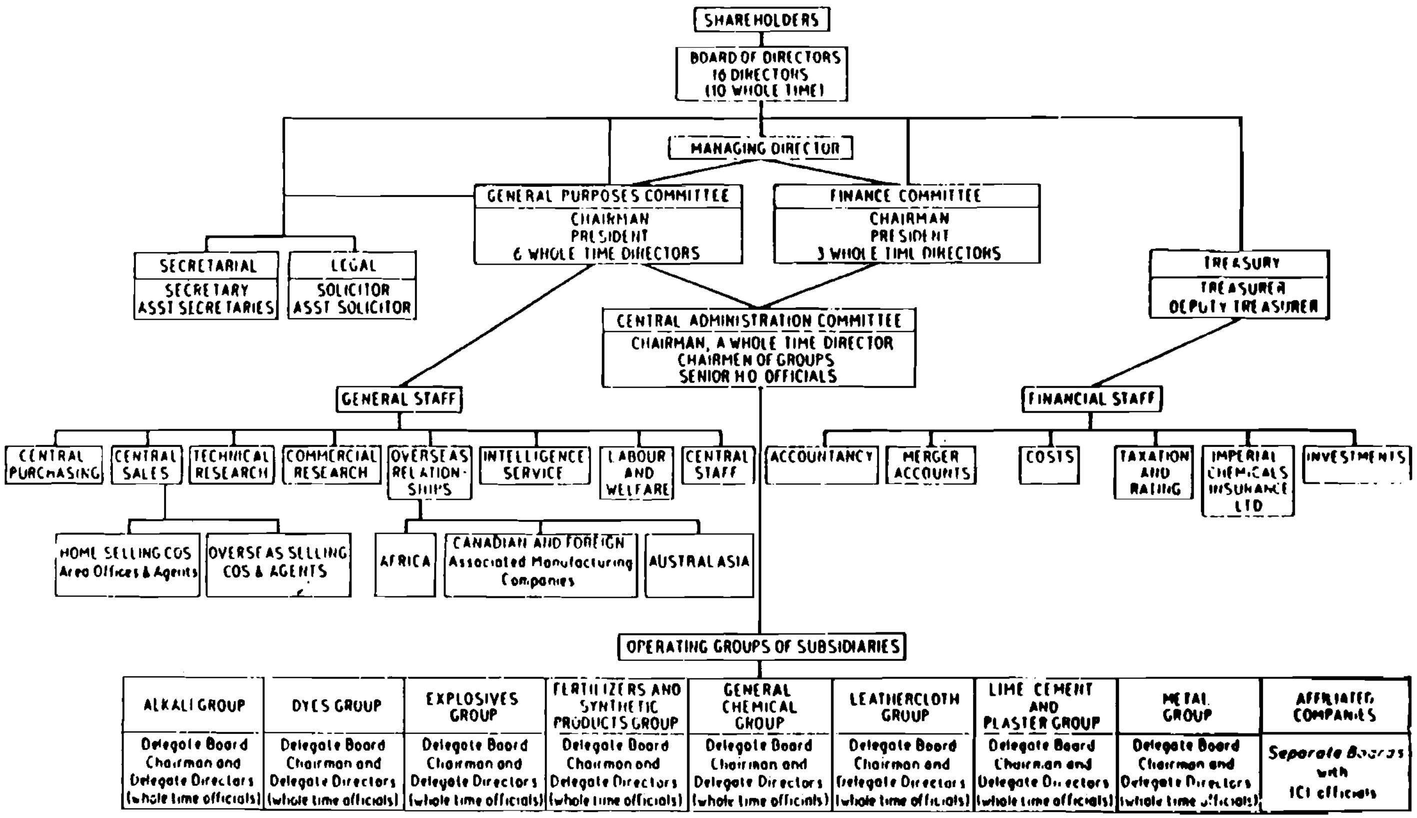
RCA organization, 1962



RCA Laboratories organization, 1962
(functional organization)



RCA and RCA Laboratories organization charts, 1962.



Organization chart of Imperial Chemical Industries Ltd, 1935. Source: *H. J. Mitchell, 'Methods of inculcating modern management principles and practices in large-scale undertakings', in Sixth International Congress of Scientific Management,* Development Section Papers (*1935*).

3.7. SESSION THREE DISCUSSION (Excerpts)

Liebenau: I would like to comment on what I see as the key issues that we have to deal with in addressing the general issue of the management of the technological life cycle. One is the relationship between the life cycle concept and industrial policy on the one hand and managerial practices on the other. The extent to which we can regard our contributions as useful will be the extent to which we can prove the validity of these concepts for changing managerial practices and influencing industrial policy.

Now, the way to go about seeing that, according to our three speakers this afternoon, has been to look at the explanatory power of life cycle theory. Dr. De Bresson uses the data associated with the life cycle to identify a number of interesting issues. He chooses thresholds and this question about the scope of production. He says that life cycles themselves do not provide explanations. On the other hand, they give him an opportunity to identify key issues for which he can provide explanations, leaving the conceptual basis of life cycle theory behind. I rather like his approach because his effort to use the data that is available, to find interesting issues which are perplexing to people who look at the industry in general and which do not derive naturally out of the data associated with life cycle, but which confound people looking for questions as to why batch versus continuous processing.

Prof. Lundstedt on the other hand wishes to replace the concept of life cycle altogether with some concept of patterns. These he regards as having less explanatory power, but he claims to show how to analyze the components of patterns and then, by analyzing these components, to stress how they might be coordinated so that patterns can yield some kind of benefit to show managers how to get these patterns coordinated more efficiently. I have trouble, I think, understanding exactly what the utility is beyond the inspirational. I think that if presented to managers, it can point out underlying components to patterns of change, but he does not propose really to explain how these patterns take place.

Lundstedt: I said you have to make a distinction between genuine cycles and patterns. I was not criticizing life cycle essentially, because there are cycles, but it is logically wrong to call a pattern a cycle and a cycle a pattern. When you do your analysis, you have to see what is developmental and what is repetitive, and what is also repetitive and developmental at the same time. So that is a very important distinction to make in your analysis of things that change over time. If you lump everything together under one concept, without distinguishing that, you lose a lot of important data.

Liebenau: I did want to make the distinction between the claims of explanatory power, between your proposition and that of Dr. De Bresson who looks not to the concept of a life cycle at all for its explanatory power, but I think uses it for its limited utility in identifying key issues which he can then justify.

Lundstedt: I would just add this, that the way you get a better or higher degree of explanatory power is by a proper differentiation, proper creation of taxonomy. Then you can code and encode things properly. By so doing, you can make distinctions and differentiations, you can create frequencies, and so forth. You can go to higher order relationships.

Liebenau: Perhaps there are more legitimate goals that we as a group can identify for ourselves easily. But one is the theoretical or perhaps academic goals that we have in understanding what this concept of life cycle is and how best to apply the methodologies that we have at hand to understand it.

The second is a heuristic goal, which is very high on the minds of many people here for both pedagogical reasons and for reasons of communicating to people who might not be our students, but whom we wish to make understand what the components of our theoretical structure and our observations are.

But the third goal, which I think we all regard as legitimate and as perhaps most difficult for us to confront directly, is the goal of influencing beneficial change. We have three audiences. We have an academic audience, we have students and policy analysts for our heuristic goal, and we have in the very difficult case administrators and managers who we hope our analyses will influence to make beneficial change.

I do agree very much that we have to use a systems approach and to see the firm as an active agent in a large context. In particular, this can force on people the aspects of our contributions which imply possible non-intuitive practices, that is asking managers to invest at times when they might think that it is better to leave things well enough alone. But I think that that kind of systems approach can provide an explanation for how and when and why to act non-intuitively. It is very difficult to make people respond that way.

Rosegger: I would like to start by quoting approximately the definition of theory given in the famous "On War" which was goes something like this: "Theory exists so as to put the facts in good order in order to have them ready at hand. Theory is meant to train the mind of the commander, not to accompany him into the battlefield." We economists are often accused of putting facts in good order by seeking regularity where there is simple recurrence. We impose semantically or mathematically or statistically the pattern of cycles as an ordering principle on an aggregation of facts which perhaps if we were cleverer we could order to some other principle.

The point in any event is that the flare-up of this discussion that was triggered by Dr. Lundstedt's valuable contribution, I think, is essentially around this very issue. It is more than taxonomic and it is more than semantic because as long as we use the word 'cycle' we are clearly imposing on ourselves a mind-set that speaks of regularity, of some discernable patterns of regularity, which may or may not exist.

The second comment I want to make is on Dr. De Bresson's presentation in which he talked about the accumulation of knowledge and very rightly said that whatever you do when you learn by doing is like riding a bicycle; you do not forget it. That unfortunately tends to be true for individuals only, and the analogy for organizations is not there.

For organizations and for technical systems, there is such a thing as forgetting by not doing. In the consequence of the so-called energy crisis of 1973-74, there was a tremendous revival of interest in the United States in windmill technology. At that time, there was one windmill engineer left in the United States at one of the more obscure state universities of Oklahoma, and I guess the only reason he was left was because there is such a thing as tenure. In any event, all of a sudden this one last person who still knew something about windmill engineering became one of the country's great experts, made a pile of money as a consultant because all the organizations that had used windmills, many of them in agriculture in the Southwest, had forgotten. Windmills died in the 1930's, when rural electrification came in. Organizations collectively can in fact forget something that we as individuals do not forget.

Ayres: I doubt if that is terribly controversial. The real problem it seems to me is that the pattern is not invariable. Taxonomy may be a beginning; we certainly need to start with that. What we need to explain is the variations: why does the life cycle work this time and not the other time? or why do these occasional exceptions or deviations occur? That is where we are, I think.

Dr. De Bresson made a fairly strong point of interpreting some of the bumps in the curve of adoption of the BOF technology in terms of changing technological capabilities. I must admit that his suggestions as to what those changes might have been corresponding to, the big leaps and the big jumps forward in the adoption, have a certain plausibility.

On the other hand, we have many cases (and BOF is certainly one) where the technology is changing at the same time that it is diffusing. That certainly confuses the analysis. I do not know whether in this case the technological changes were crucial to the apparent changes in the rate of diffusion that occurred from time to time. I tend to doubt it a little bit. But that of course is an open issue we could talk about.

Acs: I should like to ask Dr. Liebenau whether he knows the study of Zacyznik from Harvard University, based on the theory of a Swedish psychologist, who introduced the concept of the life cycle for the managerial activities. The problems of motivation, of driving forces of management decisions were explained on a psychological basis. Zacyznik had a special theory, with very much empirical evidence investigation. If Dr. Liebenau could compare his concept and methodology with that of Zacyznik, I would be eager whether he could maintain his concept, or change that especially to find some evidence between the technological life cycles and also for the managerial life cycles.

Liebenau: I think this addresses a key question now for planning the methodology about the extent to which this kind of evidence can be made compatible with other kinds of empirical and in particular quantitative information about life cycles and about the general history of these industries. We do want to take into consideration psychological characteristics and in particular career characteristics of managers, place in career when the good decisions are being made.

The greatest problem of this whole methodology is its tendency to expand uncontrollably to try to ask too many questions. We have to rely very much on what other people have done to refer to the appropriateness of the evidence for a particular kind of theory. I am mainly concerned with the comparability of our material with the long-term quantitative material, which the IIASA group has collected. That is my first priority. Other characteristics will have to be analyzed later on, as secondary results from the project.

De Bresson: I am trying to think through how this would be useful, and I think it would be mainly useful for development policy people. So basically this type of studies are useful for governmental policies in terms of having a sense of what type of people will be able to develop at what stage. For the individual who is already in a firm, I think it has no direct use.

Another thing that is generalizable is that in the early stage of development of innovation, families, clans, and fairly tightly knit groups are crucial. It is normal that family or clan structures nurture. But in the later stage, when you have a technology which is launched and is at the improvement stage, it seems to be very different types of people. I think it only has a usefulness for general policy, not for somebody who is already a manager.

Liebenau: Well, you started and ended with the same point, so I will address that one first. Its utility depends on where the study is placed and what kind of opportunities for leverage it has. In some context, it could influence governmental policy-makers, I agree, to shift resources in order to encourage certain kinds of people to do certain kinds of activities. I do think that it could influence business leaders in the sense not that they are going to give up their job for their competitor in the company, but that they are perhaps going to recognize that people in such situations, dealing with a particular kind of decision-making problem, in other places have relied on financial or technical information more than they are used to dealing with, and they will bring in people to supplement them in their decision-making which they previously thought they could deal with alone or restructure the flow of information within the organization so that they are able to act on kinds of information which in other cases have proven utility.

I am not discouraged about the possibilities for influencing managers. I also think that a study like this ought to be directed to influence management trainers. If this material enters business schools, I will be very happy to see it used there. The people we studied, I think, are not necessarily skewed towards larger firms. The influential people in an industry do become known, maybe much later than their influence was actually felt, but experts in the industry looking back over a 30-year period do tend to pick out people who might not have been involved in large corporations, but whose influence was such that they gained a reputation. They come into the survey.

Goldberg: This is in connection with the life cycles. One problem we have not addressed during this workshop is its time dimension. One of the tricky problems with using the life cycle concept is that the pulses are not defined or not definable. Time may be very slow at some period, and then suddenly becomes very rapid. Two things change the pulse. One is crisis. The other is managers who see something happening in the organization, in the environment of the organization, and that is where I address your point. They see an opportunity or a strength. Suddenly the time changes. This is one point I want to make.

Number two, I would rather see the life cycle concept replaced by a spurt because we are talking about revitalizing a firm by introducing new technology. Let me show you with a picture on organizations. At the entrepreneurial stage, you see a clear open system, viewed looking to the outside. Somebody has found a new thing and wants to bring it to the market or is exploring a market with a new thing. A tricky problem in organizations is you cannot neglect any part of your constituency in the long-run. You can favor or emphasize a constituency for some time, but after that time, you must look at other parts of the constituency and please them. Otherwise, they will rush away.

So the next phase, called collectivity stage, is much more a human relations kind of an emphasis. You have the entrepreneur still working with the outside, but he is not capable of doing it by himself alone. He must have people who share his opinion about the technical idea of the firm's situation in the market. But later on, you come to the formalization and control stage, where we are approaching the life cycle concept of maturity, and have become internally oriented. This dimension is flexibility, control which is saying that you can look at an organization in the continuous phase, but still the problem is that the time dimension is flexible. You cannot say you have a constant time around which you are measuring.

Now to your questions about the dimensions here which you can use and where the managers come in. First, I started with the open system model, where the emphasis is resource, acquisition and growth. In this flexibility versus control situation, it is external/internal orientation of the firm.

The second is human relations and here the ends resources, acquisition and growth mean flexibility and readiness, a high degree of flexibility, and it is very much an autocratic style of leadership. The second phase means cohesion and morale, to get more people than the entrepreneur himself, to work for this idea. The ends are the value of human resources.

The third is then moving into the internalized view of the organization, hence stability, control, and high productivity, milking the organization, milking the accounts, means information management and communication.

The next one is rational goal model, means the end productivity, efficiency, planning, goal-setting, evaluation, very much looking inside. But if you stay there and forget about flexibility you will be out in the long-run. You cannot neglect any part of the constituency of a curve or the stake in the long-run.

Here is one open question for you; it was a kind of expanding on what kind of management and what kind of organizational culture you need in the organization.

Maly: As we look at these problems of leadership and of companies and the problems of entrepreneurship and so on, I have the following problem. As we know very well, the MTL activity has various aims, and one of them is East-West comparative analysis. Now I have the problem comparing the managerial profile of leadership of Western companies and Eastern companies. What will be the results and will the results be useful for Western and/or Eastern decision-makers?

The second problem about the hypothesis which was done here by Prof. Goldberg is the problem of entrepreneurship for the leaders of Eastern companies. In Eastern companies, the problem is completely different because the main decision-making concerning investment and so on is made on the higher level of ministry or state planning. How to compare these results and what will be the usefulness of these results for all IIASA member countries, not only Western, but Eastern countries as well?

Liebenau: The key to this is to identify what the significant factors creating management of technology in each country are going to be and then to design a set of questions which address those issues. Now we are not interested in how many Czech managers went to Eton. That is an absurdity, and it may have no functional equivalent in Czechoslovakia. What we have to find out is that, because a lot of British steel leaders went to Eton, this is a weighty factor in the background of steel leaders, and we want to know what are other weighty factors in the backgrounds of Czech steel leaders. One of the reasons why I hedged so horribly about the definition of entrepreneurship when Prof. Goldberg asked is because I had used the term leadership in the title of my talk and most of my description. One of the reasons for that is that it is a vague term which is more easily comparable East and West. We do not have to look for Schumpeterian characteristics of entrepreneurs in Czech industry, but we can identify people who were in positions of power and influence and who were making decisions about technical characteristics or investment in technology where the results were comparable. When we ask who introduced BOF technology and why they introduced BOF technology, we can identify individuals, groups of individuals and characteristics of those groups which I think are useful and of approximately equal utility to Easterners and Westerners.

Ranta: My comment is related to the life cycle concept and some managerial implications. Let's take the example, for instance, of the automobile industry. You have new concepts of luxury cars and clearly different kinds of products which means that you can also have different kinds of production concepts according to products.

Then we can take the example of the paper and pulp industry and consider that industry to be in the maturity stage. But what has happened during the last 10 or 15 years is a totally new kind of concept of product. Originally we had soft papers and then standard printing paper for newspapers and books. But now during the last 10 years, we have the concept of cold-feed paper, sub-coating and lightweight coating, with high quality printing purposes. Then we have fine papers, a totally new concept of products, requiring new kinds of production concepts.

One implication for management is first to try to concentrate on the products which must be produced, and then to try to find a proper production method, and try to find out the competition through the product specialization. This can be advantageous when the industry is at the maturity stage. It is the same in the semi-conductor industry concerning the standard memory chips and micro-processor chips, and then the semi-custom components and custom designed components. Even in robotics today, you have a standard robot and then specialize in robots where you utilize vision, image processing, and tactile sensors, etc.

A second comment related to the problem is that the whole concept of management is changing. This is when you cannot distinguish so clearly new products, but they are in a very interactive way, as a whole. One such examples is the textile industry, ready-made clothes industry, where the whole concept of market, product design and production is changing. This is also related to flexible manufacturing and computer-integrated manufacturing.

My final comment is related to the point that was raised by Mr. Nachev, concerning small or medium scale industry, especially in a small country. I think that the life cycle theory as IIASA has studied it so far is more related to big companies and maybe to big countries. But there are special problems which are related to product-oriented small companies in a small country where the domestic market is sufficient for profitable production and organization which is oriented to international markets must be created. I think the problems with big companies, such as those in the steel industry, are very different. I hope that in that respect, the Finnish National TES program (maybe we can collaborate with the Bulgarian National TES program) can give some real contribution to the life cycle management concept. A small company with an original product, not necessarily a very new one, but one that means improvement in a mature industry, is always in an emerging stage. It must create high quality products and marketing knowledge which is quite different from the production development. The stage of growth, as Mr. Nachev said yesterday, is a very important problem for a small technology-oriented company. How to create inside the life cycle international competition so that you are also competitive internationally is a very difficult problem and very interesting also from a managerial point of view.

Goldberg: One problem we are facing is that in small countries managers disregard theory. Sweden has foreign trade theory, and the two Nobel Laureates in foreign trade theory are both of them Swedes. When I was attending business school, I was read a text on Foreign Trade and Foreign Trade Policy, which stated there is no natural possibility for a car industry in Sweden. About 20 years later, Volvo and Saab together were paying for the entire trade deficit which had accumulated because of increased oil prices. What this text was saying is there is not enough market for cars, not enough capital and not enough management. The founder of Volvo, however, organized the firm disregarding all three limitations and organized in a different way.

Now to take the Volvo example a little bit further: the following year, the next General Director of Volvo went to the Finance Minister and the Minister of Foreign Trade, with the request to get the possibility to export $10 million, to build up a sales organization and service organization for Volvo in the United States. Both of them refused thinking it crazy to take cars from Sweden to the United States, the greatest producer of cars. But Volvo's idea was if they did not compete in the toughest market, they would be out in the long run.

One of the reasons Ford and General Motors were doing badly with their foreign subsidiaries was they did not permit Ford or Opel to sell their cars on the American market, competing with their own makes in the American market. They had to change this, and one of the reasons, I think, Ford surpassed General Motors in profits for the first time since 1927 was that Ford was the first one to permit foreign-make Ford cars to be exported to the United States, in order to get the foreign subsidiaries to compete on the American market, which still is the toughest.

So what I would say is we may find it difficult to give a theoretical answer to pushing not only the S-1 curve to the left, but also the S-2 curve to the left, but practical managers may find the ways. But it is the manager we should be studying, not the theory. We have to have the theory in mind, but a good manager will invent a new kind of behavior.

Haustein: In Ranta's paper, he thought the diffusion of FMS and CIM concepts has been rather slow, and in fact the flexibility of FMS has not always been as great as expected. That is obviously true also for our FMS systems, but concerning the fact that the diffusion of FMS has been rather slow, I think beginning with 1983, there was a rapid growth phase coming under both scales. What do you think about this small correction to your thesis?

Second, can we say that obviously the new flexible automation technology will be important for mass production, for mature industries, or is it so that this flexible automation is also very important for such industries which are in the rapid growth phase from the standpoint of product innovation, and not only important for mass production of already existing products.

Ranta: For the second question, I think that if we look at some applications from the USA, maybe also from Japan, we can conclude that mainly flexible manufacturing systems have been applied for mass production. But if we look at some European applications, we can see really that rapid growth markets and specialized products are more and more often producing with flexible automation. There are two kinds of possibilities that you come from mass production. You first have more freedom and can increase flexibility, and then after that you have your CAM design product, your custom product, and that means in fact more limitation. Maybe you must design the whole product concept again, use the group technology and modularity to give possibilities to utilize advanced products and technologies.

That is one problem, for instance, for small and medium scale industries. So far I think that applications have mainly been on this side. This is also the case in Finland. The first flexible manufacturing systems are related more to mass production. You have a very specific product and make 200,000 pieces for your FMS production. But nowadays this is gaining and that was also the reason for the first question, that one hypothesis has been that flexible manufacturing is a tool for small and medium scale industries, but this has not been the case, not yet. That is why I think the diffusion has not been so rapid as we have been expecting.

APPENDICES

"LIFE CYCLE THEORY AND MANAGEMENT PRACTICE"
IIASA Workshop, held in Sofia, Bulgaria
April 27-29, 1987

MONDAY, APRIL 27, 1987

Chairman: Prof. L. Glushkov

10.00-10.45	REGISTRATION - Palace of Culture, Sofia
10.45-11.00	IIASA National Member Organization Address Prof. O. Panov, NMO Council Vice Chairman
11.00-11.20	TES Program Introduction Prof. R. U. Ayres, Deputy Program Leader
11.20-11.40	MTL Activity Introduction Dr. Evka Razvigorova
11.40-12.10	Technological Progress in Economics: On Theories of Innovation and the Life Cycle (Prof. R. U. Ayres)
12.10-12.30	Questions & Remarks
12.30-14.00	LUNCH - Palace of Culture Restaurant

Chairman: Dr. D. F. Anderson

14.00-14.20	Introduction (Dr. D. F. Anderson)
14.20-14.45	Structural Change & Substitution in the Steel Industry (Dr. N. Nakicenovic)
14.45-15.00	Dynamics of Technologies: Diffusion & Performance Improvements in Steel Technology (Dipl.-Ing. A. Grübler)
15.00-15.30	Questions & Remarks
15.30-16.00	Main Stages of Technological Progress in the USSR Steel Industry (Dr. Aleshko)
16.00-16.10	Cyclical Dynamics of Diffusion Rates (Prof. I. Tchijov)
16.10-16.30	Questions & Remarks
16.30-17.00	BREAK

Chairman: Dr. Uziakov

17.00-18.30	DISCUSSION: Life Cycle Theories, Methodological Issues and Practical Applications (Facilitators: Haustein, Acs, DeBresson)
18.30	FINISH
19.30	Evening Program - Buffet hosted by the Bulgarian National Member Organization

TUESDAY, APRIL 28, 1987

Chairman: Prof. D. Haustein

9.00- 9.20	Managing a Mature Technology: The Case of Iron & Steel (Prof. W. Goldberg)
9.20- 9.40	Future of Steel: International Outlook of Economics & Management (Prof. G. Rosegger)
9.40-10.00	Economic & Social Impacts of Technological Changes in the Steel Industry (Dr. O. Stepanov)
10.00-11.00	DISCUSSION: World Trends & National Differences in the Steel Industry (Facilitators: Lynn, Anderson)
11.00-11.30	BREAK

Chairman: Prof. G. Rosegger

11.30-12.30	DISCUSSION continues
12.30-14.00	LUNCH - Restaurant Forum, Blvd. Vitosha
14.00-14.30	Beyond the Life Cycle: Organizational & Technological Design (Dr. C. DeBresson)
14.30-15.00	Innovation Management of Product Life Cycles as a Function of Time (Prof. S. Lundstedt)
15.00-15.25	A System-Approach to Innovation and the Interrelationship of Branches of Science (Dr. B. Szanto)
15.25-16.00	DISCUSSION: Management of the Technology Life Cycle (Facilitators: Goldberg, Liebenau)

16.00-16.30	BREAK

Chairman: Dr. J. Ranta

16.30-17.15	Management Strategy & Its Dynamics Along the Life Cycle (Dr. E. Razvigorova, with Dr. S. Velev and Mag. W. Leitner)
17.15-17.30	Questions & Remarks
17.30-18.00	Bulgarian Case Study (Mr. G. Nacev)
18.00-18.30	Company Size, Age and Innovation Activity (Prof. M. Maly)
18.30	Informal Demonstration of Computer Software, organized by Bulgarian organization "Avangard"
20.00	Dinner in Hotel's Main Restaurant, "Vitosha Room"

WEDNESDAY, APRIL 29, 1987

Chairman: Dr. O. Stepanov

9.00- 9.20	Management of Technological and Organizational Development in Research and Industrial Enterprise, Electrotermia, S.A. (Mr. V. Peev)
9.20- 9.40	Bulgarian Steel Industry (Dr. U. Alkalai)
9.40-10.00	Questions & Remarks
10.00-10.30	Leadership in Different Phases of the Life Cycle: UK Case Study on Steel Managers (Dr. J. Liebenau)
10.30-10.45	Questions & Remarks
10.45-11.15	BREAK
11.15-12.00	Questions & Remarks continue
12.00-12.10	Short presentation by Dr. Danielsson
12.10-12.40	Capital Intensive Factors of Technological Restructuring in the USSR Steel Industry (Dr. Uziakov)
12.40-14.00	LUNCH - Palace of Culture Restaurant

Chairman: Prof. J. Acs

14.00-15.00	DISCUSSION: Management Implications: Methodological & Practical Issues (Facilitators: DeBresson, Lundstedt, Ranta)
15.00-16.00	DISCUSSION: Future Collaboration between Workshop Participants and IIASA (Facilitators: Ayres, Razvigorova)
16.00-16.30	BREAK
16.30-17.30	DISCUSSION continues
17.30	FINISH
20.00	Evening Program - Dinner in Hotel's Bulgarian Restaurant, hosted by "Avangard"

LIFE CYCLE THEORY & MANAGEMENT PRACTICE
(The Case of Steel Industry)

Sofia, Bulgaria
April 27-29, 1987

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