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

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

Milan Maly

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FOREWORD

This paper is basically a final report of a comparative analysis of FMS use in Czechoslovakia (CSSR), Finland, Austria and Sweden. It was carried out during the year 1988-1989 while the author was part of the Computer Integrated Manufacturing (CIM) project team at IIASA. This work in suitably revised and updated form will be a part of Volume IV of the final published report of the CIM project, to appear some time in 1991.

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1. INTRODUCTION

This working paper summarizes the results of the analysis of Flexible Manufacturing Systems (FMS) of the broader (questionnaire) data base, consisting of case studies collected at IIASA during the period 1988-1989 (questionnaire data from 9 FMS in Finland, 5 FMS in Czechoslovakia, 6 FMS in Austria, 5 FMS in Sweden, 10 FMS in the GDR and 4 FMS in Bulgaria).

The above-mentioned sample establishes the substantial FMS base of the respective country (except for Sweden and Czechoslovakia) and can be taken as the representative sample of FMS in that particular country. The IIASA case studies data base was reinforced by comparative studies published in literature, e.g. Jaikumar (1986), Margirier (1986), Ranta (1986), Bessant and Haywood (1987), Lim (1987), Ettlie (1988), Warnecke (1987), Brooks (1989), as well as by case studies of individual firms, successful in FMS adoption, such as MBB (1984), Ingersoll (1986), TOS Olomouc (1989), and IBM Järfälla (1989).

Our methodological approach is based on the hypothesis established in previous stages of our research work (see Maly, 1988). The main aim of this work is to generalize the results with special attention on outlining the specific features of a comparative analysis between centrally planned and market economies.

The main topics on which we concentrate our attention are:

- characteristics of the users;
- strategic goals;
- organizational and operation characteristics, communication systems;
- economic characteristics;
- social characteristics.

2. CHARACTERISTICS OF THE USERS

In view of the main issues of our study it is suggested to characterize the adopters under review by the following criteria:

- size of enterprise adopting FMS (expressed by number of personnel);
- position on the market;
- product program specification;
- position in the manufacturing chain;
- export rate and orientation.

The prevailing part of the enterprises under review, adopting FMS, are large companies with a number of personnel over 500.

This is typical for all countries except for Bulgaria, where all companies are of medium size. In Finland there is a mix of large and medium-size companies (about half large/half medium). The rest of the countries have only large companies adopting FMS (Czechoslovakia, Sweden, Austria, GDR). These results practically confirm the tendency in the U.S.A., where small firms are not likely to adopt programmable automation (Brooks, 1989).

Companies adopting FMS are either strong domestically or worldwide. None of the adopters is domestically weak. This is logically correlated with the previous point, where we did not have any small company. The interesting division between market and centrally planned economies is that in market economy countries there is a mix of companies which are strong worldwide and strong domestically, unlike the companies in centrally planned economies which are, without any exception in our sample, only strong domestically.

Mainly for planned economies this outcome is not surprising, as the countries under review are small countries, where strong worldwide companies are, generally, rather an exception.

Analyzing the product program we can state that the program consists mainly of fixed and semi-fixed product variants. Semi-fixed product variants mean, in principle, fixed variants, but the customer can specify detailed features within a fixed range offered. There are some exceptions (2 cases in Finland and one case in Austria). In these cases the product program consists of semi-fixed and customized products, where the maximum ratio of customized products is 50%. A customized product is defined as fully customized, which needs, e.g., constructional changes in some parts. The other interesting feature is that Swedish FMS produce only semi-fixed products, it must, however, be taken into account that the data are incomplete.

In this case it is impossible to make a comparison between centrally planned versus market economies, which is due to the absence of FMS data for the centrally planned economies.

From the data available we may, however, deduce a tendency of shifting from fixed to customized product programs, as the most sophisticated FMS clearly tend towards semi-customized and customized production.

There are practically three possibilities with regard to the position in the manufacturing chain, i.e., to act as component manufacturer, a subsystem manufacturer or, finally, as a system integrator. The other possibilities (mostly theoretical in case of FMS) are basic metal producer, job shop position, etc. The data from our case studies show clearly the mixture of the position in the chain. The majority of adopters (about 66%) has clearly one position, mainly as system integrator (typical for a market economy as in Finland), or component manufacturer (planned economy as in Czechoslovakia). The rest (about 33%) has a combination of two positions, either as component manufacturer combined with subsystem manufacturer (typical for Swedish and Bulgarian companies), component manufacturer combined with system integrator (typical for Swedish and Bulgarian companies), component manufacturer combined with system integrator (2 Austrian cases), or subsystem manufacturer combined with system integrator (one Bulgarian case). The only exception is the combination of three positions (component and subsystem manufacturer combined with system integrator) in one Bulgarian company.

The above mentioned results do not show any distinctive differences between market and planned economy adopters.

The typical feature of the companies and enterprises adopting FMS is a relatively high export rate. The average export rate of the market economy FMS in our sample is about 66% and it includes companies with a higher than 90% export rate. A typical country with a very high export rate is Austria. It amounts to about 80% on the average and the sample even includes a company with a 99% export rate. The range of export rates in this country is from 60 to 99%. In other market economy countries the range is wider, e.g. in the Finnish sample it is from 20 to 95%, and in the Swedish sample from 30 to 95%.

In planned economies the above range is generally lower. E.g., in Czechoslovak companies adopting FMS the average value is 45%, ranging from 30 to 65%.

The orientation of the export follows the common trends and it does not seem to be influenced by the adoption of advanced technologies. The orientation of companies in market economies is mainly directed towards Western countries, including the U.S.A. and Japan (about 70%), and companies in planned economies export mainly to CMEA countries (also about 70%). But, of course, there are some exceptions to this rule. One Finnish company exports 50% to market economies and 50% to CMEA countries, and the same ratio applies to one of the Czechoslovak companies.

3. STRATEGIC GOALS

One of the most important issues of strategic management of the companies adopting different kinds of advanced technologies is to specify their position on the market and make a decision concerning the main future strategic goal. Following the previously elaborated methodological approach (Maly, 1988), we divided the company strategies into a defensive (survival) and an offensive (growth) strategy and formulated the hypothesis that CIM is multi-objective and the goals can be changed in the course of time. In many companies CIM and FMS fulfill not only one, but various goals.

Testing the above-mentioned hypothesis, we tried at the first step to specify the main driving forces behind the strategic decision of decision-makers to adopt FMS in the companies in our review sample, and, as a second step, to compare the expected and real results reached in the second year after FMS implementation. This comparison may serve as the logical indicator showing us to what extent the investment was successful.

The results obtained from the analysis of the broader sample of companies and countries clearly confirmed our previous hypothesis. FMS adoption has multi-objective goals. FMS fulfill not only one, but various goals (see Figure 1).

Contrary to the previous study (Maly, 1988), we concentrated at the first step only on expected (not real) goals and this approach helped us to obtain more precise results. The average number of the highest priority factors (4 and 5 from the whole scale of 1 to 5) in the factories taken into account (in some of the factories the strategic goals are not available) is 3.8, compared to the number 2.9 in the previous study. The average number of these goals in market economy FMS is 4.9, in planned economy FMS it is 2.5. The big difference is mainly due to the fact that in centrally planned economy FMS there is a distinctive lack of flexibility and, to a certain

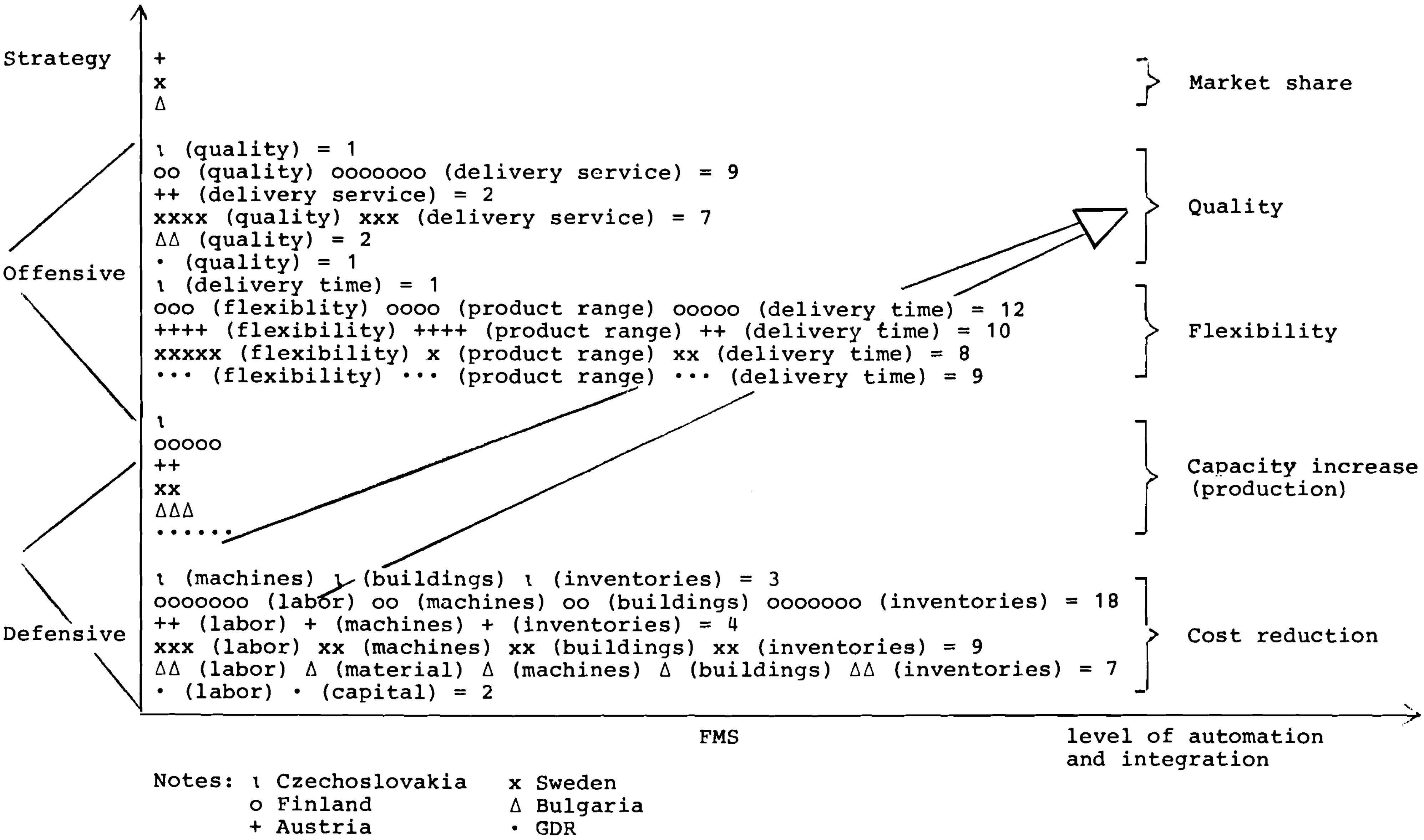

Figure 1. Strategic goals (expected)

extent, quality goals. The only exception are FMS in the GDR, where flexibility has a similar priority as in market economy countries. We can observe similar rates in cost reduction goals. On the other hand, the centrally planned economies prefer goals of capacity (production) increase. All these results fit into the conclusions of the previous study (Maly, 1988), explaining this phenomenon by the still prevailing heritage of a strict central planning system, resulting in a lower push of market conditions and competition and, on the other hand, in strict long-term targets, which can not flexibly fit into the real short-term consumer needs.

The comparison of expected and real results reached in the second year after FMS adoption was used as the criterion for the success of this particular adoption. The coincidence of expected goals and real benefits proves the success of the installation. The evaluation of the benefits (factors) is done by a scale, ranging from 1 = not important at all, to 5 = very important. The success can be reinforced, for example, when expected benefits of a factor — e.g. "capacity increase" — are ranked by a value of "4" and the real results are ranked "5"; in the opposite case the unsuccessful factors give a negative difference between these figures.

The benefits (factors) are moreover divided into dominant goals (expected evaluation is 5 or 4) and secondary goals (expected evaluation is 3-1).

The survey of expected and real benefits is shown in Figure 2.

We can derive the following conclusions from this analysis:

Generally speaking, the FMS installation was successful. This applies mainly to the adoption in Austria, Sweden and Bulgaria. In Finland we have obtained some controversial results. Employing our approach, we have to denote company no. 4 as relatively unsuccessful because of its negative score of -10 in the dominant goals. However, in reality the experts consider this company as very successful. The question is now how to interpret the results correctly. The only explanation is that an FMS, being only a small part of the whole company, does not yet have a decisive influence on the total company results.

The other surprising result is the almost total lack of dominant goals in Czechoslovak FMS. The most logical explanation of this phenomenon is that the idea to adopt the system does not come from inside the company and is not implemented by decision-makers of this particular company. It comes from a central governmental agency whose criteria are often unclear or even unknown to the company management. But the target is a part of the state plan and as such it has to be fulfilled, frequently without any incentives of the company top management.

4. ORGANIZATIONAL AND OPERATION CHARACTERISTICS, COMMUNICATION SYSTEM

We are aware of the fact that the organizational activity is the most important feature of an implementation phase, substantially influencing its success. This is why we concentrate our attention on this particular phase in the beginning of this chapter.

Country, system		Highest priority factors				Secondary priority factors				General conclusions
		N	+	-	Σ	N	+	-	Σ	
SF	1	7	0	3	-3	8	2	2	0	Dominant
	2	8	0	0	0	5	6	0	+6	goals: 6 cases success
	3	2	0	1	-1	1	1	0	+1	3 cases not
	4	8	0	10	-10	8	9	0	+9	satisfactory
	5	8	0	1	-1	0	0	0	0	Secondary
	6	11	4	0	+4	4	1	0	+1	goals: very successful
	7	9	1	5	-4	7	2	1	+1	
	8	2	0	0	0	10	0	0	0	
	9	4	0	0	0	9	0	0	0	
CS	1	0	0	0	0	12	4	1	+3	No dominant goals
	2	0	0	0	0	12	7	2	+5	Secondary
	3	0	0	0	0	12	9	1	+8	goals: very successful
	4	0	0	0	0	11	7	1	+6	
	5	7	1	2	-1	6	2	2	0	
A	1	6	2	1	+1	8	3	0	+3	Dominant
	2									goals: expected success
	3									Secondary
	4	7	0	0	0	5	1	0	+1	goals: " "
	5	9	0	0	0	2	2	0	+2	
	6	5	1	0	+1	9	0	0	0	
S	1	6	1	1	0	7	0	0	0	Dominant
	2	6	1	1	0	7	0	0	0	goals: expected success
	3	6	1	2	-1	6	7	0	+7	Secondary
	4	6	1	0	+1	8	8	2	+6	goals: very successful
	5	10	2	3	-1	3	6	0	+6	
BG	1									Dominant
	2	3	1	0	+1	6	4	0	+4	goals: expected success
	3	6	2	0	+2	4	2	0	+2	Secondary
	4	7	0	1	-1	5	3	0	+3	goals: very successful
GDR										Data not available

Notes: SF = Finland
CS = Czechoslovakia
A = Austria
S = Sweden
BG = Bulgaria
GDR = German Democratic Republic

Figure 2. FMS benefits scoring

The first hypothesis is that the probability of a successful adoption will increase with a more intensive and appropriate organizational form of involvement of the top management, of designers and operators in the development and implementation phase.

We distinguish three forms of top management participation in the system implementation, according to the intensity of participation, i.e., approval, some participation and regular participation. Analyzing our case studies, we come to the conclusion that there is no dominant form of participation in the Finnish, Austrian and Swedish case studies (all three forms are applied), and some participation is the prevalent form in Czechoslovak cases.

We specify the intensity of the designers' collaboration with the system during the implementation phase according to the intensity of their participation, i.e., consultancy, part-time, full-time and no collaboration at all. Moreover, we analyzed the duration of collaboration. The analysis shows us again that in the Finnish and Swedish cases all forms are used and the duration of collaboration ranges from 2-150 weeks. In the Austrian cases the prevalent form is full-time collaboration and a 70 weeks duration. In the Czechoslovak cases the only unified form is part-time collaboration with a duration of 100 weeks.

The role of operators in the design process is specified in three forms, i.e., no role at all, a weak role, and regular cooperation. The results of our analysis showed again different forms. In the Finnish and Swedish cases "no role at all" and "regular cooperation" occur almost at the same rate (half no role and half regular cooperation). In the Czechoslovak cases a "weak role" prevails and in the Austrian cases "no role at all" is predominant.

But the main purpose of this analysis originally was to compare the different forms of involvement of top management, designers and operators with the planned and real system development and implementation time (to develop, install and start operation), and to try to specify, on this basis, the most proper forms of participation. Unfortunately comparable time data are available only in two cases, and this is why we can not draw any generalized conclusions.

The important indicator, widely discussed in literature (see the case studies of Ingersoll, 1986; TOS Olomouc, 1989; IBM Järfälla, 1989) is the organization of the project implementation. We can practically specify the following organizational forms: in-house team, system vendor and consultant company. Analyzing the data from our case studies and the literature sources mentioned above, we found only two forms of project implementation: in-house team and system vendor. In all our case studies the combination of these two forms was used, but their respective share was different, ranging from 10% in-house and 90% system vendor to 70% in-house and 30% system vendor (Finnish cases). In many cases the share is more balanced (Czechoslovakia, Austria and Sweden). Here again the same original idea of specifying the most proper form (or share) was assumed by means of comparison of the planned and real system development and implementation time, but for lack of the necessary data it was impossible to carry out such a comparison.

The next managerial issue, again frequently discussed in literature (Jaikumar, 1986; Warnecke, 1987), is presented in the hypothesis that FMS adoption leads to a drastic reduction of hierarchical levels and gives rise to very small self-managed groups with a high responsibility for running the system.

Our findings show some controversial results and we must say that the hypothesis was not fully verified. The question: "Is the FMS run by a self-managed team?" was answered to exactly 50% positive and 50% negative in the Finnish, Austrian and Swedish cases.

There are no data from centrally planned economies.

The next question: "Have some hierarchical levels disappeared after adopting FMS?" was answered with almost the same ratio of yes/no distribution. But, what is also very interesting is that there is no significant correlation between the existence of self-managed teams and the decrease of hierarchical levels.

From these results we can draw the conclusion that in those cases, where the FMS is only one small part of the whole company structure, it is not yet capable of changing the traditional organizational structure.

The other hypothesis, based on the notion that the most acceptable form of labor organization or job/task assignment is job rotation, was confirmed in 60% of our case studies. This share neither indicates extreme forms of job specialization nor of rotation, which can most probably be explained by the fact that the work on FMS can be characterized as very diverse, where both complex and simple tasks have to be performed.

Analyzing the question of who or which department is responsible for the initial design (specification) of a system and who is responsible for the realization of the system, we came to the following results:

The responsibility for the initial design is mainly divided into system vendor (typically in Finnish cases) or company experts and developmental staff (typical for Czechoslovak and Swedish cases). In the Austrian cases the responsibility is typically divided into two or even three participants (again mainly system vendor, company experts and development staff, in one case the third participant is a consulting company).

The responsibility for the realization of the system is again divided into two groups, the system vendor (typical for Finnish cases) or the factory staff (all Swedish cases). A mix of responsibility is typical for Czechoslovak cases (mainly system vendor plus company research and development departments) and Austrian cases (system vendor plus factory staff).

The next parameter is operation rate. The main purpose of this analysis is to compare the data before and after FMS adoption. Data of this kind are usually available and thus provide a very good basis for profound analysis. The big majority of our case studies shows an increase in number of shifts, i.e. in the Finnish cases by 70%, in the

Bulgarian cases by 75%, in the Swedish cases by 80%, in the GDR cases by 80%, and in the Czechoslovak and Austrian cases by 100%.

In the majority of the market economy cases, as well as in majority of the GDR cases, the number of shifts was increased to 3. The only exceptions in our sample are Bulgaria and Czechoslovakia with a majority of 2 shifts a day. The most probable explanation we can find is that fact that the investment (including FMS) in centrally planned economy countries is generally financed by governmental funds and the economic push on maximum utilization is not so massive. The only exception -- the GDR cases -- may be explained by cultural factors as, for example, by the traditionally high discipline of the German people.

A further system characteristic, whose importance is permanently growing, is the communication system. According to our previous hypothesis, formulated in Part I (Maly, 1988), higher states of automation and integration require a higher level of the communication system. We can classify the development stages of information exchange and processing from relatively simple to highly integrated, sophisticated and standardized communication systems:

- mainframe;
- mainframe with terminals;
- network distributed PC systems;
- local area network (LAN);
- LAN using standardized protocols (MAP, TOP, etc.)
- wide area network (WAN) with electronic data interchange (EDI);
- integrated services digital network (ISDN) including telex, telefax, etc.

Analyzing the data of our sample we come to the following conclusions:

The connection of FMS to a local area network is differentiated by countries. The connection of the system with LAN has so far been more typical for market economy countries (almost all Austrian and Swedish cases, the exception are all Finnish cases which do not have such a connection). In centrally planned economy countries LAN has not yet been applied and the systems are mostly based on a mainframe with terminals.

Standard protocols like MAP and TOP have not yet been used either in centrally planned economies or in market economies (the only exception are two Swedish systems using MAP).

A similar situation practically exists for the use of Electronic Data Interchange (EDI) with customers and subcontractors. Only in Swedish cases and in one half of the Austrian cases EDI is used for order processing, design data interchange, production planning and business data interchange. In centrally planned economies and Finnish cases EDI is not yet utilized.

5. ECONOMIC CHARACTERISTICS

The economy of FMS can be characterized by various parameters specifying different consequences of adoption. Generally we can divide them into several main groups, such as labor and capital savings, flexibility and quality increase and the group of general consequences.

The economic indicators were analyzed and compared by clustering into different groups, as described in a number of previous IIASA CIM Project Working Papers (mainly by Tchijov, Sheinin and Alabyan). Therefore we concentrate now only on the analysis of total FMS investment and its composition, which is in our opinion one of the most important features of FMS adoption, closely related to above-mentioned groups.

A survey of the results of our analysis of total FMS investment and its composition in the countries under review is given in Figure 3.

Analyzing these data we come to the following conclusions: The average total investment in the countries in question does not exceed 6 million US$. The absolute value of a single FMS does not exceed 10 million US$ (maximum value 9.6 million $ in one of the Czechoslovak cases), and in one case the value is even smaller than 1 million US$ (0.6 million US$ in one of the Austrian cases).

There are almost no distinct differences between centrally planned and market economies regarding the composition of total investment. The only fundamental distinction is the absolute lack of machining center costs in centrally planned economies (only NC-machines are available in this case). But if we, on the other hand, add up the costs (in % share) of NC-machines and machining centers, the combined results are very similar, ranging from 40 to 60% approximately. The only small exception is Bulgaria with an extremely low 30%-share of NC-machines. In this country the share of robots and transport costs is, on the other hand, extremely high. The robot share is 19% compared with the average value of 6% and the transport share is 18% compared with a 9% average value in other countries.

The reasons for these differences can be twofold. Either the number and technical level of robots and transport devices is higher, or the price of similar level devices is simply different. Checking the number and technical level (type of IR and material transport equipment) in different FMS in Bulgaria and other countries, we came to the conclusion that the number and technical level are different. Comparing Bulgaria with the average number of 14 IR in the rest of the systems, it is less than 1. The highest type of IR in the rest of the countries is a maximally numerically controlled type of IR as opposed to 40% of intelligent robots in Bulgaria.

Analyzing material transport equipment and its types, we come to the conclusion that the level of transport and warehousing systems is at almost the same level in all countries. The only exception is again Bulgaria, using a high number robots for that purpose. This fact most probably explains the high percentage (28%) of the transport share in its systems.

Country	Total US$ mill.	Shares (%) approx.										
		NC-machines	Machining centers	Robots	Transport	Storage	Inspec-tion	Control hardware	Control software	Planning	Training	Other
SF	1.7	10	48	6	10	9	1	7	6	1	3	-
CS	5.5	59	-	2	7	3	6	12	9	1	1	-
A	2.3	-	38	13	12	10	9	7	10	1	1	-
S	5.1	20	32	5	7	6	4	13	11	0.5	0.5	-
BL	?	30	-	19	28	0	13	?	6	2	3	-

Notes: SF - Finland
CS - Czechoslovakia
A - Austria
S - Sweden
BL - Bulgaria

Figure 3. Composition of total FMS investment by countries.

An other explanation can be that, in view of a zero-level storage share, the storage costs were in this case most probably included in material transport equipment.

In the other items, such as inspection, control hardware and software, planning and training costs, the differences are not substantial.

6. SOCIAL CHARACTERISTICS

One of the most important issues influencing the future results of FMS is the selection of proper operators for FMS. We specified practically four main ways of selection of employees:

- employees having previously worked with machining centers (NC-machines);
- young recruitees;
- employees from manufacturing areas close to FMS;
- selection from the best operators, who took part in special courses (creaming off policy).

Based on the 15 case studies analyzed we came to the following conclusions:

Firms predominantly combine the ways of recruiting employees (two-thirds of all case studies). They combine mainly 2 ways (80% of firms) of selection and the most frequent combination is "employees having previously worked with machining centers" and "creaming off policy". The second combination is "employees having previously worked with MC" and "young recruitees".

One third of the firms in our sample use only one way of selection. In this case they either apply the "creaming off policy" or they take workers from "manufacturing areas close to FMS" (Austrian cases).

Only in Swedish cases did the combination of more than two ways occur. In one case the combination of all four possibilities was applied.

Unfortunately, due to the total absence of data from centrally planned economy FMS, there is no possibility to compare the experiences between these two systems in the area of recruitment policy for FMS.

The general conclusion then is that the most frequent way of selection of employees for FMS is a combination of different ways, mainly two, and the most frequent ways are the selection of employees having previously worked with machining centers (NC-machines) and of the best operators, the so-called creaming off policy.

The next issue of high importance is connected with such features of labor force as the ratio of skilled/unskilled workers, of engineers/workers and of direct/indirect labor. All the hypotheses connected with the anticipated development of these indicators were now confirmed in this broader sample (for a detailed description of the hypotheses see Maly, 1988). Almost in all FMS of the sample the ratio of skilled/unskilled workers is 100%, which practically means that no unskilled workers are working on the system. The ratio of engineers/workers increased on the average by a factor of 4 and ratio of direct/indirect labor equally decreased on the average by a factor of 4 compared with conventional systems.

No statistically distinct differences were observed when comparing centrally planned and market economy FMS in this respect.

Analyzing the so-called quantitative angle of the technocentric and the anthropocentric approach in the man-machine architecture in FMS, we came to the conclusion that the results obtained from the other countries (Austria and Sweden) are somewhere in between the previous conclusions for Finland and Czechoslovakia. On the basis of previous results we found that, assuming the quantitative angle of the technocentric and anthropocentric approach (personnel reduction), the Finnish FMS distinctly tend to the technocentric and the Czechoslovak FMS to the anthropocentric approach. The Austrian and Swedish FMS in our sample are somewhere in between, tending slightly more to the technocentric approach. An illustration of these results is offered in Figure 4.

On the basis of the previous results (Maly, 1988), where we divided the average length of operators training/retraining into two groups (in the first group the time period ranges between 1-4 weeks with the average costs amounting to about 3,000 US$, and in the second group the time period ranges between 6-9 months and the average costs amount to about 17,000 US$), we can state that the cases in Sweden and mainly in Austria tend towards this second group. The average length of training/retraining amounts to about 6 months in Austria with average cost of about 10,000 US$, and to about 3 months in Sweden with average costs of about 6,000 US$. The engineers training time and cost data are available only in Swedish and Austria case studies; on this basis we can draw the conclusion that the engineers training/retraining time and costs are slightly higher, i.e. by 1 month and about 1,000 US$, respectively.

The comparison of centrally planned (represented here only by Czechoslovak cases) and market economy FMS in this respect shows distinct differences. In the case of market economy case studies the length of training/retraining time and costs are generally higher compared with centrally planned FMS.

We also wanted to analyze the contents of training/retraining courses with regard to FMS adoption. Unfortunately the frequency of lessons and the ratio between theory and practical training are not available in our case studies. The only available indicator of "total hours" shows us the division of teaching hours among occupations. The average teaching hours for machine and system operators and foremen range between 80-100 hours, for mainframe personnel they are 40-80 hours, for programmers 40 and for other staff 20 hours. From the above mentioned data we see the emphasis in this respect is on machine and system operators as well as on foremen. The data are only available for market economy FMS, and therefore we can not make a comparison with centrally planned economy FMS on this issue.

The broader sample of case studies gave evidence that higher stages of automation and integration improve the working conditions. Compared with the previous Finnish-Czechoslovak case study (Maly, 1988)

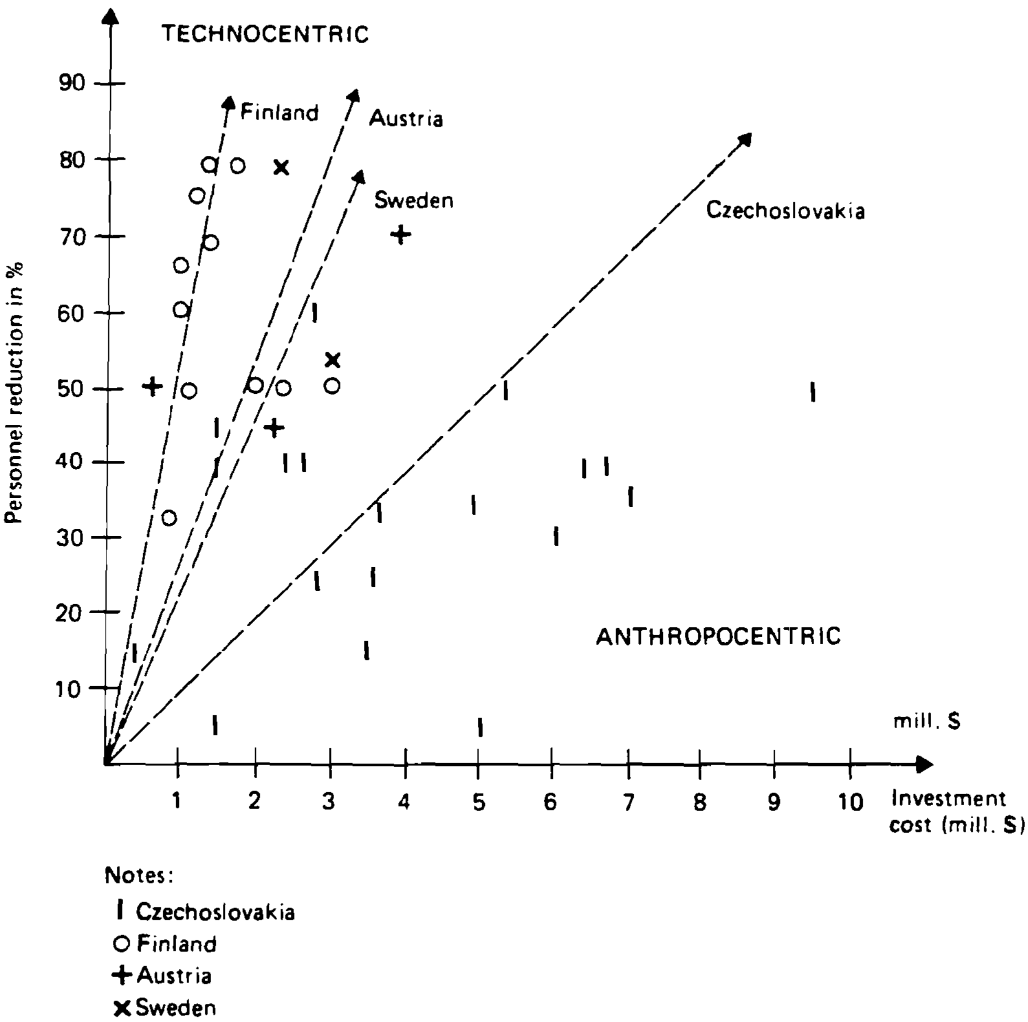

Figure 4. Personnel reduction in FMS.

we have now obtained more illustrative results. The manpower turnover ratio was going down in almost all Swedish cases and in one Austrian case. The same development was observable in the sick leave ratio in Swedish and Bulgarian cases. One case study indicates a decrease in the absenteeism ratio, in other cases this indicator is either unchanged or the data are not available.

Generalizing the achieved results, we can say that the hypothesis on automation improving the working conditions was confirmed in centrally planned as well as in market economy countries. The development of the above mentioned indicators either confirmed the anticipated tendency or showed no changes. In no one case was the tendency to the opposite. Thus the results reinforce the previous evidence presented in Part I of this study (Maly, 1988).

One of the interesting social indicators is the development of the average age of FMS operators. In spite of the evidence confirmed in all case studies that there are no non-adaptable FMS operators and engineers, the average age of operators is generally decreasing. Compared with the situation before FMS adoption the average age has declined from 32.5 to 29.5 in the Finnish case studies, from 36.5 to 31 in the Swedish cases and even from 42.5 to 29 in the Austrian case studies. Centrally planned economy data are not available in this respect.

Generalizing the results we can come to the interesting conclusion that, regardless of the previous situation, the average age of FMS operators in all countries oscillates around 30 years. In almost all individual cases the age was decreasing. Only in two Finnish cases there was no change, but the age had already before been 30 years. The only exception is one Swedish case where the relatively high average age of 40 years remains unchanged.

The reward system for FMS operators is the other indicator testing the hypothesis. 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. We do, however, have to say that in this case the hypothesis was not confirmed. Taking into account two main forms of reward system, i.e. individual and group wage, dividing these forms in more detail to individual time wage, individual premium wage, individual mixed wage and group time wage, group premium wage, group mixed wage, and analyzing the forms used in individual case studies, we come to the following conclusions:

The reward system is mostly differentiated by countries. The prevalent form is individual wage, mainly individual mixed (100% Czechoslovakian cases, 50% Swedish, 50% Austrian). The rest is individual time wage, individual premium and individual mixed wage. The distinct exception are the Finnish cases, where the group wage presents the prevalent form (70%). The main form is group premium wage (5 cases), one case is group mixed wage. The remaining three cases use individual wage, viz. individual mixed wage (2 cases) and individual time wage (1 case).

Generalizing the results we conclude that our hypothesis on global responsibility and the correspondingly prevalent group wage forms was confirmed only in the Finnish cases. In the other cases individual wage forms are used regardless of the economic system (market or centrally planned). The predominant form is individual mixed wage.

The new indicators which have not been analyzed before are the improvements in FMS after implementation, the kind of improvements, their number and percentage of operator initiative in this activity.

Analyzing the number of improvements we can state that in the Finnish and Austrian cases the average number is about 3 improvements. A distinctly higher average number of 261 improvements occurs in Swedish cases. The Swedish cases cover all kinds of improvements, i.e. technology, product, material handling, organizational, software and informational. The Finnish and Austrian cases cover mainly technology and software improvements, The Czechoslovak cases comprise technology and organizational improvements. The initiative of operators is either negligible or data are not available. The only exception are again the Swedish cases with 60% operator initiative in major improvements in FMS after implementation.

As there are no distinct differences between the Swedish cases and the cases in other countries with respect to other social indicators (training/retraining, reward system, etc.), the only way to explain this phenomenon is to take Haywood and Bessant's conclusions (Haywood and Bessant, 1987) stating that one of the major advantages found in Swedish companies is that of co-determination with regard to the introduction of a new technology. Principles of consultation before and during the installation of such equipment, widespread acceptance of best practice techniques and upgraded skills, dispersion of graduates through all functions within the company are most probably the explanatory factors of this phenomenon.

The last but not least indicator analyzed in this area concerns the changes in work content as a consequence of FMS adoption, specified as less monotonous, more monotonous, less skill needed and more skill needed (multi-skilled operators). Our basic hypothesis formulated in Part I (Maly 1988) anticipated an increase in the number of multi-skilled workers and managers and multi-skilled maintenance personnel and a decrease in the number of unskilled and craft-skilled workers and specialized maintenance personnel as a consequence of the increasing level of automation and integration.

The results obtained from our analysis confirm very clearly the above mentioned hypothesis. With the exception of one Swedish case, where all four possibilities are indicated, and one Finnish case, where the work content was reduced to more monotony, the work content was, in the rest of the 17 cases, predominantly directed towards less monotonous work, more skills required, or both.

7. CONCLUSIONS

On the basis of the refined version of the IIASA case study questionnaire, in which many of the strategic and social parts were extended, we can come to the final conclusions, generalization and comparison (mainly centrally planned vs. market economy) of the results obtained for this particular stage of our research work. But we have to emphasize at this point that the enlargement of the IIASA case study data bank is a continuous process and the results so far achieved will be continuously elaborated and improved, as the data bank is continuously growing.

At present the typical characteristics of the user adopting FMS are as follows:

- large size;
- strong on domestic (centrally planned) and/or world (market economy) market;
- shift from fixed to customized production program;
- no distinct position in the manufacturing chain;
- high export rate (relatively smaller in centrally planned economies).

The analysis of the driving forces and the comparison of expected and real results shows the following generalized results. The driving forces behind FMS adoption are clearly multi-objective. But market economy cases prefer flexibility in different forms, centrally planned economies give the priority to capacity (production) increase.

The comparison of expected and real benefits allows us to state that in general the FMS installations were successful. Surprising results were obtained from Czechoslovak cases, where the dominant goals are almost absent. This can be explained by the heritage of tight, centralized decision-making in the investment area.

In the area of organizational and operation characteristics and communication systems we concentrated at first on the organizational forms of involvement of managers, designers and operators in the development and implementation phase of FMS adoption. The results of the analysis show no dominant organizational form of involvement of these three groups of participants.

The analysis of the organizational forms of project implementation specified two dominant forms: in-house team and system vendor, which are used not separately but in combination and at different ratios.

The widely spread notion that FMS adoption leads to a drastic reduction of hierarchical levels and the creation of small self-managed groups with high responsibility was only partly justified and there is furthermore no significant correlation between these two phenomena.

The analysis of the responsibility for initial design (specification) and realization of the system specified the system vendor and/or company experts and development staff.

One of the important operation characteristics is the operation rate. The analysis showed very clearly an increase in number of shifts in the majority of the case studies. The number increased to 3 shifts mainly in market economy cases and in the GDR, while in the rest of the centrally planned economies it increased on the average to 2 shifts.

The conclusions from the analysis of the communication system can be described as a qualitative difference between market economy cases, using mostly the connection of FMS with LAN, and centrally planned economy cases, where the systems are mostly based on a mainframe with terminals. Application of standard protocols is not common in any of the systems.

The analysis in the economic area concentrated exclusively on total FMS investment and its composition. The average total FMS investment in our sample amounted to about 6 million US$.

The average share of different items shows no distinct differences in centrally planned and market economy cases. The share of NC-machines and/or machining centers ranges from 40 to 60% and is the highest compared with the rest such as robots, transport, storage, inspection equipment, etc.

The analysis concentrated relatively intensively on the social characteristics of FMS adoption.

In the first item the selection policy of FMS employees was analyzed. The results confirm that firms predominantly combine two modes of selection: "employees having previously worked with NC-machines/machining centers" and the "creaming off policy".

All the hypotheses anticipated the rise of the ratio of skilled/unskilled workers, engineers/workers and the decline of the ratio of direct/indirect labor, which were confirmed without any distinct differences in centrally planned and market economy cases.

The analysis of the technocentric and the anthropocentric approach analysis showed some differences in the quantitative angle of this approach, an angle from which market economy cases tend towards the technocentric approach.

The comparison of training/retraining policies shows that the length and costs are generally higher in market economy countries.

The sample under review also justified the hypothesis that automation improves the working conditions (analyzed by means of manpower turnover, sick leave, absenteeism) in all economic systems. Our analysis furthermore revealed the decline in the average age of operators, which is now oscillating around 30 years.

The analysis of reward systems has not confirmed a tendency towards group wage systems. The prevalent wage system is still based on different forms of individual wage. The only exception are Finnish cases with prevalent (70%) group wage forms.

The analysis of improvements in FMS after implementation and the percentage of operator initiative showed a distinctly higher number in Sweden compared with the other countries, which can be explained by a different organizational culture in Swedish companies.

The analysis justified very clearly the anticipated increase of the number of multi-skilled workers and managers, as well as multi-skilled maintenance personnel and the decrease of the number of unskilled or craft-skilled workers.

All the above mentioned generalized conclusions demonstrate how different firms cope with FMS adoption, which system relationships have to be taken into account by the relevant decision-makers, and what pacing factors are decisive for a successful adoption of FMS.

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