WORKING PAPER

IMPACT OF TECHNOLOGY ON MANAGEMENT STRUCTURE

Lubomir Glushkov
Evka Razvigorova

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

FOREWORD

The problem of type, characteristics, and factors which influence organizational structure has always been a basic problem in management, both for researchers and for managers. Organizational structure, in addition to being a management tool, is also an expression of power and social status, and this obviously makes it an attractive problem for everyone. In management literature, particularly in the literature on the management of innovation processes, there are few studies more numerous than those on the relation between technology and organizational structure. The results from these different studies are very contradictory.

Woodward and her supporters established a direct relation between the type of technology and organizational structure. About ten years later, however, Hickson and his associates discovered than structure is influenced considerably by many factors, and its relation with technology is indirect. In spite of the contradictory nature of the results from a large number of empirical studies, their importance in this field is constantly increasing. This has been especially true in the past few years because of major technological changes and the introduction of technologies essentially different from those with which researchers and managers had been familiar in the past.

A special place in contemporary studies is occupied by the problems relating to the influence of information technologies on organizational and management structure. Here again the conclusions and hypotheses are rather diverse. Therefore, each step forward, even the smallest one, in this direction is important and valuable for practical activities.

The project "Management of Technological Change" (MTC) investigates some of the possible links between the phases of the life cycles of technologies and the elements of management, including its organizational structure. Recognizing the importance of information technologies during the present technological revolution, we can say that there is no change greater than that caused in all fields by the introduction of information technologies. Even the simplest innovations in this field essentially change the content of many management functions, change the place of hierarchical levels and decision-making centers, and create new links and relations.

This paper is based on results from studies of Bulgarian organizations as well as results from past studies and information about organizational structure collected from the MTC pilot study. The results direct attention to the impact of information technologies and to the special role of the level of technology in changing organizational structures. On this basis, the introduction of so-called high technologies is a special factor which provokes such changes. In this sense, the conclusion is that the dynamics of structural changes are much greater in the case of high technology. To this influence is added the influence of information technologies whose invariant phase structure allows them to be defined and considered as analogous production technologies.

F. Schmidt-Bleek
Leader
Technology, Economy & Society Program

IMPACT OF TECHNOLOGY ON MANAGEMENT STRUCTURE

Lubomir Glushkov

Institute for Social Management
Sofia, Bulgaria

Evka Razvigorova

IIASA, TES-MTC Project
Laxenburg, Austria

The structure of management is influenced by too many factors, external as well as internal. Parts of these factors are regular, well-known and even controllable. Other parts are accidental, out of control, and difficult to foresee. Technology as a factor of influence has a specific place. Until recently, it has been regarded as a purely internal factor, well-known, with a steady and regular influence. The situation has changed drastically in the last decades with new technologies in almost every single area, available on the world market, competing strongly and penetrating even the most traditional and conservative sectors of industry.

This article argues that different types of technologies at different phases of their life cycle have a limited (not decisive), but still quite important impact on the structure of management.

A lot of effort and time has been devoted, both in theory and in management practice, to answer the question, "what kind of structure is appropriate"[1] for a specific organization. If we agree with Drucker that the structure should make it possible to attain the objectives of the business and that certain activities are needed to attain these objectives, then the importance of the number, type and volume of specific activities to be fulfilled in every single organization is clear.

Organizational structure is attracting the attention of scholars and practitioners for many reasons. It is the visible part of the iceberg, called the system of management. The description of a specific organization almost always starts with (and quite often stops at) its organizational structure.

Management theory has developed a variety of methods and techniques to formalize, generalize and classify different types of structures. Their applicability in practice make the analysis and design of concrete organizational structures a kind of routine managerial task.

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[1] Drucker, 1967.

The problem of the impact of technology on the structure of management is not a new one. References point out Weber as the first to investigate it by introducing the bureaucratic system of management in the very beginning of this century, which means with the introduction of "Scientific Management" and the relative distinguishing of production from its control.

A new insight of this problem has become wide spread recently with the drastic increase in the dynamics of technological changes, the use of the concept of technological life cycles and the introduction of modern information technologies. All this leads to the revision and redefinition of traditional management functions and a shifting of the decision centers up or down to the information centers with all consequences for structural characteristics of the organizations.

The technological boom has led to a sharp increase in research on the impact of technologies on the system of management[2] and in particular on organizational structures.[3] In this area, two schools can be distinguished:

* the school of technological determinism and
* the school of strategic choice.

The school of technological determinism holds the thesis that the efficiency of an organization depends on building a structure corresponding to its technology. Most distinguished representatives of this school are J. Woodward, T. Burns, J. Stalker, D. Pugh, and S. Perow. Investigations covering more than a hundred companies in the U.K., according to the authors cited above, shows that a strong connection between the organizational structure and the technology exists only in small enterprises with a limited managerial staff, mature technologies and simple business activities. For the majority of cases investigated, the evidence is against the basic assumption of this thesis.

The school of strategic choice, represented by H. Bravermann, D. Dixon, S. Clegg and D. Dunkerly holds that organizational structure is a tool for management and is determined by the objectives of the business and the ways of attaining these objectives. As the objectives depend on the needs and demand and the ways are determined by socio-economical conditions, the technology does not play any role in the choice of a specific structure.

The starting points of the two schools are entirely different. As far as results are concerned, there are more similarities than differences. Both schools agree that there are too many factors affecting the choice and that not the technology

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[2] Simon, 1977.

[3] Buchanan & Boddy, 1983.

itself, but rather the way it is used to fulfil the objectives is actually influencing the decision.

The evidence leads to the necessity of investigating the impact of technology on managerial structure from the point of view of the different characteristics of technology itself.

The division of technological processes in two main types, continuous and discrete, is well-known. Continuous technologies are used in the chemical and petrochemical industry, etc. Typical representatives of discrete technology are machine-building, electrical appliance industry and others.

In the case of continuous technology, there is a high degree of standardization of the final product as well as of the processes used. Operator activities are limited to reaction in emergencies or in case of deviation from limits derived in advance by someone else. No management decisions are taken at the shop-floor level. As a rule, a simple two-level organizational structure is common for small to medium firms. Functional departments are limited in numbers and staff. What is typical for this case recently is the "system" department, comparatively large and staffed with highly qualified personnel. Buchanan and Boddy[4] are reporting a study in a pigment-producing chemical plant in Glasgow, a subsidiary of the pharmaceutical company, Ciba Geigy. The statements above are confirmed by the data provided.

Organizations using the discrete type of technological processes are classical examples of sophisticated multi-level organizational structures. The great number and variety of different production processes requires that decision centers be formed at very low levels. Batch processing leads to buffers and to creating stores at the shop-floor levels. The impact of technology at this level is strong, and the technological determinism is valid. At the next level, this impact is very weak.

At company level, there is no evidence of an impact of the type of technology for either discrete or continuous processes.

It can be summarized that:

* the impact of the type of technology on the organizational structure is strong only at the lowest level of management;

* a discrete type of technology leads to more sophisticated multi-level structures;

* new technologies and a higher level of automation lead to decreasing the structural differences between companies using continuous or discrete types of production.

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[4] Buchanan & Boddy, 1983.

Another aspect of the impact is the so-called level of technology. In recent decades, a lot of entirely new technologies have been created, using the latest achievements in physics, chemistry and biology. The term "high technology" is used to qualify some of the most advanced and sophisticated of them.[5] A classification of technologies according to their level can be made as follows:

* low technological level, with very limited impact on the economy of developed countries;

* high technologies (micro-electronics, bio-technology, nuclear and space technologies, etc.), with a still minor impact on the economy even of the most developed countries;

* middle level technologies, wide-spread, with a major impact on employment, production of goods and services, and GNP.

Organizations with low-level technologies usually have a simple linear structure; one decision level and all management functions are united in a single unit.

A great variety of structures and mixtures of different types are observed at high technology organizations. Matrix forms are widely used, with project-oriented structures dominating. The dynamics of structural changes is high, depending on the priorities of research, development or implementation.

Organizations with middle-level technologies show impressive similarity in their structures at the level above the production units. Typical are multi-level forms with divisional decentralization, a lot of functional departments, boards, and consultative units.

It is possible with a degree of certainty to say that:

* the level of technology has a greater impact on the structure than its type; and

* the dynamics of structural changes is higher at a higher level of technology.

The investigation of the impact of different phases of the technological life cycle on the structure of the organizations is part of the Management of Technological Change (MTC) project, within the Technology, Economy & Society (TES) program. The activity analysis of a variety of companies shows the changing of main managerial characteristics as shown below:

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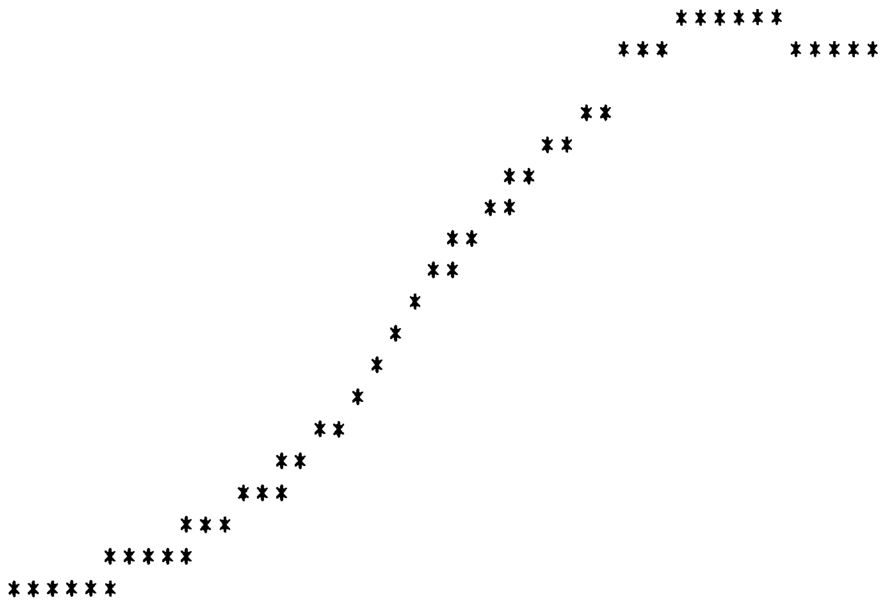
[5] Ayres, 1984.



PHASE: / CHARACTERISTICS:	INFANCY	RAPID GROWTH	MATURITY	DECLINE
Risk	High	Relat. low	Low	High
Investment	Low	Very high	Relat.high	Low
Economic results	Nil	Relat.low	Very high	Declining
Structure	Project-oriented	Matrix	Functional	Functional
Formal Proceedings	Nil	Moderate	Widely used	Common use
Main Activity	R&D	Investment	Production	Sales

If this distribution of main characteristics is valid for an "average" company, then it is logical to expect (and very limited evidence confirms these expectations) the following changes in the organizational structure along the different phases of the life cycle. In the infancy phase, two levels of decisions are formed: a project level and a program level. The flexibility of this structure corresponds to the nature of prevailing R&D activities.

In the phase of rapid growth, changes in main activities leads to the creation of functional departments and the introduction of more levels of decision-making. With a lot of R&D

activities still going on, the matrix structure is the best choice.

The phase of maturity requires a sophisticated multi-level structure with divisional decentralization and a great number of functional departments. Multinational firms are the best examples of this kind of structure, where probably not the size, but rather the complexity is decisive.

In the phase of decline, the multi-level multi-divisional structure reaches its limits and can be regarded as a cost center, rather than a tool for decision-making.

It can be summarized that:

* the relations of the different phases and organizational structure is valuable and clearly identifiable;

* the shift along the phases of the technological life cycle is continuous and smooth, while changes in structure are discontinuous. The appropriate synchronization in time of these two processes is a problem of strategic choice;

* the type and complexity of the structure can be used in a way to identify the phase of the technological life cycle.

The conclusions stated above have been confirmed during the investigation of three case studies carried out in Bulgaria within the MTC collaboration network.

<u>The "Predima" Case</u>

The "predima" technology is a new concept for yarn making with good appearance and pleasant touch. The infancy phase in this case covers approximately the period 1977-1980. Activities during this period were predominantly applied research and development; staff was made up entirely of researchers and designers. The organizational was project-oriented. No economic results were obtained, but investments were comparatively small. During the next phase of rapid growth, which covered approximately the period 1981-1986, the firm's organizational structure changed to a matrix form, and the first functional units were created. Large investments were made in production capacities, both for producing technological equipment and for exploring possible new products to be made with the Predima technology (i.e., different varieties of yarns and knitted garments). The company is now a complex business-oriented organization, with 6 divisions. The structure is a typical functional one, and the economic results are high. For a 3-year period, between 1982-1984, production doubled every year; for the next 2-year period, 1985-1986, it tripled each year; and for the last year of investigation (1987), it increased by 70%.

Together with the other structural changes, the R&D unit was recently developed and has become a well-equipped laboratory for applied research, along two main directions: developing the Predima technology and its equipment and developing new products made by this technology.

The "Electrotermia" Case

The enterprise concentrates on the exploration and development of a technology for the optimal utilization of graphite electrodes in electric arc furnaces and the related technological and design problems. The company's activities include developing protective coatings and machines to produce protective folia and developing and improving the technological process. The period under study covers the entire technology life cycle from idea generation in 1958 to 1986. The idea generation and development, as in the prior case, were carried out by the inventor himself, both independently and as part of his institutional research activities. In the period 1960-1964, a small research group was formed at a large steel plant laboratory and given the opportunity to do applied research and develop the technology. This small group was supported by a relatively small investment. The steel company itself was very interested in the research and provided the research group with good working conditions. In 1968, a protected electrode production line was installed, and the first technological operations were performed. Production started (for use by the steel company), and later during the early 1970's, the first license was sold to British Steel Corporation. The infancy phase started in 1968 and was completed around 1974.

In the meantime, the research group was moved to the Research Institute for Non-Ferrous Metallurgy and set up the necessary production facilities to satisfy completely the entire domestic demand. Until 1975, the group worked as part of the institute and their activities operated separately. R&D activities were performed by a small group of people within the frame of a large institute for metallurgy, and their research was only a very small part of the whole effort. At the same time, facilities for producing electrodes were developed outside, in the steel company. This resulted in a slow-down of the implementation process and significantly reduced the quality of coated electrodes.

A separate research and production laboratory, Electrotermia, was established in 1975, and developed in 1980 into a research and production enterprise. The enterprise now has responsibility for research, design, delivery and installation of production facilities for protective coatings; design and production of equipment; staff training for technical plant maintenance; side activities for better utilization of graphite. This period was very successful, production increased sharply, and many licenses were sold (through 1984, in more than 15 countries).

Since the merger of R&D and production of coated electrodes, a rapid development of new coatings and equipment has been noticeable. During this period, a special automatic lathe has been developed, and machinery improvements have been made. The beginning of the 1980's marked the maturity phase of this technology, and the activities were mainly directed to fundamental and applied research in new coatings and also engineering activities abroad. Being a small company with the framework of a large association, Electrotermia has no opportunity to conduct its own market research and trade activities. This complicates and slows down the process of licensing sales abroad and engineering activities.

The creation of a separate enterprise embracing both R&D and production activities would provide facilities for a rapid development of production capacity and better R&D facilities.

The Counter-Pressure Casting Case

The idea and fundamental research developed during the period 1956-1961, within a department of the Bulgarian Academy of Sciences. The same department carried out applied research and constructed a prototype of the equipment. During the period 1962-1966, the unit grew to 100 people and was transformed into a central laboratory for research in the field of casting aluminum alloys, developing new alloys, casting steel alloys, physics of metals, developing metal alloys with gas, developing non-metal materials, and designing machines. Investments were made for R&D activities and the necessary R&D equipment. In 1967, a separate research institute of metals technology was set up, and a year later, a business organization "Casting Equipment" was created. The two have worked together to develop the technology and necessary equipment.

The implementation stage started with a relatively small investment, and the organization's structure was simple, but functional, activities being closely coordinated with the research institution.

Due to the difficulties faced in coordinating R&D and production activities within this organizational setting, the "Metals Technology Corporation" was created in 1973. It joins R&D and fundamental research together with production, engineering, and sales activities, both domestically and abroad. Investment from that time until 1986 was large and directed to capacity development and some R&D activities. During the period 1969-1973, production for the domestic market increased 10 times, almost doubling each year. During the period 1973-1986 (the infancy phase), production for the domestic market increased 20 times, with an average growth of over 120% each year. After 1977, a rapid increase in the production of counter-pressure casting in other countries was achieved. Production has increased from 200 to nearly 10,000 tons per year, with an average growth of nearly 170%. At the same time, the technology continues to develop, including new applications of the counter-pressure method in steel and plastics. The vertical integration between fundamental R&D activities and production had a very powerful influence on the development of the technology of counter-pressure casting. The fact that the organization was directly subordinated to the Ministry Council gave it greater flexibility and more opportunities to explore the possible multiple effects in different branches of industry to diffuse the technology rapidly, also on an international scale.[6]

Returning to our discussion at the beginning of this paper, we can also cite the examples from steel companies under study in the MTC project. During the investigated period between 1950-1985, the basic oxygen furnace (BOF) technology was introduced and developed (from infancy to maturity) in all companies under study. This period coincided with the rapid post-war development of steel production in many countries and with the last growth period in international steel production. The 1970's saw the beginning of the steel industry's mature phase, followed by a crisis in steel production.

Looking at the studied companies (6 companies representing 6 different countries have been studied in more detail regarding organizational changes) as they approach their maturity phase with middle-level technology, we see structural similarities at the level above the production units. All companies are typically multi-level, divisional, decentralized to a varying degree, with many functional departments, boards, and consulting units. The dynamics of organizational changes is very low, even in the beginning of the studied period, and the only noticeable instrument in organizational structure is the varying degree of centralization or decentralization in decision-making.

The studied cases give us the opportunity, not only to demonstrate the validity of the previously stated summary, but also to draw some additional conclusions.

It is important for newly emerging technologies to create through the organizational structure favorable conditions for the vertical integration of science, development, and production. The case studies of Bulgarian technologies have shown that when such conditions are created in time, the diffusion of the technology, both vertically and horizontally, is accelerated and the economic results are better.

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[6] Detailed information about the technology of counter-pressure casting and the development of the organization's form can be found in "Management and Technology Life Cycle: Bulgarian Case Study on the Technology of Counter-pressure Casting," IIASA working paper WP-87-88, by J. Djarova, G. Nachev, I. Nenov, and T. Tonchev. Information about other technologies can be obtained from the TES-MTC Project at IIASA.

In mature industries within large companies (see the example of steel), structures remain generally stable, even with a change in technology at the production level. As expected, changes appear at the production level, but changes in the structure above are usually due to new strategic directions and are mainly brought about by changing the degree of centralization/decentralization in various functions.

A new agent of impact on the structure of management, only recently taken into account, is information technologies. With computers and communication facilities available at low prices and the possibility of organizing large data bases with immediate access, it is now possible to shift decision centers to the most appropriate place. This makes it feasible to build a flat structure with all the consequent advantages.

"Information technologies" is a comparatively new term, widely used recently and heavily loaded semantically, the result of convergence and integration of telecommunications, computers and microelectronics.

By the term "information technologies," many authors mean the application of computers in management. This narrow approach is limited and involves the danger of leaving out many technological innovations with a substantial impact on management activities. Those are (to mention only a few of them) the methods and the tools for: creating documents (printing, copying and reproducing); fixing, storing and retrieving information represented in visual and audio form (dictating machines, audio and video recording techniques, slides, films, microfilms, microfiches etc.); means for information transition (telephone, telegraph, telex, optical cable, local and integrated systems, radio, USW and satellite communications etc.) as well as many other approaches, methods and techniques used traditionally in management practice.

Considered separately, some of these techniques for registration, processing and transmitting information are not new. What is new in modern information technologies can be illustrated in two main directions. First is the integration between computers, telecommunications and microelectronics, leading to the creation of fundamentally new solutions (management information systems, computer-integrated manufacturing, data networks, expert systems, artificial intelligence etc.).

Second is the analysis of management as an information process with four invariant cyclical phases: acquisition, storage, processing and transmitting of information.

This second point is one reason to consider information technologies analogous to production technologies as a set of methods, tools, procedures, knowledge and skills to influence the subject of work. In this aspect, widely spread definitions of information technologies[7] containing mainly word processing, electronic spread sheets, electronic mail or combinations thereof are too narrow and do not explain the nature and real content of the problem.

As far as the substance of management process (decision-making) is concerned, information technologies have a real or potential impact on the structure of organizations. The organizational units are formed around centers of decision-making. Tactical decisions lead to the creation of centers (and units respectively) at the lowest level of organizational hierarchy, and strategic decisions - at the highest. From the bottom (shop floor) to the top (board of directors, etc.), there are usually four, five or even more levels.

The disadvantages of too many levels in organizational hierarchy are well known, and many efforts have been devoted to build flatter structures. One of the most effective ways of solving this problem is introducing modern information technologies into the process of management. Decentralization of decisions and authority is aimed not only to reduce the number of levels and units in the organizational structure, but mainly to focus the efforts of managers on business performance and results. And this can be achieved only when a new type of information technology is used.

The analysis of potential opportunities to use information technologies to improve and simplify the structure of management leads to the following paradox: the more centralized the information needed for decision-making is, the more decentralized the decision centers can be. This statement requires explanation and more precise definition. By centralized information is meant the creation of a common data base, accessible to many users. In such case, there is no more need to look for instructions and to wait for approval from above if authority (responsibility) to make decisions can be delegated to a lower level. Several organizational units now become obsolete. A real possibility of reducing the number of levels is created by introducing information technologies.

The methods of creating large data bases and their effective management are well-known[8] and have been worked out in detail. The computers and communication networks needed to create, maintain and deliver large data bases to many remote users already exist and the cost of their services are going down. What is still missing is the managerial approach and the right attitude to use information technologies effectively.

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[7] Bradbeer, 1984.

[8] Fry/Sibley, 1976.

The principle of centralizing information resources must not be carried to the point of absurdity. A common data base is an effective tool in improving the organizational structure when many users are involved. At the same time, the new technology provides rational solutions for a reasonable degree of centralization: personal computer with data base for one user; local area network with common memory for a small group of users; national, regional and international information networks; etc.

Decentralizing the decision-making process is always accompanied by an integration of management activities. In organizations where the production system contains elements of automation, this is absolutely essential. Even in the simplest case of introducing automatic material handling (a fairly minor technological change), a series of new decision centers at the production level appear. This centers are no longer the orthodox functional "chain of command," but rather a "task force pattern," cutting across functional lines. In terms of management structure, this means that instead of organizing work along lines of functional centralization, it can be organized in a decentralized way, although still involving functional units with the maximum of information and decision and the broadest possible scope.

Black, MacDonald, and Trushell[9] describe in detail the changes in organizational structure and business performance after introducing information technologies at several large and medium companies in the United Kingdom.

A comparison of the potential opportunities created by information technologies to improve management structure and their impact shows that there is a big reserve. This is especially true for the highest hierarchical levels.

It can be stated that information technologies have a tremendous potential impact on the structure of management and, paradoxically, create more freedom for strategic choice.

There are many more factors influencing the structure of management simultaneously with the technology. The impact of size, geography, product-market scope (to mention only a few) is sometimes much more decisive. There is also another phenomenon to take into account: an organization's historical development. In the early 1960's, Alfred Chandler observed that as an organization grew, its structure of management tended to change through a series of so-called "stages of development" -- well-known patterns from 'one-man band' to highly sophisticated multi-level, multi-dimensional structures.

In an age of technological turbulence, the choice and implementation of a sound strategy is a key factor for a company's

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[9] Black, 1983; MacDonald, 1983; and Trushell, 1983.

survival and success. This is why the implicit impact of technology is much greater than the explicit one.

As far as information technologies are concerned, as organizations grow and become more complex, their structure much be adopted continually in order to provide the best pattern for channeling key information[10] to the decision-making centers.

It can be stated now that if "structure follows strategy" and the strategy is influenced by technological change, then the impact of technology on management structure must be investigated very carefully as a somewhat indirect, yet apparently very important, factor.

In Summary

The investigation of technology's impact on management structure is made based on observations in a number of Bulgarian state-owned companies, IIASA's Management of Technological Change project data files and bibliographical sources. The main conclusions derived from this investigation can be summarized as follows:

* There is no possibility to define an exact demarcation line between the school of technological determinism and that of strategic choice. Both agree that technology has a certain influence, more clearly defined at the lower structural levels.

* The level of technology shows a greater impact than the specific type of technology. The classification of low, middle and high technological levels is conditional, and for this reason no explicit conclusions are possible.

* The phases of the technological cycle have a clearly pronounced impact on the structure, and their consecutive shift is accompanied with organizational changes.

* The limited number of investigations concerning the impact of information technologies does not permit final conclusions. The opportunities are still more potential than real.

[10] MacMillan, 1986.

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