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Strategic, Organizational and Social Issues of CIM: International Comparative Analysis (Part I)

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WORKING PAPER

STRATEGIC, ORGANIZATIONAL AND SOCIAL ISSUES OF CIM: INTERNATIONAL COMPARATIVE ANALYSIS (Part I)

Milan Maly

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FOREWORD

There are many hypotheses regarding different social issues of CIM technologies. The paper gives a review and synthesis of the key hypotheses on the impact of managerial, organizational issues and work content, which are presented in the literature. The paper furthermore presents a procedure to test these hypotheses against the data coming from the concrete case studies and to draw conclusions from the respective cases.

Some results and conclusions are presented by using data obtained from IIASA's world-wide FMS interview, survey and pilot cases in Finland and Czechoslovakia. The method of the paper forms a basis for making international comparisons and for drawing conclusions from the case studies, which will be pursued by the IIASA CIM Project in the near future.

Prof. Jukka Ranta
Project Leader
Computer Integrated
Manufacturing

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

1. INTRODUCTION

The Computer Integrated Manufacturing (CIM) Project as a part of the Technology-Economy-Society (TES) Program at IIASA emerges from the idea that the choice by firms, industries, and governments of specific strategies to take advantage of CIM will depend on how well the relevant decision makers understand the mechanisms through which CIM will benefit different firms and industries. The deeper the level of understanding, the more productive will their strategic choices be.

This Working Paper aims at contributing to a better understanding of the mechanisms of CIM adoption in companies and enterprises. The dominating idea is that the probability of a successful adoption of CIM is to a great extent dependent on managerial forms and methods applied to different phases of CIM adoption, such as the planning phase, in which the strategic goals and prerequisites are specified, the implementation phase, where the proper organizational conditions for the adoption are created, and the daily operation, where the importance of social aspects is increasing.

From prior studies we can find many examples supporting the idea of the high importance of managerial factors in CIM or FMS adoption.

Willenborg [Willenborg, 1987] pointed out that not only financial and technical factors, but also organizational aspects impede the successful implementation of FMS.

Ranta [Ranta, 1986] assumes that managerial and social factors (management practice, the managerial design process, training, etc.) are more immediate issues than purely technical questions when studying application possibilities.

Bessant and Haywood [Bessant & Haywood, 1985] carried out interviews at 23 manufacturing engineering companies and 10 suppliers of machine tools and software in the UK. Almost all of the firms interviewed for this study have stressed that one of the major consequences of planning and/or installing FMS has been a change in the management/organizational side of the company. This has had considerable implications for improvement strategies, shifting the emphasis away from technology per se, towards the way in which it is used.

Our methodological approach is based on testing of alternative strategic, organizational and social hypotheses, taken from published sources, with the results acquired from the IIASA questionnaire database. The special comparison of the results such as centrally planned vs. market economies, large vs. small countries, different industry branches, Western Europe vs. USA vs. Japan, etc., allow us to develop some new conclusions and hypotheses. Generalized conclusions for different environmental, economic, cultural and other conditions will be drawn from the results of our investigation in its final stage.

In the first stage of our research work the Finnish-Czechoslovakian pilot study, covering 9 FMS as a part of CIM, has been carried out. The data were compiled and computerized. The main purpose of this step was to conceive the hypotheses and to carry out a preliminary testing of some of them, due to the relatively small number of statistical data at that stage. The comparison is also limited to centrally planned vs. market economies. The results from this stage and the first conclusions present the substantial part of this Working Paper.

A further result from that stage was the final refinement of the questionnaire as a consequence of the experiences gained from the pilot study. The final version of the questionnaire is, of course, the result of many other previous steps of its development and improvement starting in the middle of 1987 at the IIASA CIM project workshop in Ivalo, Finland. Its development also includes a number of consultations with experts of different countries.

The questionnaire now covers about 400 items and the following structure:

- General indicators of company adopting FMS
- General indicators of FMS
- Technological and logistic specifications of FMS
- Economic consequences of FMS
- Social issues of FMS
- Managerial issues of FMS
- Logistic issues of FMS.

In the second stage of our research work it is intended to increase the data base substantially (we expect responses from

100) and all the managerial hypotheses will be tested on the broader basis. We expect responses from 5-6 centrally planned economies (USSR, Czechoslovakia, GDR, Bulgaria, Hungary and Poland) and from 10 market economies (USA, Austria, Italy, France, Sweden, Finland, Japan, FRG, UK, Netherlands). The final results from that stage will be contained in a Working Paper on Managerial Issues of CIM - Part II.

2. SURVEY OF MANAGERIAL HYPOTHESES

The managerial hypotheses are divided into the following areas of managerial activities:

- strategic issues of FMS adoption;
- organizational issues;
- socio-economic issues and consequences.

The managerial hypotheses were specified by means of literature sources (either theoretical studies or published case studies). The main purpose was to outline the basic tendencies of different factors as a result of the production automation and integration development. The stages of production automation and integration are understood to be the following steps:

- conventional machines;
- NC-machines;
- MC (machining centers);
- FMS;
- CIM;
- A.F. (automated factory).

On the above-mentioned basis we can now specify the predicted tendencies of the development of different factors.

2.1. Strategic Issues of FMS Adoption

The strategic decision makers are facing in these days complex and very complicated questions, i.e. what are the main reasons for introducing CIM or FMS, what are the main driving forces behind the strategic decision of companies top management to adopt CIM or FMS? An investment in that case is a strategic decision for the entire company to which management should be fully committed. If we go through different literature sources we will find many different reasons for FMS adoption.

The first strategic question is the basic orientation of production. Brödner [Brödner, 1986] shows the two main variables for alternative product strategies, the type of competition to which they are exposed, and the volume in which they are produced. According to these conditions production could, in the past, be divided into low-volume production of customized quality-competitive goods, or into high-volume production of standardized price-competitive goods. New technologies, such as CIM or FMS, permit to apply another type of production: high-volume production of customized quality-competitive goods.

The latter technology may be able to react to a substantial shift on the world markets, characterized by an excess of products and the need to react quickly to very frequent changes of customer demands. The CIM technology promises to become highly flexible as to product and process innovations, higher productivity, production times reduction and increase of quality and functionality of the products.

Similarly, but in more detail, Kristensen [Kristensen, 1986] presents two main strategies by means of which mass production firms can respond to the pressure of increased competition. The first strategy, called neo-Fordism, is to cut the production costs of the existing line of standard goods. The second strategy, called Flexible Specialization, is to avoid competition on prices and to shift to the production of specialized goods, catering to changing niches in the market.

An ECE survey [ECE, 1986] shows the main motives for FMS investment specified as follows:

- strategic investment, including those projects, whose economic return is difficult to calculate. It includes
    - pilot investment, the purpose of which is to evaluate the technology and to gain knowledge advantages over other firms, and "showroom investment" used mainly by FMS component manufacturers as a sales argument to show potential customers the advantages of the system.
- rationalization investment, whose main objective is to reduce the costs, increase profits and competitiveness of the company. It also includes

- <u>expansion investment</u>, whose purpose is to increase capacity and remove bottle-necks, and <u>replacement investment</u>, replacing worn-out machines or shop-floors.

Bessant and Haywood [Bessant and Haywood, 1985] specified in their study, devoted to small and medium-size companies, the range of motives for moving into FMS technology:

- the need to reduce lead times;
- the need to reduce working capital costs;
- the need to replace an existing plant;
- the need for more accurate control;
- the need for improved machine utilization;
- the need to offer a wider range of product variants to retain the marketing edge;
- the need for higher quality.

Bullinger [Bullinger et al., 1987] specifies four goals of production, which were conflicting in the past:

- high capacity utilization;
- high productivity;
- short throughput time;
- much flexibility.

Conflicts of goals arose between capacity utilization and throughput time and between productivity and flexibility. FMS is able to weaken or almost eliminate the above conflicting goals.

Lim [Lim, 1987] analyzed the management objectives for FMS development in 12 companies in Britain and found that the most important aims were predicting customer demands (the main aim), followed closely by the need to maintain a competitive edge internally (among subsidiaries) and externally (local and overseas competitors in similar market segments) as well as to provide extra capacity for rising demand. The next, so-called operational objectives, were reduction in inventory and work-in-progress, followed by reduction in manufacturing costs, improvement in quality of output and machine utilization.

One of the examples of the case studies on that topic is Margirier's study embracing French FMS. Margirier [Margirier, 1987] investigated 19 FMS in the machining industry in France.

One of the major questions was: what economic reasons are behind their introduction by the industrialists in this sector.

Two main strategies for maximizing profit were specified and tested:

- to reduce unit costs by means of time, capital and labor saving;
- and to improve product diversity and reach market demand more rapidly by offering greater flexibility.

The main conclusion from that investigation is that product diversity and rapid reaction to the market do not seem to be major criteria for introducing flexible equipment. The findings of the Margirier's survey lead him to the conclusion that "... it is the reduction of the unit costs which above all determines the choice of this type of equipment, rather than a strategy aiming at product diversity."

On the other hand, many other authors [Jelinek & Goldhar, 1984; Talaysum, Hassan & Goldhar, 1987] mention flexibility as a main driving force for FMS adoption. This is also connected with the discussion about the shift from economies of scale to economies of scope.

Ayres [Ayres, 1986] suggests that from the long-term point of view, quality increase is one important driving force behind FMS, or better -- in our case --, CIM adoption.

Summarizing the goals of FMS or CIM adoption, we get the following list of different motives:

- production increase;
- elimination of bottlenecks;
- productivity increase;
- capacity augmentation;
- cost reduction;
- labor saving;
- lack of labor force or of highly skilled workers;
- material saving;
- energy saving;
- reduction of machine-tools;
- floor space saving;
- inventories reduction;
- W-I-P reduction;

- product range extension;
- product mix extension;
- different time reductions (lead, set-up, cutting, throughput, tendering, delivery);
- revenue and profit increase;
- decrease of return on investment, payback time reduction;
- market share expansion;
- acquiring experiences as a pilot plant;
- costumer claims reduction;
- reject fraction reduction;
- quality standards (tolerance) improvement, etc.

Analyzing the above-mentioned examples we can specify the following main groups of factors of FMS adoption:

1. cost reduction;
2. production increase;
3. flexibility increase;
4. quality increase including service.

From the above and from other literature indications we come to the conclusion that CIM can attain different goals depending on the strategy a firm prefers. CIM is multi-objective and the goals can be changed in the course of time. In many cases CIM fulfills not only one but different goals. If we divide the company strategies into a defensive and an offensive, or according to Lim [Lim, 1987] into a survival and a growth strategy, we can now combine the CIM goals with these strategies. We can logically conclude that the defensive strategy is connected mostly with rationalization investment, while the offensive strategy corresponds to strategic investment, flexibility and quality increase. Moreover, the higher and more expansive stages of production automation and integration also aim to meet the offensive strategies.

The hypothesis regarding the tendencies in strategy goals development is represented in Figure 1.

Figure 2 gives a survey of the preferential strategic goals in Finnish and Czechoslovak FMS. The picture clearly shows the combination of strategic goals, i.e. mainly flexibility (expressed in such factors as delivery time -- mostly in

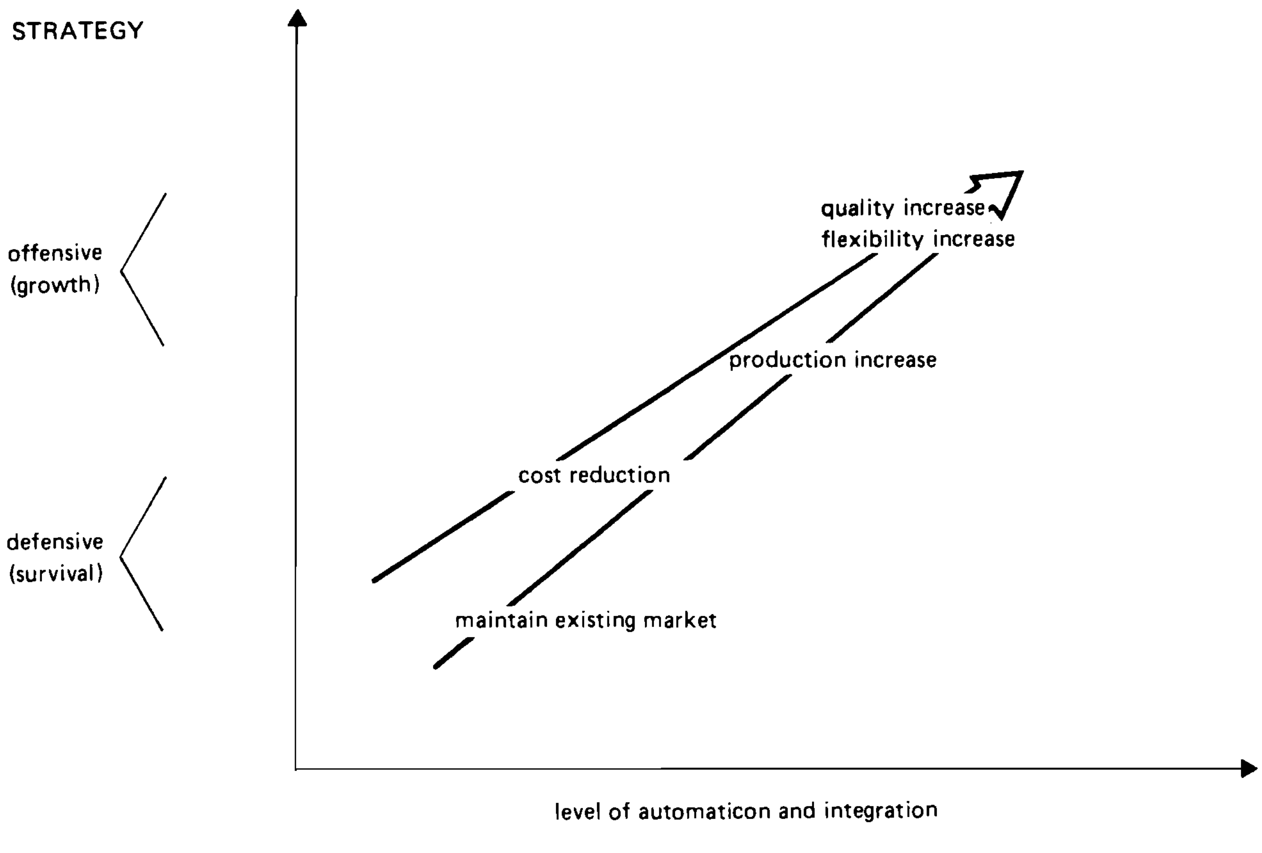


Figure 1. Strategic goals.

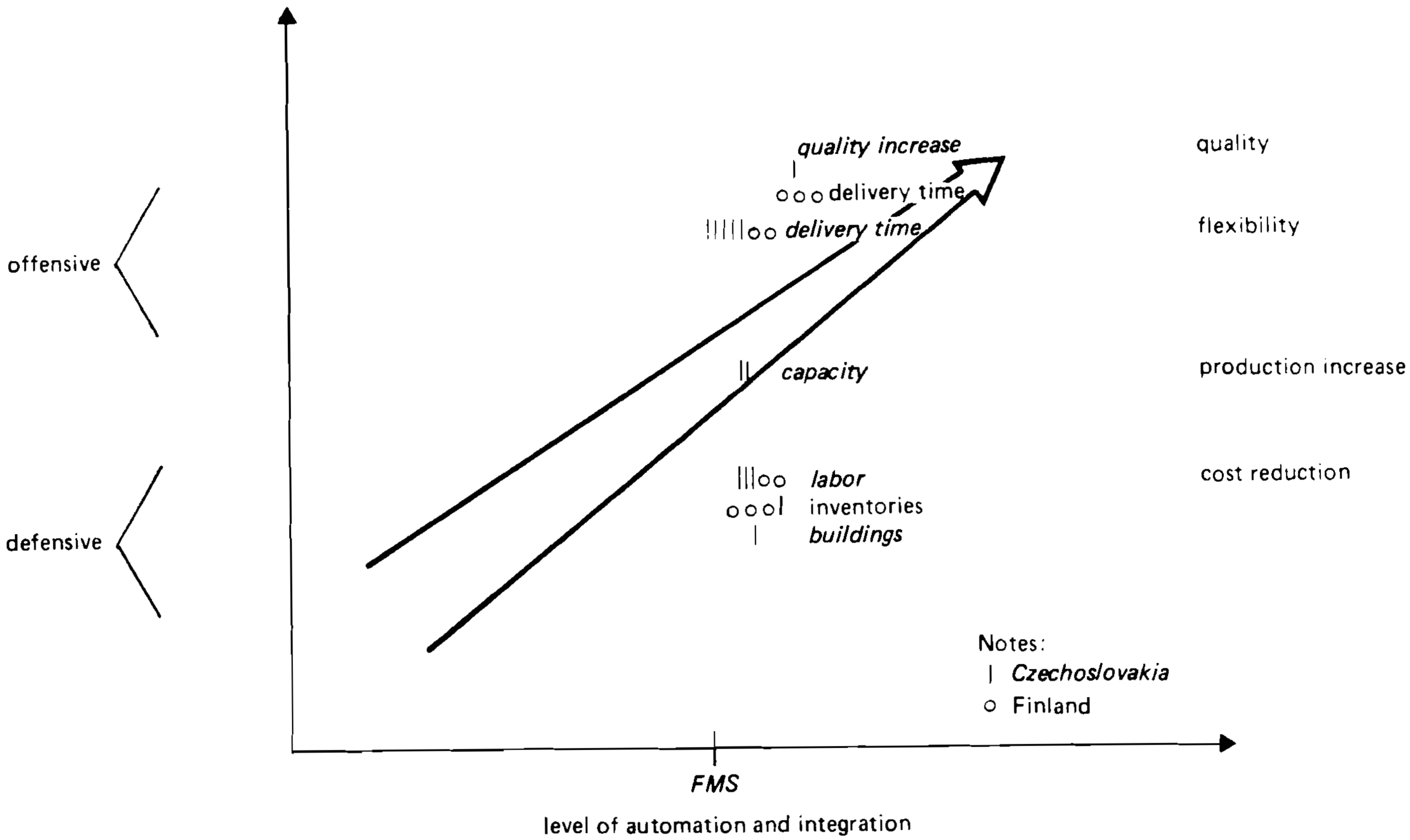


Figure 2. Strategic goals -- F-CS Pilot Study.

Czechoslovak FMS), quality (expressed in delivery service -- mainly in Finnish FMS) and cost reduction (expressed in labor reduction -- mainly in Czechoslovak FMS, and labor and inventories reduction in Finnish FMS).

In Finnish FMS the main emphasis is on quality increase (delivery service). In Czechoslovak FMS the practical absence of quality increase as a priority strategic goal is somewhat surprising. This factors appears only in one FMS. But, on the other hand, this is the case of most sophisticated FMS in Czechoslovakia. This example supports our hypothesis about the tendency of strategic goals in connection with the level of automation and integration. The opposite example can be found in the case of FMS consisting only of NC-machines where the priority goal is cost reduction (inventories and buildings), which supports our hypothesis as well.

The number of the highest priority factors ranges from 1 to 5 in one system. In one case only 1 factor of the highest priority is presented (inventory decrease). Three FMS have a combination of 2 factors, in two systems there is a combination of 3 factors, two systems show a combination of 4 factors, and one FMS presents a combination of 5 factors. In Finnish FMS the average number of dominating factors is 2.75, and in Czechoslovak FMS the corresponding number is 3.00.

From the above we can assume that there are no substantial differences between the strategies chosen in planned and in market economy systems. We can state that the companies combine offensive and defensive strategies. Even in the most sophisticated systems the same combination exists. But the ways of realizing the offensive strategy are different. Finnish FMS stress mostly quality and Czechoslovak FMS stress, on the other hand, flexibility increase.

The task of choosing a proper strategy is, of course, a complicated process, in which we have to take many different system connections into account. The most important factors influencing the choice of the strategic goals are represented in Figure 3.

Strategic decision-making has to reflect mainly environmental conditions such as shifts in the international division of labor, market conditions and changing customer

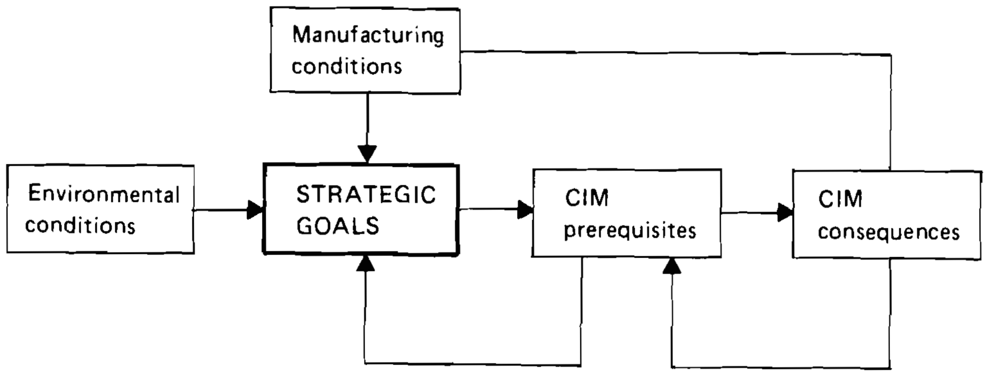


Figure 3. Model of strategic decision making of CIM adoption.

demands. Warnecke [Warnecke, 1987] sees the shifts mainly in the changes in highly developed countries which start to produce more competitive and more know-how intensive products, and in buyer markets with weak demand and excess production capacities. Under such conditions profit depends mainly on the speed and quality of fulfilling of the customer's needs. By speed and quality we understand flexibility, faster responses to customer demands, excellence in product design, higher reliability and uniqueness of products. The effective use of new technologies in products and processes becomes a key factor in international competition.

The feedback between strategic goals and CIM prerequisites expresses a very tight connection among financial prerequisites, such as a good independent financial position for investment, the possibility to obtain venture capital, loans, state subsidy, etc., technological prerequisites connected with the possibilities of hardware and software vendors, of system integrators and the quality of their products, and social prerequisites, such as the necessity of improving working conditions (monotonous, dangerous, hard work), the educational level of the employees, the qualifications as well as training and retraining conditions, etc.

The feedback between CIM prerequisites and consequences plays an important role in the process of iteration between design and real possibilities. Socio-economic consequences expressed, e.g., in the cost-benefit model, expected cost reduction, productivity increase and capacity augmentation, flexibility and quality increase, changes in operation rate, flexible working hours, job rotation and other factors like logistics, create the manufacturing conditions with a close feedback to the strategic goals.

2.2 Organizational Issues

The development to higher levels of manufacturing automation and integration requires adequate changes of organizational forms and managerial structure according to many authors [Bessant & Haywood, 1985; Jaikumar, 1986; Kristensen, 1986; etc.]. The old, so-called Taylor type of structure is noted for differentiation of functions, tasks and organizational roles, and a tall hierarchy with a high number of organizational (hierarchical) levels, with an essentially top-down authority for decision making.

Diffusion of automation to the production process calls for substantial changes of the organizational structure, such as a more flexible and organic structure, and a closer collaboration between all functions. A new development requires the elimination of the traditional boundaries between marketing, design and production, and a closer collaboration among researchers, suppliers, vendors and sales people with management, manufacturing engineers, plant managers and users. The role of application engineering is rising.

The above described development leads to the drastic reduction of hierarchical levels and gives rise to very small self-managed groups with high responsibility, consisting of highly skilled generalists.

The hypothesis drawn from these ideas are represented in Figure 4.

Case studies published in literature confirm the above-mentioned development. For example, Toikka, Hyötyläinen and Norros [Toikka, Hyötyläinen & Norros, 1986] describe the organizational changes in one Finnish middle-size machine engineering factory, producing diesel engines. Six workers from the present production scheme were selected to operate the system in two shifts. The task of this group is to be collectively responsible for the functioning of the system. The group also takes care of the production planning, scheduling and sequencing as well as of the method development and of part of the maintenance. Another example came up with similar conclusions [Jaikumar, 1986; Braczyk, 1986; Kristensen, 1986].

The results from the Finnish-Czechoslovakian pilot study clearly confirm the first hypothesis regarding the decrease of the hierarchical level. The average decrease in Finnish FMS is 4:2, while in Czechoslovak FMS it is 4:2 or 3:2.

The second hypothesis (small highly qualified self-managed groups) was not sufficiently confirmed, because only 3 examples are available. In other cases the responses looked like a misunderstanding of the question.

The other hypothesis is based on the notion that the most acceptable form of labor organization is job rotation in order to

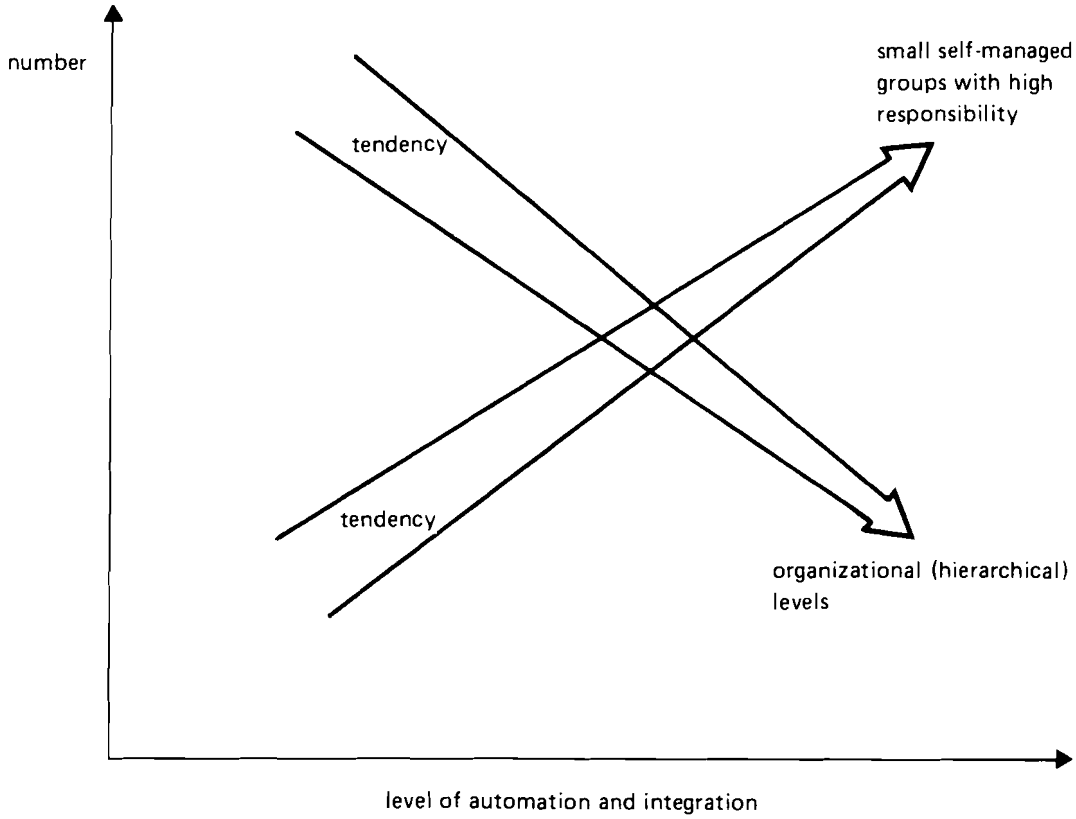


Figure 4. Organizational structure development.

increase motivation and skills of personnel. This idea prevails in literature [Bessant, 1986; Bullinger & Warnecke, 1985; Ferdows, 1983, Graham, 1986; D'Iribarne, 1983; Jones & Scott, 1986; Toikka, 1986]. The hypothesis established on this basis is represented in Figure 5.

Brödner [Brödner, 1984] on the other hand asserts that most installed systems have job specialization.

Willenborg's [Willenborg, 1987] empirical data showed neither extreme forms of job specialization, nor of rotation. In fact, the work on CIM (mainly when we analyze less sophisticated systems) can be characterized as very diverse: both complex and simple tasks have to be performed and managers have to decide what labor organization to choose: job specialization or job rotation. The third alternative, i.e. the combination of both of them, is, of course, possible too.

Our pilot study confirmed the hypothesis of job rotation (Figure 5). The example of Finnish FMS shows that in 3 out of 4 FMS (for one FMS data is not available) all working places use job rotation. In Czechoslovak FMS 2 places use job rotation on the average.

The next hypothesis is connected with the operation rate (number of shifts, unmanned time period). The logical expectation is that the unmanned time period is getting longer, up to its theoretically possible limit, as a consequence of the higher level of automation and integration.

In this case the number of shifts is expressed in the so-called "shift" coefficient Sk:

$$Sk_1 = \frac{\text{total number of operators in system in all three shifts}}{\text{number of operators in system in the morning shift}}$$

This information holds true for men. Similarly we can define the shift coefficient for machine-tools:

$$Sk_2 = \frac{\text{total number of machine tools in system in operation in all three shifts}}{\text{number of machine tools in system in operation in the morning shift}}$$

The practical limit values of Sk_1, Sk_2 are $\langle 1;3 \rangle$.

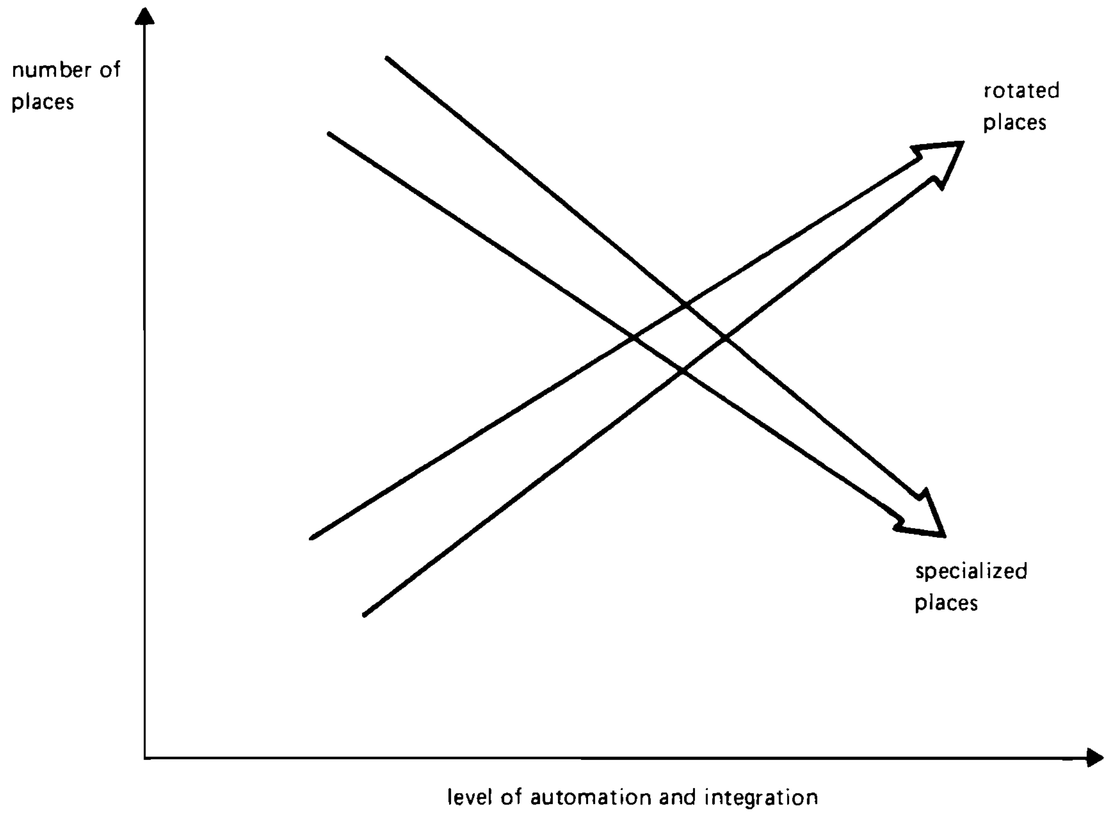


Figure 5. Job specialization and job rotation.

We also logically expect that Sk_2 will increase as a consequence of the higher level of automation and integration.

The development of the value of Sk_1 is not so simple. Sk_1 is closely connected with the unmanned time development but it is not a linear interdependence.

At first we have to assume that the economic reasons imply the necessity of a maximal value of Sk_2 as soon as possible. The only possibility from the beginning is to increase Sk_1.

Later on, when the system is able to work one or more unmanned shifts, we can decrease the number of manned shifts or decrease Sk_1 while keeping Sk_2 on a maximum level.

But there is another possibility to decrease the number of manned shifts earlier, without decreasing Sk_2. The solution lies in operation rate changes or in the adoption of flexible working hours. For example, at the moment when a system is able to reach the period of 4 hours unmanned time (in an 8-hour shift system), this allows us to change the normally used system (morning shift from 6 a.m. to 2 p.m., evening shift from 2 p.m. to 10 p.m. and night shift from 10 p.m. to 6 a.m.) to a two-shift system of the following type: morning shift from 6 a.m. to 2 p.m., 4 hours unmanned time, evening shift from 6 p.m. to 2 p.m., 4 hours unmanned time. Of course, there are many other possible variants solving these problems.

Such a type of solution can resolve the lack of skilled work-force, the negative social consequences of a 3-shift system, etc. The above discussed hypothesis is represented in Figure 6.

The results from our pilot study show that the possible unmanned time ranges from 25 minutes to 30 hours (but the latter is only a theoretical possibility, practically 8 hours shift is in use). Mostly (in 6 from 9 analyzed cases) the period of unmanned time is 8 hours. This allows to work on 2 manned and 3 machine shifts, i.e. $Sk_1 = 2$ and $Sk_2 = 3$.

One example of the Finnish FMS is very interesting. The system is working during working days in 3 shifts, on Saturdays and Sundays moreover 1 morning shift, utilizing students from a technical school as operators. Compared with conventional or stand-alone NC-machines the operation rate changed and the number of machine tools shifts increased on the average by 1 shift (5 cases).

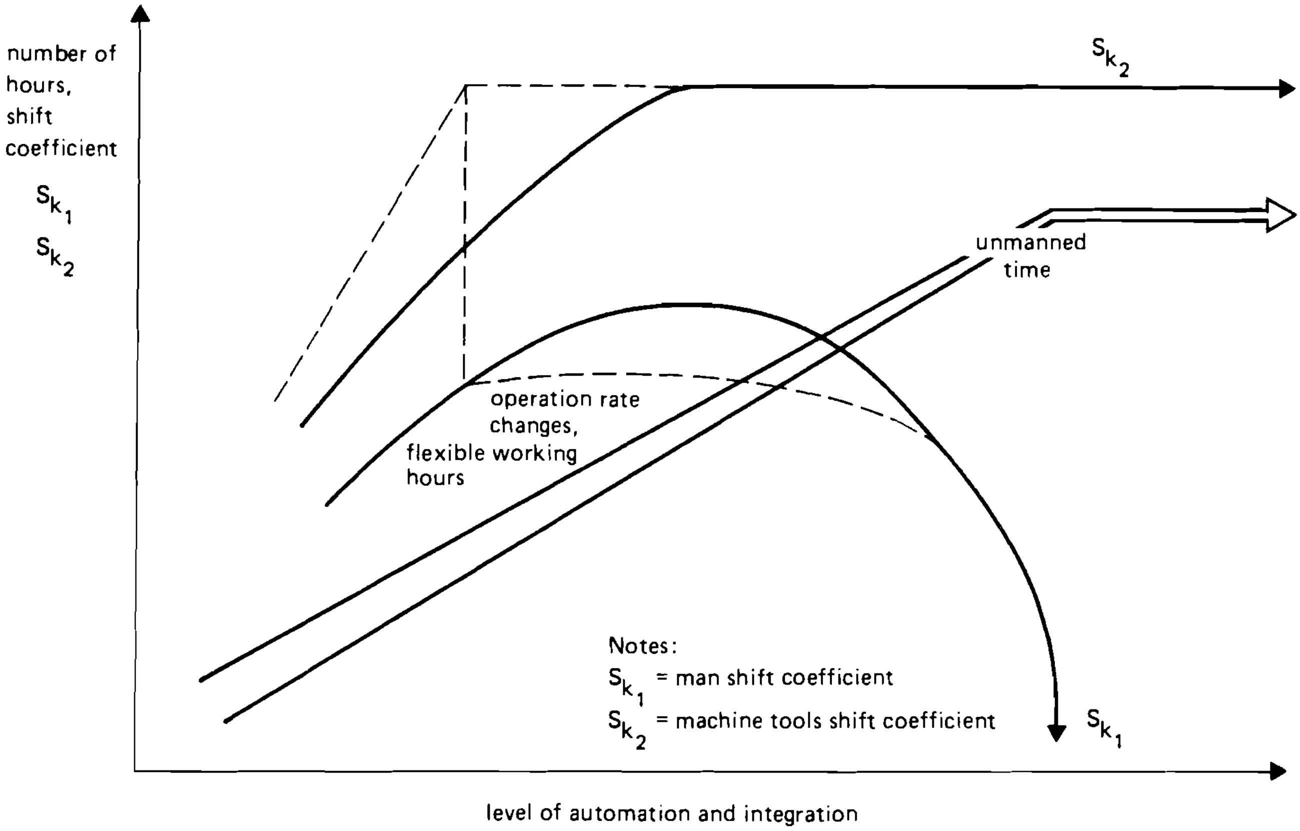


Figure 6. Operation rate, unmanned time.

Flexible working hours and periodical rest of employees are not used in any case. This shows the big reserves for the rest of the systems, where the unmanned time is smaller than 8 hours and where the machine tool operation rate has not yet changed. The possible use of flexible working hours is described above.

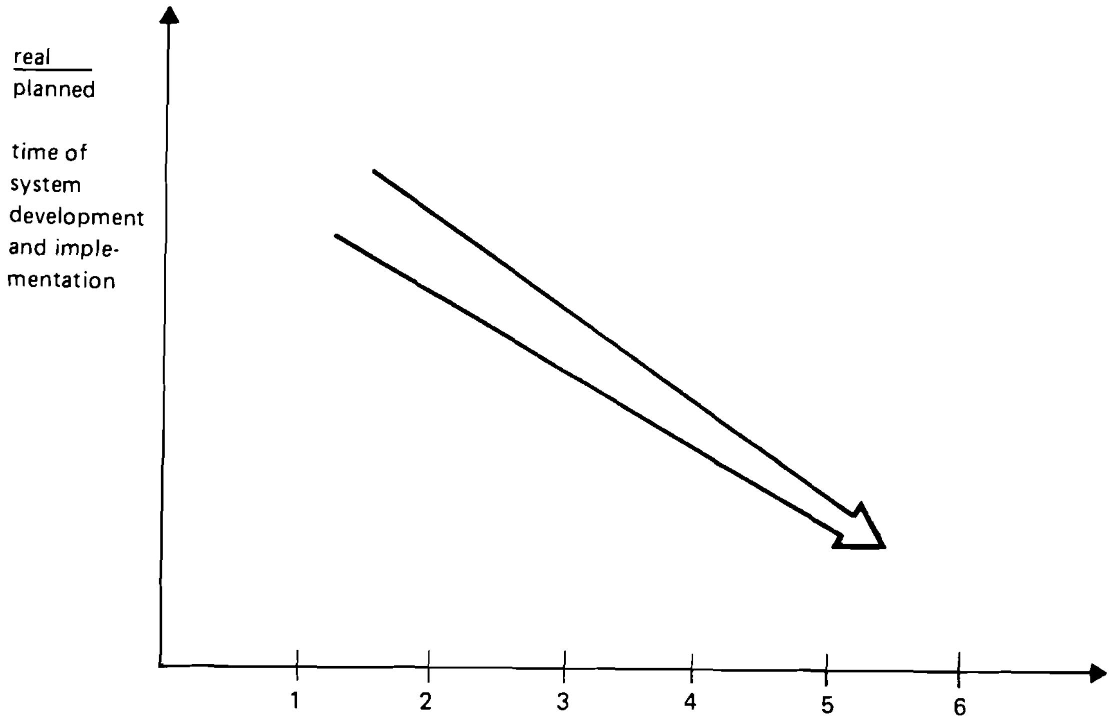
The next hypothesis ranks among the so-called open hypotheses, which can be tested after analyzing the data from the final version of our questionnaire in part II.

The hypothesis shown in Figure 7 expresses the interconnection between development and implementation times of CIM adoption and organizational forms of top management involvement in CIM development and implementation. The more intensive the involvement of the top management in this development and implementation is, the shorter will the time of development and implementation be.

Different configurations and investment costs do not allow to compare real values of the development and implementation time. This is why we use real time to planned time ratio for the comparison.

The following three "open" hypotheses are similar and express the interdependences between development and implementation time on one side, and organization of designers and operators involvement in that process as well as basic organization of project implementation on the other side. The interconnections are represented in Figures 8, 9, and 10.

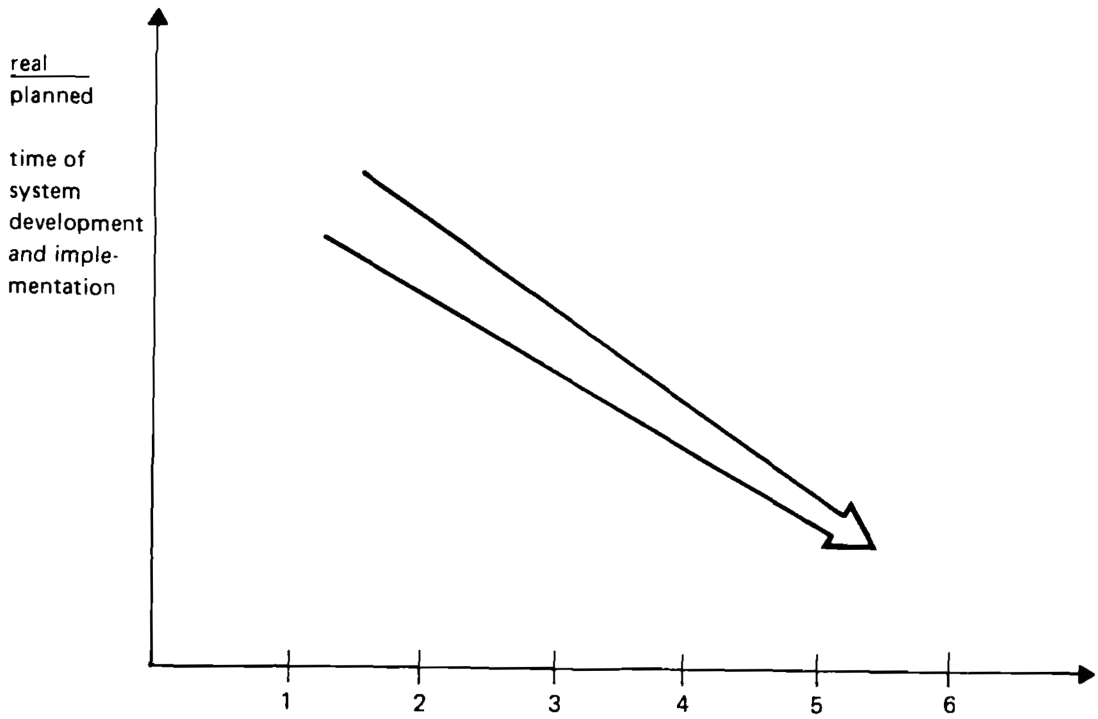
Another hypothesis concerns the infrastructure of the industries. The idea is that FMS and CIM are able to manufacture more complex parts, the part family and product mix are getting broader, and flexibility is increasing. All these factors have important consequences on the number of subcontractors, on the level of imports of semiproducts and parts, and on international specialization and cooperation. We expect changes of the location of the subcontractors, moving more closely to the manufacturers, and improvements in the balance of payments in the national economies. The basic interconnection between complexity, part family and product mix increase on the one hand, and the number of subcontractors causing closer links between manufacturers and their subcontractors on the other, is represented in Figure 11.



Organizational forms of top management involvement:

1. any special organizational forms, consultancy
2. ad hoc meetings
3. temporary advisory committee, indirect participation of top management, consultancy
4. special organizational unit with direct participation of top management
5. top management on the head of the special organizational unit

Figure 7. Organizational forms of top management involvement.



Organizational forms of designers involvement (prevalent):

1. consultancy
2. part time participation
3. full time participation

Figure 8. Organizational forms of designers involvement.

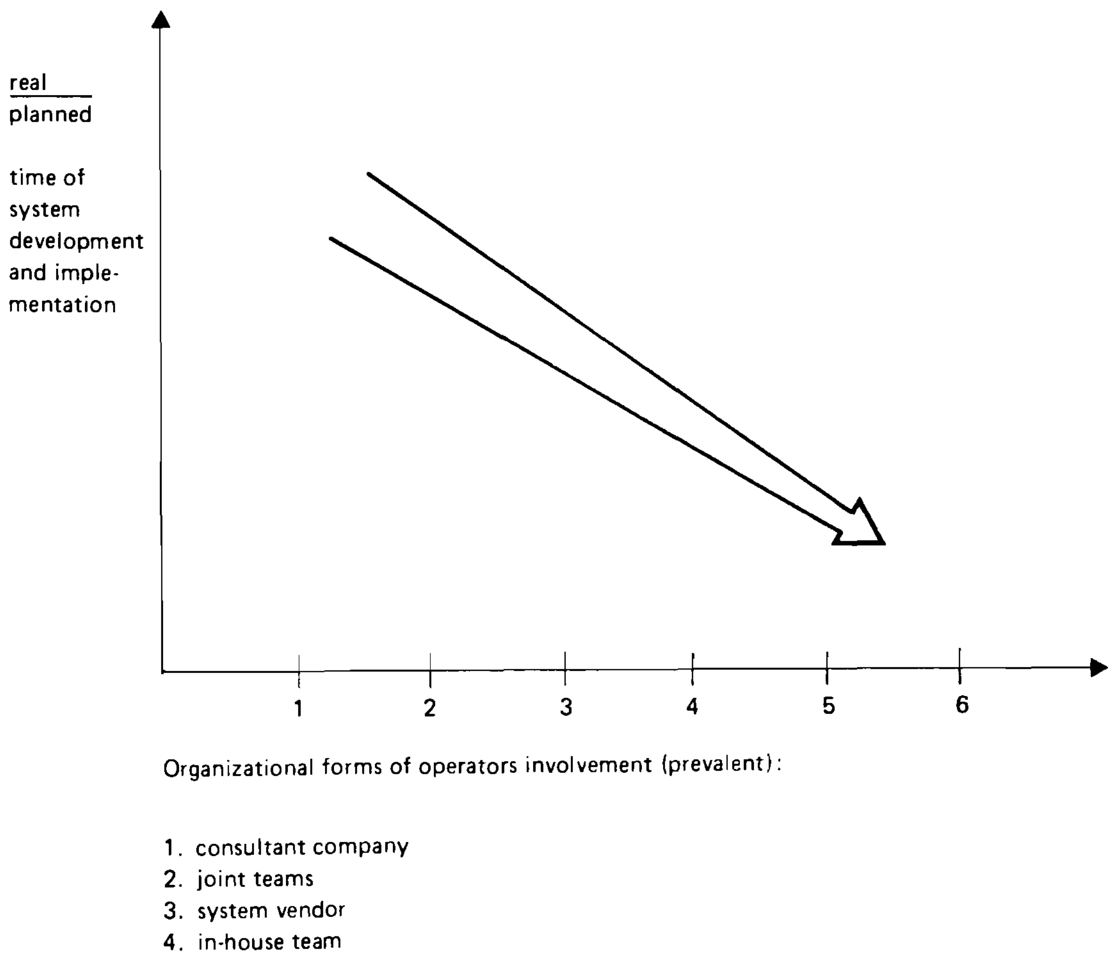
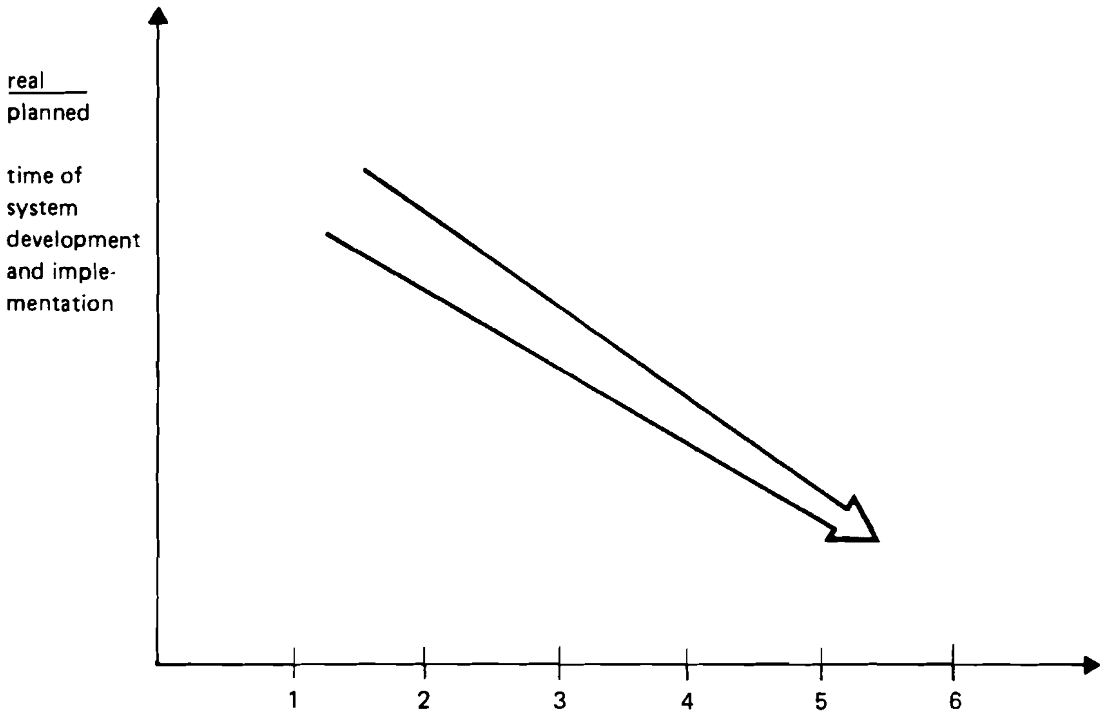


Figure 9. Organizational forms of operators involvement.



Organizational forms of project implementation:

1. consultant company
2. joint teams
3. system vendor
4. in-house team

Figure 10. Organization of project implementation.

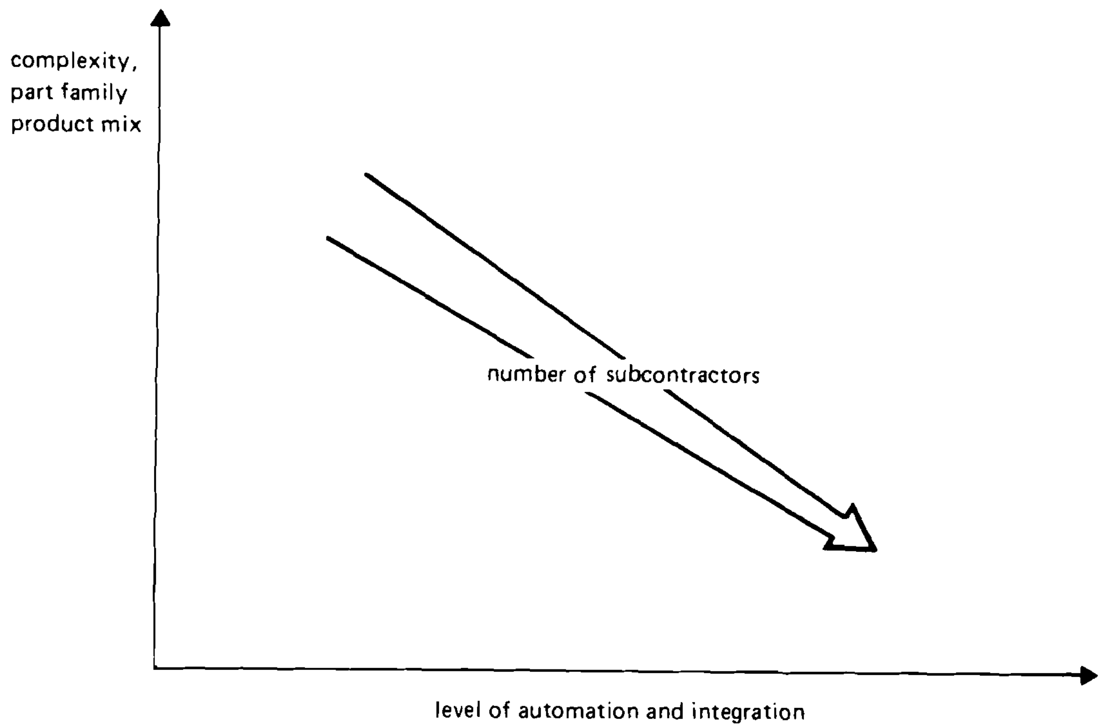


Figure 11. Level of automation and integration.

The next hypotheses have some organizational context, but they rank with a very important area whose relevance is permanently growing -- the information area. Of course we can not analyze this area in detail, and for reasons of specific problems connected with such an analysis we tried to concentrate only on some issues.

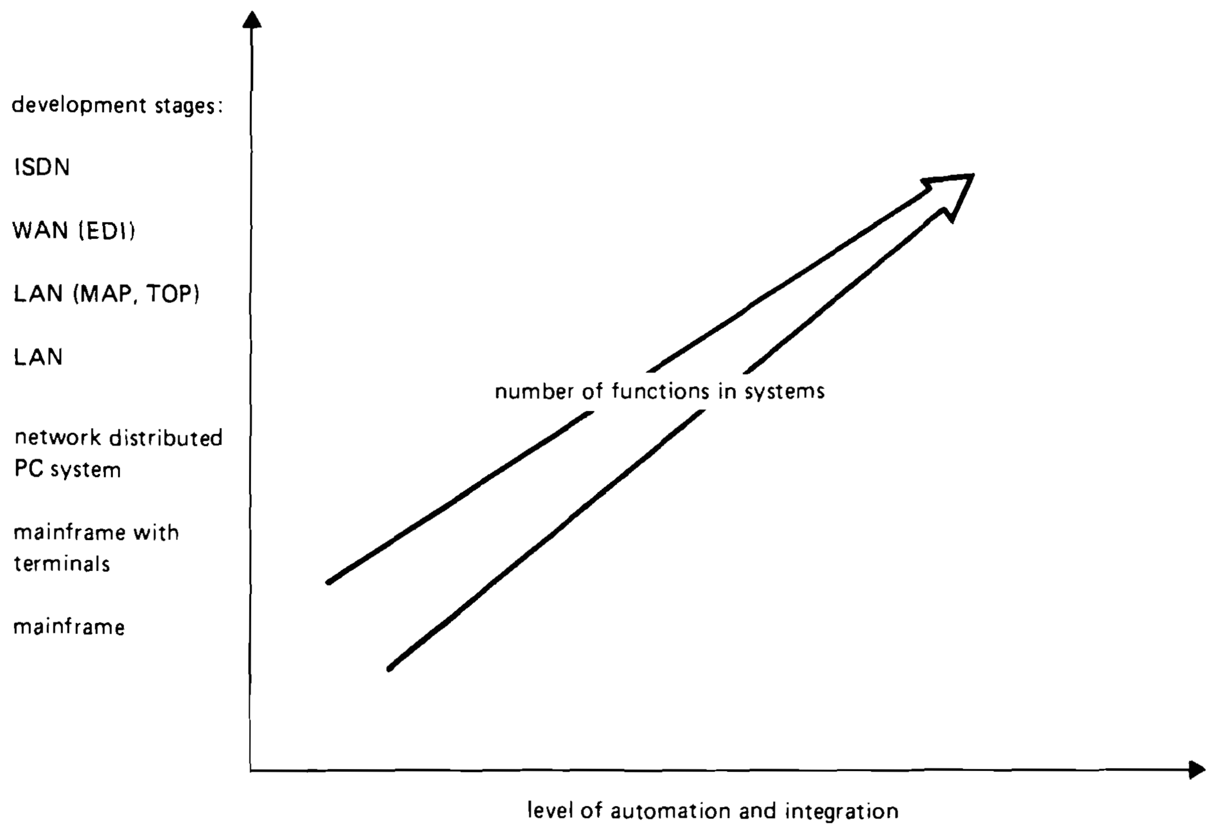
The first hypothesis shown in Figure 12 expresses the relationships between the level of automation and integration and the development stages of information exchange and processing. Higher stages of automation and integration require a higher level of integration and more sophisticated and standardized communication systems.

The results from our pilot study show that the Czechoslovak FMS use mainly mainframe systems with terminals and, surprisingly, no PCs. The Finnish FMS are oriented mainly on network-distributed PC systems. None of them have so far used LAN and communication standards and protocols.

The second hypothesis tries to show the relationship between level of automation and integration and the number of function processes in different stages of information exchange and processing. The hypothesis can also be demonstrated in Figure 12 and is formulated in the following terms: the higher the level of automation and integration, the higher the number of operation processes in higher stages of information exchange and processing.

The results from our pilot study show that in all of the analyzed systems practically all functions are computerized. Within the Finnish systems only one system uses a Minicomputer for CAD/CAM functions, the other functions are computerized by means of PCs, but in CAD/CAM the functions are not computerized.

In the Czechoslovak systems the functions such as material requirement planning, inventory control, order processing and sales monitoring are computerized by means of mainframe computers, and the others by minicomputers including CAD/CAM. Only one system uses PC for material flow control and inventory control.



Notes:
ISDN = Integrated Services Digital Network, including as well telex, telefax, etc.
WAN = Wide Area Network
LAN = Local Area Network
EDI = Electronic Data Interchange
MAP, TOP = communication standards and protocols

Figure 12. Development stages of information exchange and processing.

2.3. Socio-economic Issues and Consequences

The knowledge from theoretical studies and published case studies leads mostly to the conclusion that the development of skills of manpower goes to multi-disciplinary skilled shop floor personnel and to multi-skilled managers [Ranta, 1986; Braczyk, 1986; Schumann, 1986; Bullinger et al., 1987; Bessant & Haywood, 1985].

The division of labor in conventional systems is characterized by a very narrow specification of operators, by a division between traditional crafts and skilled workers, and by division and specialization of labor. The other groups consist of semi-skilled and unskilled workers (mainly for loading and unloading operations). The number of direct operators (handling the machine-tools and other devices directly) and mechanical maintenance-men is relatively high. This is the typical Taylor type of division and specialization of labor.

In course of the time, when a higher level of automation and integration is introduced in the production process, the nature of the process requires integration of skills; thus the number of direct operators is decreasing and, on the other hand, the number of indirect support staff is increasing. The ratio of electrical to mechanical maintenance men is going up, as well as the number of system analysts and programmers. We can examine the gradual substitution of the best qualified production personnel in a system for unskilled workers, such as loaders and unloaders.

Multi-skilled maintenance personnel combine mechanical, electronic and software knowhow.

Even today it seems that the skills of many managers, based mainly on law and economics, might not be sufficient to solve the problems of managing the new technology and they must be changed to a multi-skilled profile.

Work structuring in production tends to job enlargement, job enrichment and job rotation, as well as to an integration of skills.

The basic hypothesis drawn from the above mentioned ideas is represented in Figure 13.

The Finnish case studies [Toikka et al., 1986; Ranta, 1986] distinguish two basic strategies in this area: substitution and development strategies.

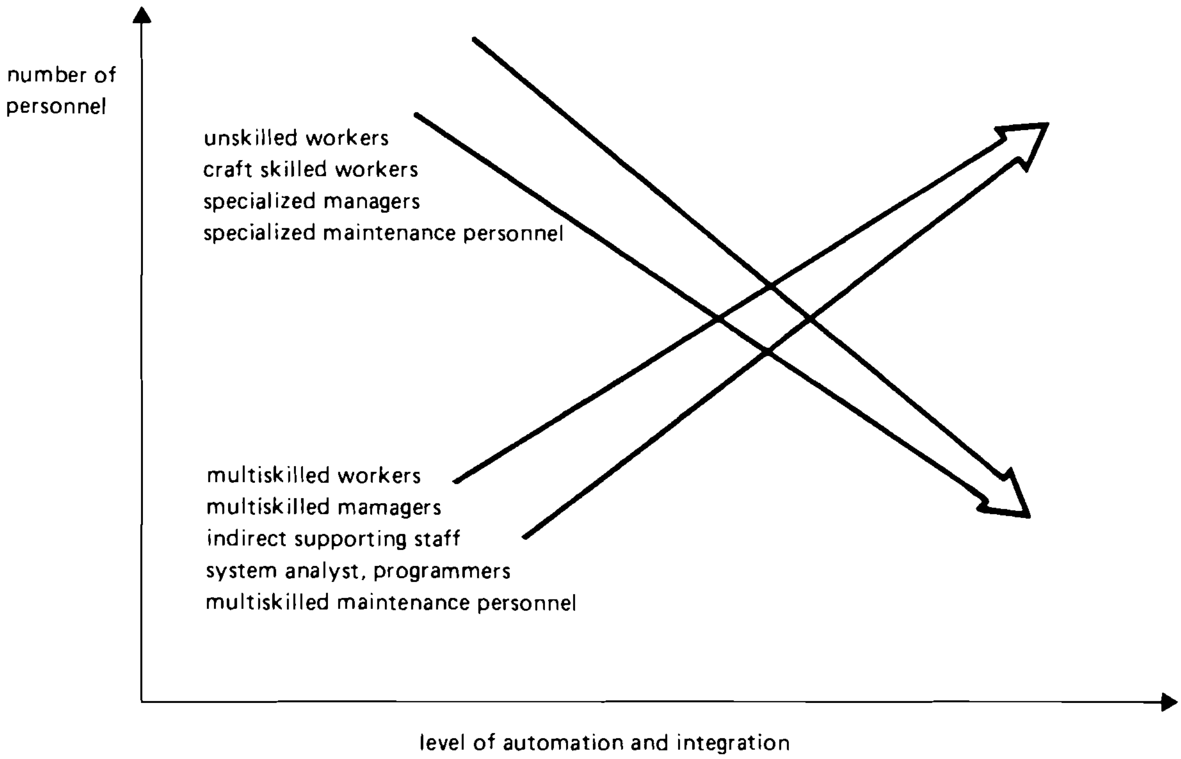


Figure 13. Skills development.

The substitution strategy corresponds to the traditional job structure, characterized by a relatively low level of personnel skills; even unskilled workers can be considered useful in this case.

The production is divided among the different groups of workers: the internal manufacturing operations that require overall planning and management are allocated to the few skilled foremen or group leaders; less qualified groups of specialized workers are placed outside of the actual production process, and unskilled auxiliary workers take care of the loading and unloading tasks; the genuine planning and preparatory operations that require high special qualifications are allocated to FMS-external partners who program and pre-set the tools and also take care of maintenance and repair.

The development strategy corresponds to the alternative job structure distinguished by the extremely homogenous, relatively highly qualified production staff. The internal manufacturing operations can be carried out by each of the workers who are rotating in different tasks. Planning and preparing of production is realized inside the system, only some programming and major repair is done outside. The time consumption for the daily production-process planning is increasing distinctly compared with a conventional system. There is discretion to regulate as much as possible on the shop floor.

The results from our pilot study show very similar outcomes in both countries. On the analyzed level of automation and integration, i.e. in FMS, there are practically no unskilled workers in the system. Compared with conventional systems or stand-alone NC-machines the number decreased from 1-2 workers to zero.

The percentage of college-educated personnel increased from 10% to 20% and the direct/indirect workers ratio changed on the average from 66/33 to 33/66 percent. Mechanical to electrical maintenance personnel changed on the average from 1:1 to 1:1.8-2.

The main changes in work content are characterized by improvement of qualifications, the rise of new professions such as automated system operators, more responsibility (wider area, not growth of task), and larger task content.

All above-mentioned tasks confirm the hypothesis shown in Figure 13. The only hypothesis not confirmed was the substantial increase of time consumption for daily production-process planning. On the contrary, this time has been decreasing in many of the analyzed systems (from 4 hours to 30 minutes).

The next hypothesis is closely related to the previous one and it is connected with the so-called technocentric or anthropocentric approach in the man-machine architecture in CIM systems, today very frequently discussed in literature. The problem has two main angles. Some of the authors stress the qualitative angle and regard the technocentric approach as "technology controlling man" and the anthropocentric approach as "man controlling technology". In the first case the technocentric approach leaves the human subordinate to the system and has no higher requirements on human qualifications. The anthropocentric approach places man in control of the system and needs the multi-skilled operator who, with a very wide, open-ended repertoire of skills, will manage the system despite unforeseen disturbances. From this angle the Finnish and Czechoslovak FMS tend towards the anthropocentric approach.

The second, quantitative angle of this problem stems from the idea that man can be replaced by machines and control devices. The role of the system operator will be to fill the gaps with the thoroughness of a designer. On this basis it is logically possible to draw the conclusion that the more expansive and complicated the system is, the fewer people will the production system need.

Figure 14 shows the results of 20 Czechoslovak and 6 Finnish FMS (in this case an extended data base from additional sources was used). The interconnection between personnel reduction (in %) and investment costs (in million US $) is presented in that figure. On the basis of these results we could come to the conclusion that, assuming only the second angle of the technocentric and the anthropocentric approach (personnel reduction), the Finnish FMS distinctly tend to the technocentric and the Czechoslovak FMS to the anthropocentric approach. However, another explanation of this phenomenon could be very prosaic, i.e. that the economic conditions in Czechoslovakia do not push so strongly for personnel reduction. The figures on the

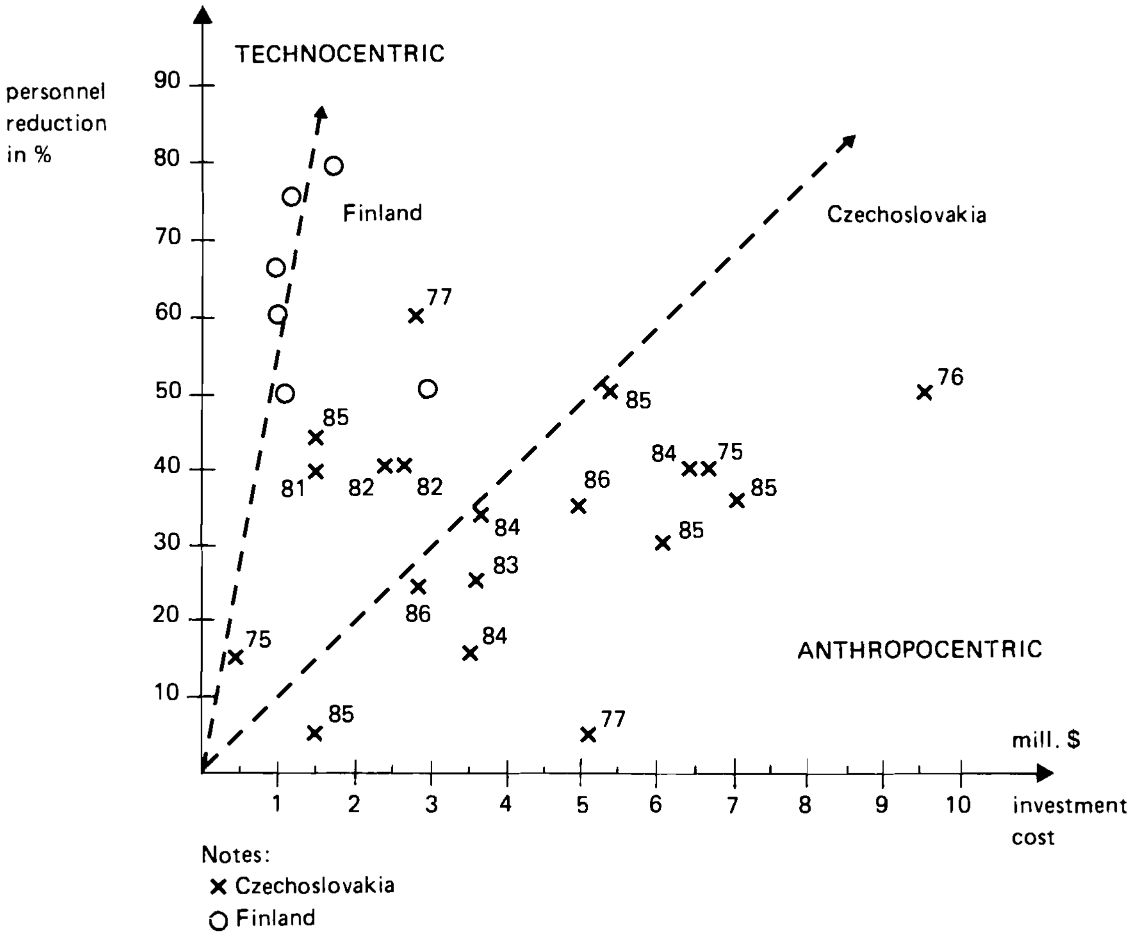


Figure 14. Personnel reduction in FMS.

graph indicate the year of installation of every system, from which it becomes clear that this factor does not have any influence on this phenomenon.

The next hypothesis expresses the notion that higher stages of automation and integration improve the working conditions such as a reduction of the hard, dangerous and monotonous work places. This fact has to have logically such a consequence as a reduction of manpower turnover (fluctuation) and sick leave ratio. The hypothesis drawn from this idea is represented in Figure 15. The results from our pilot study confirmed our hypothesis only partly. Firstly, it was stated in all systems that there are no dangerous work places. Secondly, the influence on the sick leave ratio was negligible. In all but one system no influence was indicated, i.e. the ratio remained without any change. Only in one Finnish system the ratio decreased and is now slightly lower than elsewhere in the factory. Some changes were indicated in the number of hard work places (in four systems) and the maximum decrease of that kind of work place was from 4 to zero (Finland). More distinctive changes were noted in monotonous work places, where the decrease of the number of those places compared with conventional systems was on the average 10-20%, but this applied mainly to Czechoslovak systems (only 1 case in Finnish systems).

The results for the reduction of manpower turnover (fluctuation) ratio are similar. The decrease occurred in all Czechoslovak systems and the maximum value ranges from 18% to zero, on the average from 12% to 1%. The Finnish systems do not show any changes in this respect and the value is zero.

Looking for the main reasons of the differences between the two countries, we found that the starting point of Czechoslovak systems were conventional machines and in Finland they were NC-machines. These systems were compared with FMS and we may conclude that the hypothesis (see Figure 15) is valid for the long-term perspective, assuming the stated level of automation and integration.

Further topics frequently discussed in literature are the training/retraining costs and the training/retraining and recruitment policies for CIM. The general opinion is that higher levels of automation and integration call for a longer time for training/retraining of the personnel and for higher

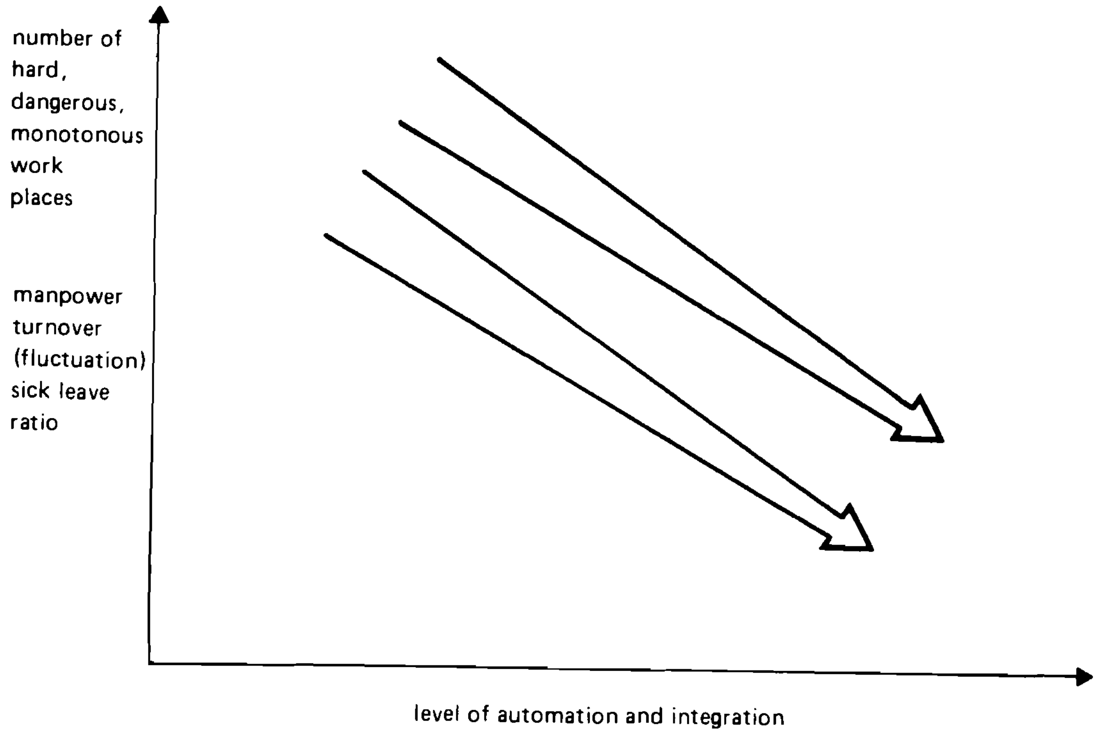


Figure 15. Changes in working conditions.

training/retraining costs. For instance Schumann [Schumann, 1986] describes a new type of multi-skilled operator as "... a man who is manually gifted and theoretically talented, able to diagnose and to act effectively, who possesses to an equal degree metal-cutting and electrical and electronic knowledge of basics. This new type of worker is not the traditional man trained on the job who gets into the position of machine operator without formal training only on the basis of years of experience. Much of the brainwork has been removed from this workplace in normal running, by steering, regulating and supervising functions taken over by computer systems. But instead, according to the new concept of use of labor, this workplace is alloted new tasks for dealing with exceptional situations. Coping with these tasks requires more than in previous times a theoretical competence to a greater extent than could be obtained only by learning by doing."

The basic tendency regarding this problem is shown in Figure 16.

The results from our pilot study contain the data regarding FMS. Unfortunately the comparable data, i.e. for conventional or stand-alone NC-machines are not available, thus it is not possible to follow up on the tendency.

However, the current data do not only show similarities, but they also show some substantial differences between countries as well as inside one country.

The average length of training/retraining ranges between 1-3 weeks in Czechoslovakia and is almost the same in all systems. There is a different situation in Finland, where the time period ranges in two systems between 6-9 months and in the other two systems it ranges between 2-4 weeks. Moreover, in systems with the longest training/retraining time the operators have an excellent background, years of experience with NC-machines and a good basic training. The total training/retraining costs per operator range between 1000-7000 US $ in Czechoslovakia and are again on a similar level in all systems.

In Finland the costs are naturally substantially higher in systems with the longer period of training/retraining: 12000 to 22000 US $. In the other systems the costs range between 1500 - 3000 US $.

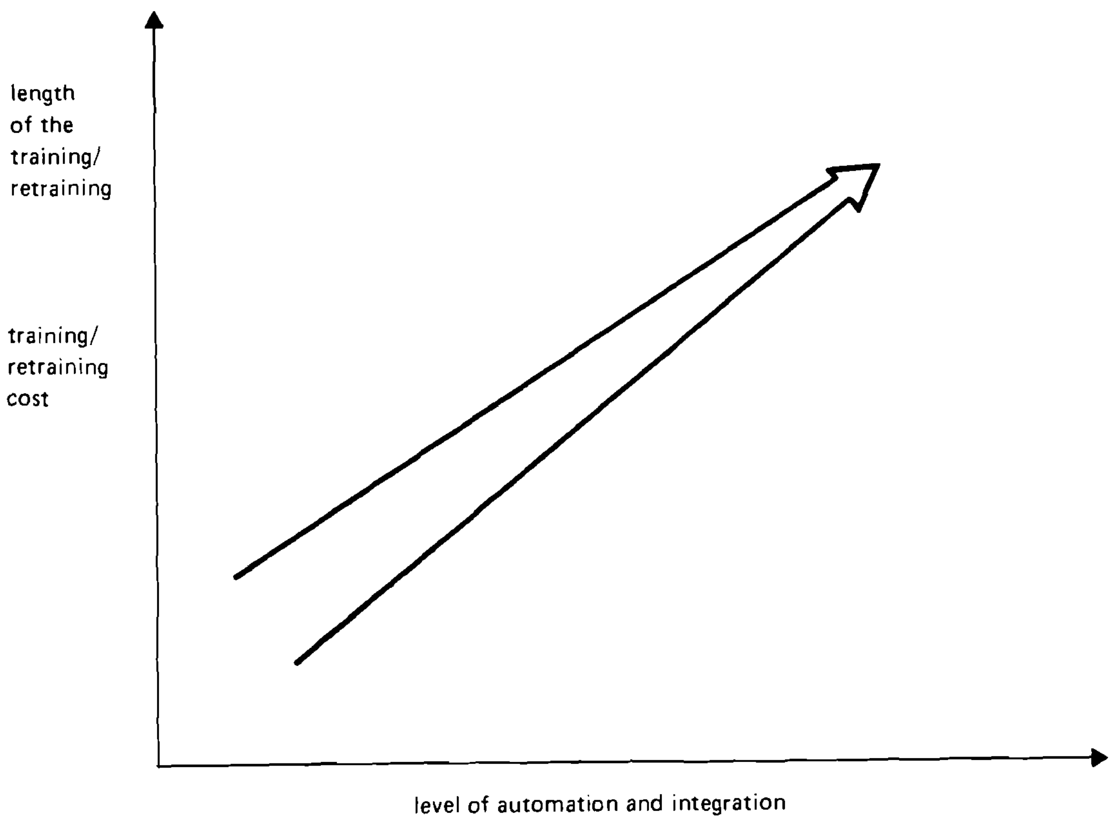


Figure 16. Training, retraining cost.

The last hypotheses in this area are again the so-called "open hypotheses"; they can be testified after gathering more statistical data.

The aim of the hypothesis is to specify more appropriate organizational forms for training/retraining. As a criterion for the assessment of such forms two factors are used, i.e. the non-adaptable operators ratio and the manpower turnover (fluctuation) ratio. The following organizational forms are taken into account:

- on-the-job training;
- off-the-job training organized by:
    - training department of user company
    - special training institution
    - vendors.

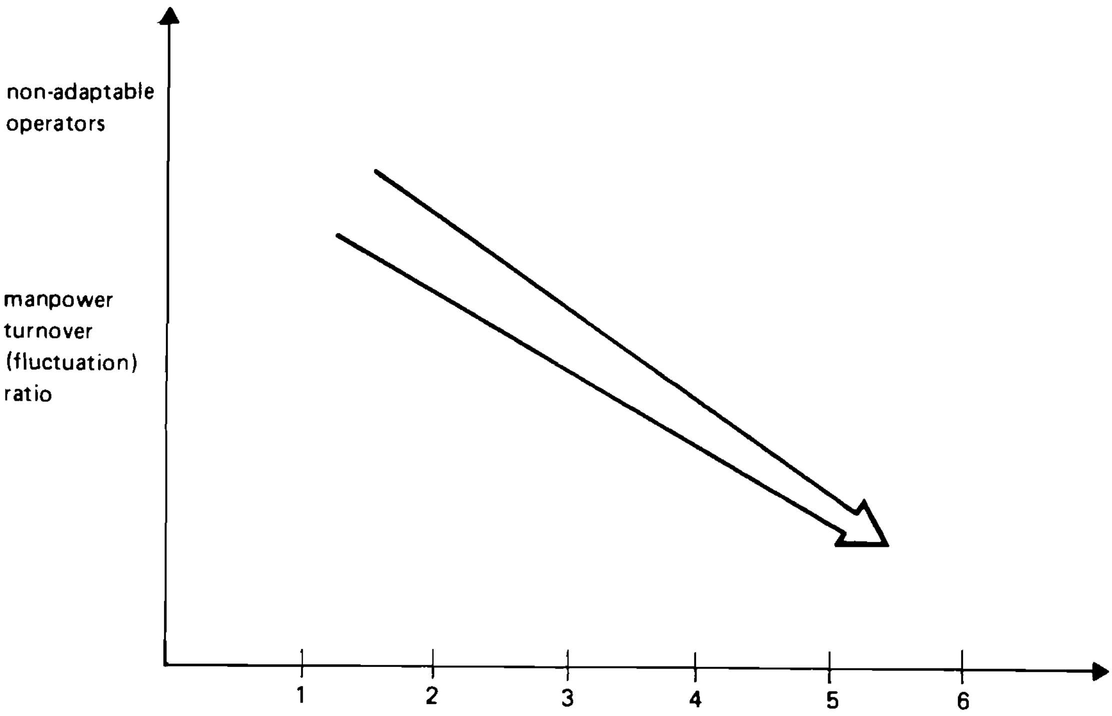
The hypothesis is represented in Figure 17.

The preliminary results from our study show that companies usually use a mix of organizational forms and that there does not yet exist a distinctive correlation between the manpower turnover (fluctuation) ratio and different organizational forms. Moreover, the other factor, i.e. the non-adaptable operators ratio could not be used at all, because no example of that kind exists so far. Maybe it would be necessary to find another factor for the correlation.

The next hypothesis demonstrates the interconnections between organizational forms of recruitment of personnel for CIM and, again, the factors manpower turnover (fluctuation) and non-adaptable operators ratio. The hypothesis stems from the idea that the better the form of recruitment, the lower will the ratio of both factors be, as shown in Figure 18. The following possible forms of recruitment are taken into account:

- recruitment from manufacturing areas closer to CIM;
- recruitees having worked with previous system (machining centers, NC-machines, conventional system);
- young recruitees;
- recruitment from the best operators (creaming-off policy).

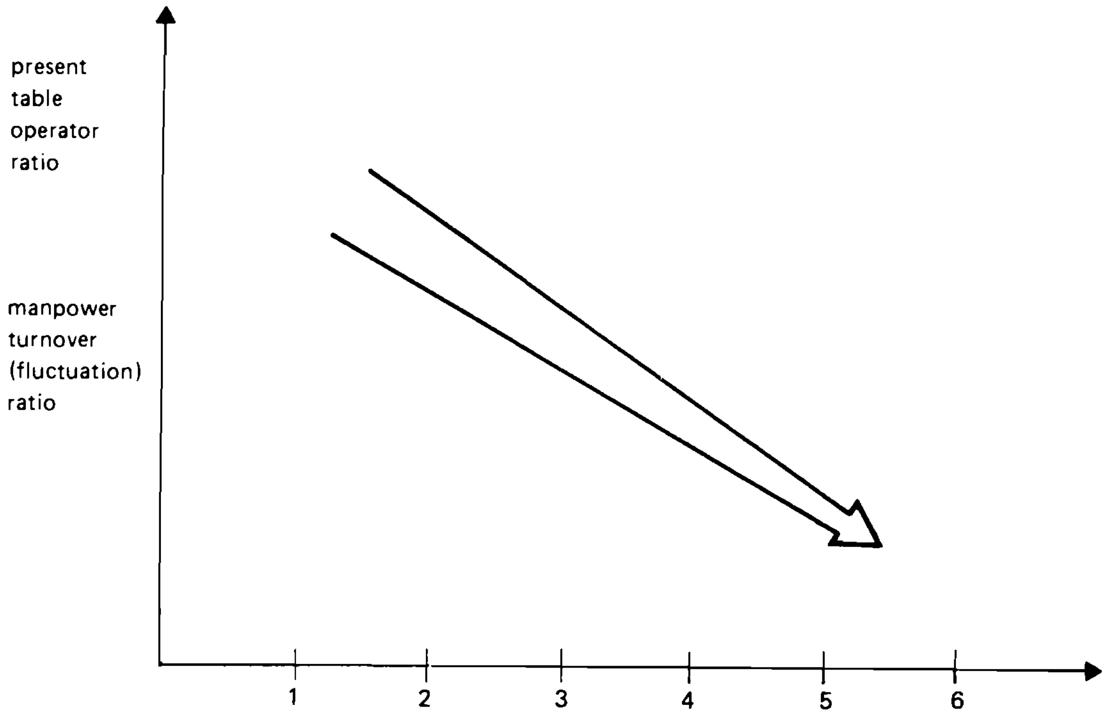
The last "open" hypothesis is connected with the reward system suitable under the changed conditions, i.e. at the higher



Organizational forms of training/retraining:

1. on-the-job training
2. off-the-job training organized by training department of user company
3. off-the-job training organized by special training institution
4. off-the-job training organized by vendors

Figure 17. Training/retraining organizational forms.



Organizational forms of recruitment:

1. from manufacturing areas closer to CIM
2. worked with previous system (machining centers, NC-machines, conventional system)
3. young recruiters
4. from the best operators (creaming-off policy)

Figure 18. Recruitment policy for CIM.

level of automation and integration. From the literature [i.e., Lasko, 1988; Krabbendam, 1986] we can draw the logical conclusion that the reward system has to reflect the global responsibility of the operators. People work as a team and have the responsibility for all the improvements in productivity. This hypothesis reflects the interconnection between the form of reward and the manpower turnover (fluctuation) ratio. The better and more appropriate the reward system, the lower will the ratio (or other indicator?) be. The following forms were taken into account:

- piecework system;
- individual wages;
- time wages;
- group wages;
- group premium payment.

This hypothesis is represented in Figure 19.

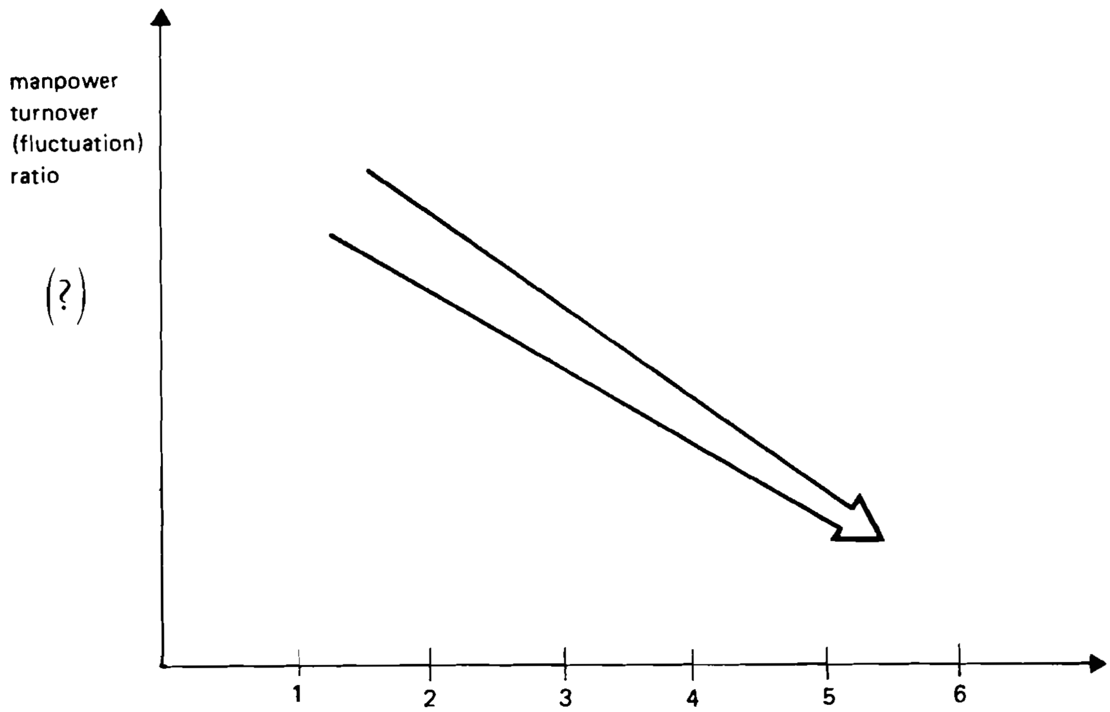
CONCLUSIONS

The main purpose of the paper was to describe and systematically classify the managerial hypotheses connected with CIM adoption.

The hypotheses embrace the strategic, organizational and socio-economic areas of managerial activities. They create an open system and will be enlarged in the second stage of our study, i.e. after gathering the data according to the refined version of our questionnaire from an expected number of 100 systems. Many of the organizational and social parts were extended in that last version.

All above-mentioned and newly created managerial hypotheses will be tested by means of the proper statistical methods and new conclusions will be drawn from special comparisons such as centrally planned vs. market economies, small vs. large countries, different branches of industry, different areas like USA vs. Japan vs. Western Europe vs. Eastern Europe, etc.

The preliminary results from the Finnish-Czechoslovakian pilot study show some interesting results. Testing the hypotheses drawn mainly from theoretical studies and published case studies, we have come to the conclusion that some of them



Forms of reward system:

1. piecework system
2. individual wages
3. time wage
4. group wages
5. group premium pay

Figure 19. Reward system in CIM.

have been confirmed, some of them not. There are also some interesting differences whose reason may lie in the different economic systems. But we have to stress that it is very dangerous to draw final conclusions from the pilot study. We have to wait for a more elaborate data base, where the final conclusions will not be only reasoned conjectures, but well researched subjects. The large data base comprising 100 systems creates the desirable precondition for drawing new conclusions and generalizing the results for different environmental, economic, cultural and other conditions. In order to arrive at interesting results for the relevant decision-makers it is intended to clarify the main factors and ways by which different companies adopted CIM and to specify the pacing factors decisive for the successful adoption of these particular systems.

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