INTEGRATED COMPUTER SYSTEMS IN THE PULP AND PAPER INDUSTRY

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May 1981
WP-81-68

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PREFACE

Today, there is an ongoing rapid development and remarkable change both in management systems and in production related control and information systems in the pulp and paper industry. The new hardware based on recent development in microelectronics has opened totally new technical possibilities and this has lead to the concept of integrated hierarchical company and/or mill-wide information and control systems.

In order that these new systems and technical solutions can be effective and useful the experiences, needs and opinions of the existing and potential users of these systems are important. At the Interantional Institute for Applied Systems Analysis (IIASA) at Laxenburg, Austria, a project studying long-term development and problematics of forest industry was initiated in 1979. One of the main topics suggested in the project proposal is the development of integrated computer systems. Later, the emphasis of the whole project progresses to other topics, however it was decided that a detailed survey to study the needs and opinions of users was an essential part of the program.

A detailed questionnaire was prepared and mailed to over 240 major forest industry companies in 17 countries. This paper reports on the results of this survey in a relatively condensed form. It is the hope of the author that this report will be useful and interesting to people developing and working with these systems in the forest industry and certainly this document is valuable to IIASA for planning further activities in this area.

ACKNOWLEDGEMENTS

The author wants to thank all those companies and individual persons who participated in this work. Without their active interest and support this work would not have been possible.

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INTRODUCTION

The rapid development of control theory, management science, operations research, instrument technology, electronics and computer science has led to rapid changes in the operation and management of mills in process industries since early 1960. Typically, this development can also be seen in forest industries, especially in the pulp and paper industry.

There was great enthusiasm during the early stages of the development of computer applications in the pulp and paper industry. For example, ambitious plans were presented for implementing the control of a whole paper mill using one big computer. This computer was also to perform management tasks. Early 1960 was the pioneer time and it is well known that many of these projects unfortunately failed. Pessimism and a stagnation of progress in this area was the result. The reasons for this were quite clear [Uronen, Williams 1978]:

1. Underestimation of problems and difficulties to be overcome. For example, too few personnel, too tight a time schedule, limited budget etc.
2. The reliability, speed and capacity of the computers then available were not sufficient for the tasks.

3. Lack of the necessary instrumentation and plant process mathematical models and algorithms.

4. Shortage of competent and specially trained personnel for the development and project groups.

5. Reluctant attitudes of management and operators.

After a few years delay the era of minicomputers which began in the second half of the 60's, opened up new possibilities especially in the operational and process control of the mills. Thus sophisticated packaged computer control systems for certain well defined subprocesses of the mills were developed. This approach in the process control has proved successful. The main reasons being [Uronen, Williams 1978]:

1. The systems were developed through cooperation between computer specialists and user engineers to solve minor and well defined problems.

2. They had the necessary instrumentation, process models and algorithms as background.

3. The minicomputers used were already reliable and capable enough at that time to handle these smaller problems.

4. The economic results of these systems could be clearly verified in a reasonable period of time.

5. The problems involved with the man-machine interface were noted and solved using the technology then available.

The success of these systems led to a rapid increase in the number of process control systems in the pulp and paper industries. The most common applications being paper machine control packages (basis weight and moisture control), stock

preparation systems, digester control systems and bleach plant control systems. After the sudden and continuous increase in the energy costs after 1973, the interest towards computerized energy management systems and boiler control systems has led to an increase in the number of these systems in use.

At the same time as the minicomputer based process control system was making its break-through in the process control application field, there was a remarkable improvement and change in the use of management or business computer systems. These computers have become more powerful, have more efficient operating systems, use high level languages etc. Their performance/cost ratio has become much more favorable.

The situation in the pulp and paper industry today is such that realtime process control systems and batch type management systems are widely implemented and used. Unfortunately there is little or no exchange of information or coordination between the two separate types of systems; normally different organizations use and maintain them.

Today there is rapid development in both process control systems and management information systems used in mills.

The latest developments in microelectronics have created digital instrumentation systems and other distributed control systems which open new possibilities for effective automation, coordination and optimization in all production operations, including higher level scheduling and planning functions. The classical control room instrumentation is also being subjected to rapid change. The control room of the 80's will be equipped with interactive multicolour video display units, graphic units, etc. The classical recorders, counters and indicators will gradually diminish in number. These developments are causing changes in

the operational management of the mills. For example, cost and efficiency control will be much enhanced because cost and effectiveness figures will be available in real-time.

The dynamism and complexity of the business and of the economy is continuously increasing. Existing methods of management will no longer be able to cope with this situation. There is also an increasing awareness that accurate and real-time information from industrial processes is a vital resource for the company and its business environment. Therefore, effective information, control and management systems throughout the whole organization are needed. This will also mean a change in style from accounting oriented management to information oriented management.

Today there is a trend towards satisfying this need to include all these separate and uncoordinated systems into one mill or company wide integrated system according to hierarchical concepts. [Uronen 1979, 1980 a, b, 1981]. Figure 1 shows the 3 different generation of computer based systems in the pulp and paper industry, as discussed above.

Many advantages are to be gained by implementing such a system policy. However there are also a lot of problems and difficulties involved defining the correct hierarchies. The big question is how to link the management and process control systems together and to what extent is this linking reasonable? In other words which one of the sketches in figure 2 is the best or optimal for different types and sizes of organizations or are there still other types of solutions? These were the basic questions for starting this study at IIASA in 1979. The only

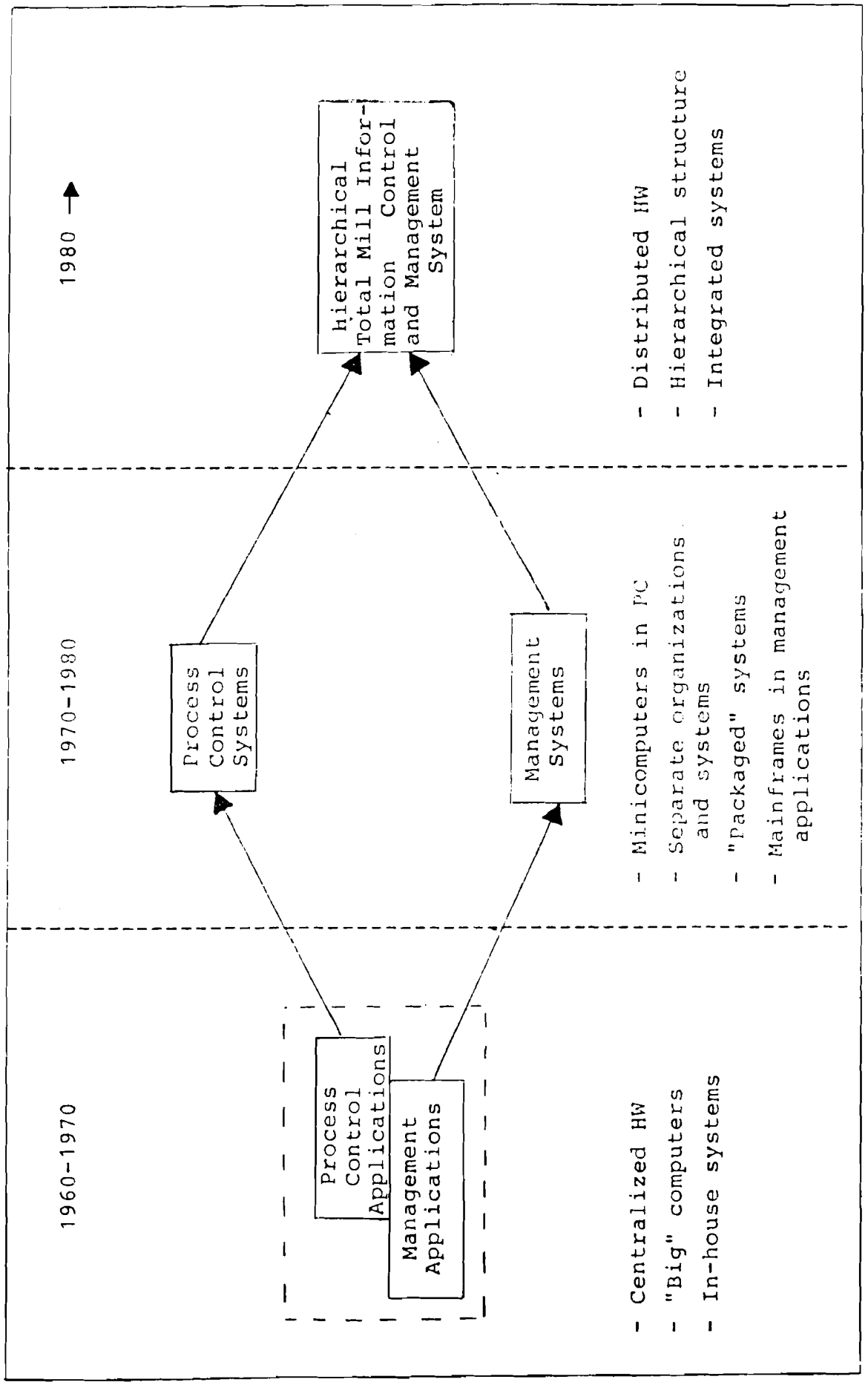
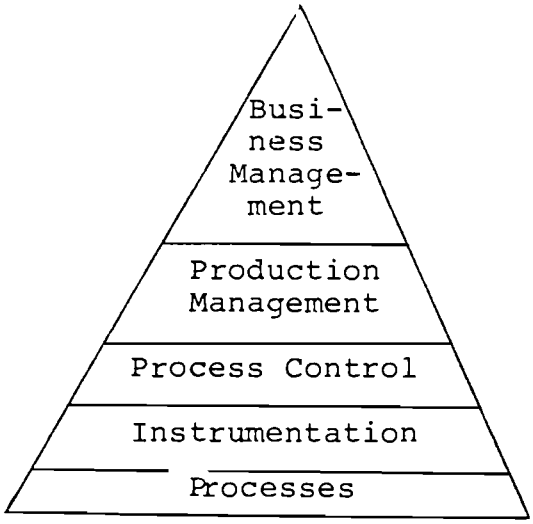
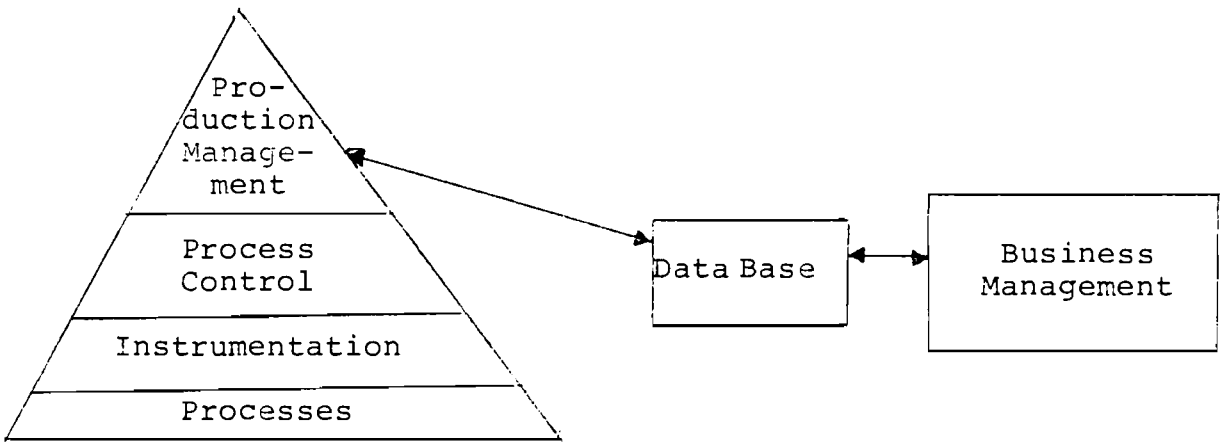


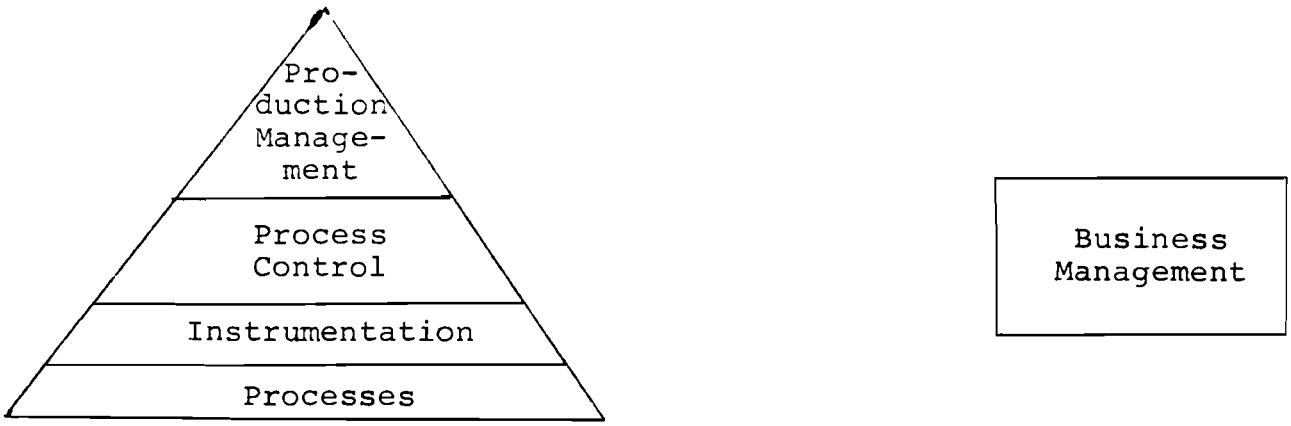
Figure 1: Three generations of industrial computer systems



a) Full integration



b) Real-time communications and common data bases



c) Full separation

Figure 2: Different degrees of integration

way to explore the future in this area is to try to get the opinions, needs and suggestions, including critisism of the existing systems and proposed trends and new directions, from the companies and people using such systems in industry. Therefore, a detailed questionnaire covering these areas was prepared and mailed to ca. 240 forest industry companies mainly producing pulp and paper in seventeen different countries, (Austria, Canada, Finland, France, FRG, Hungary, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, USA, USSR). This questionnaire is included as Appendix .

In all 39 completed questionnaires were returned representing about 16 percent yield. This can be seen as normal in these types of investigations. The production from these companies corresponds to about 33 million tons of paper per year which is more than 23 percent of the total capacity in the respective countries. Presumably they represent the bigger and (in this sense) more progressive companies. This statement is reinforced, for example, by the fact that these companies have a total of 831 process computer control systems which represents approximately 30 percent of the world's systems[Uronen 1980a].

The results will be presented in the following chapters with detailed state-of-the-art and trend disucssion of process control systems, management systems and integrated mill and company wide systems.

PROCESS CONTROL SYSTEMS

As stated previously, computerized process control in the Pulp and Paper industry is about 20 years old [Uronen & Williams 1978] and already the third generation of these systems are in use. After "big" computers like the IBM 1800 in the early sixties, there were the minicomputers like the PDP-8 and packaged systems, and now we have microprocessor based distributed digital instrumentation and control systems. The total number of these systems in the world's pulp and paper industry is very difficult to estimate. Firstly because the definition of a computer based control system is somewhat difficult (for example, in the area of order handling and roll handling) and secondly there are no reliable statistics available.

Rough estimates based on earlier reports [Gee & Chamberlain 1977, Keyes 1976, Uronen & Williams 1978] and an annual rate of increase of approaximately 20-25 percent would give about 2600 systems. For IIASA's questionnaire the respondents gave information which indicated that they have installed a total of 831 computer based process control systems at 710 mill sites. These companies represent about 23 percent of the total production capacity of the world and also represent the biggest and most modern companies (on average). This estimate confirms the rough number of 2600 systems as a total figure. Table 1 shows the results of the questionnaire concerning the process control systems in the pulp and paper industry now in use.

The following conclusions can be drawn:

There is a total of 831 systems from which 56 percent or 464 are packaged systems. Fortyfour percent are in-house or self developed systems. This is somewhat different that for example in the study of Keyes [1976],

Table 1. Summary of Process Control Systems in use

		Number	Package	%	Own Dev.	%
Pulp Mill Area	Batch Digester Control Systems	40	18	45	22	55
	Continuous Digestion Control Systems	33	21	64	12	36
	Bleach Plant Control Systems	42	22	52	20	48
	Washing & Screening Control Systems	17	7	71	10	59
	Pulp Drying Machine Control Systems	7	5	71	2	29
	Evaporator Plant Control Systems	9	2	22	7	78
	Recovery Boiler Control Systems	21	9	43	12	57
	Lime Kiln & Causticization Plant Control Systems	7	2	29	5	71
	Power Boiler Control Systems	11	5	45	6	55
	TMP Plant Control Systems	6	5	83	1	17
	Grinder Control Systems	15	2	13	13	87
	Pulp Mill Total	208	98	47	110	53
Paper Mill area	Stock Preparation Control Systems	51	14	27	37	73
	Paper Machine Control Systems	225	198	88	27	12
	Coater Control Systems	22	20	91	2	9
	Roll Handling Systems	51	22	43	29	57
	Quality Monitoring Control Systems	56	45	80	11	20
	Inventory Control Systems	49	8	16	41	84
	Trimming & Scheduling Systems	50	22	44	28	56
	Energy Management Systems	15	8	53	7	47
	Order Handling Systems	59	15	25	44	75
	Environmental Monitoring Systems	8	0	0	8	100
	Production Planning Systems	21	9	43	12	57
	Production Coordination & Control Systems	13	3	23	10	77
	Coating Kitchen	3	2	67	1	33
	Paper Mill total	623	366	59	257	41
	Grand total	831	464	56	367	44

where he reported 70 percent to be packaged systems.

This change indicates more interest inside the companies, for example, in building inventory control systems, trimming and scheduling systems, order handling systems, roll handling systems and production planning systems which typically, according to the questionnaire, are mainly in-house built applications.

There are in total 208 systems in pulp mills or about 25 percent of all systems. The share of pulp mill applications, which according to Keyes [1976] was about 18 percent, has increased but more slowly than expected. One obvious reason being the rapidly increased applications in order handling, roll handling, production planning and similar applications in the paper mill area.

From the pulp mill applications about 47 percent are so called packaged systems. This figure is surprisingly low but understandable because for some processes (for example recovery boiler, evaporation plant, lime kiln and washing and screening plant etc) packaged systems have been available for only a very short time.

In the paper mill area the number of packaged systems is a little higher, about 59 percent. This is based mainly on the dominating amount of on-machine packaged systems (about 25 percent from all systems). A further typical feature in the paper mill area is the comparatively large number of computerized stock preparation systems, quality monitoring and control systems, trimming and scheduling systems, inventory control systems and order handling systems most of them being in-house systems.

The classification of systems to be packaged or in-house system is a little diffuse, therefore, a separate question regarding own development gave a different distribution. According to the responses, concerning the process control systems 61 percent are mostly packages and 39 percent own development. Concerning the own development, the distribution that results is shown in table 2.

Table 2. Extent of own development work.

Part of own development	% from companies
0-30%	52
30-60%	19
>60%	29

The interesting question concerning the near future plans to install or develop new systems evoked the following results as shown in table 3.

From this table it can be seen that in addition to paper machine systems the planned new installations in the coming few years will concentrate in pulp mill area, especially in the energy producing and consuming processes such as recovery boiler, power boiler, TMP, lime kiln and evaporation plant.

It was the opinion of 86 percent of the companies who answered that most packaged systems need some tailoring to suit the requirement of the mill in question. In 78 percent of the cases this tailoring is handled jointly by the mill and the vendor of the system which is very understandable. In most cases the research and development work in this area is concentrated in cooperation with the vendor (70%), joint research activities with Universities (42%), consulting companies (31%) research institutes (22%) and engineering companies (19%) will also be carried out.

Table 3: New systems to be installed

System	Mentioned in % from companies who answered
Paper Machine System	39
Bleach Plant System	31
Recovery Boiler System	28
Batch Digester Control System	25
Energy Management System	25
Power Boiler System	25
Lime Kiln Control System	22
TMP Control System	22
Order Handling System	17
Production Control System	14
Stock Preparation System	14
Evaporation Plant System	14
Continuous Digester System	11
Coater Control System	11
Production Planning System	9
Inventory Control Systems	9
Drying Machine System	9
Washing & Screening System	3
Roll Heandling system	3
Quality Monitoring System	3
No specific plans	25

A question of great interest is the use of computerized production planning and control systems connected with the real-time process control systems as depicted earlier in figure 2.

This investigation gave the following result:

Number of companies having such systems: 16

Number of companies planning to build and implement such systems: 22

Number of companies having no plans to implement such systems: 8

It should be noted that the total number of companies (46) differs from the number of companies answered (39) because the same company may already have such a system in some mills and is planning to install similar systems in other mills.

Tables 4 and 5 summarize the benefits and draw-backs of these systems based on the answers concerning the companies planning to install such systems or those having negative attitudes towards computerized production planning and control systems.

It is interesting to note that hardware problems have not been mentioned among the reasons here. Hence the reliability and effectiveness of the existing and available hardware is acceptable and suitable for these tasks.

During the last few years there has been quite a lot of discussion concerning the ways of building these systems, i.e., should the existing process control systems be utilized as much as possible or should the production planning and control system be built separately. From the 16 companies having experience of these systems, five had used the former and eleven the latter method. The most important reasons for this is the difficulty in combining the subsystems of different vendors, i.e., the lack of standardization and also the fact that, until recently, there have been no compatible systems developed by vendors on the market. The first such systems have recently been introduced [Edlund & Rigerl 1978, Eriksson 1978, Peterson & Rückert 1978, Fowler 1980].

It can be concluded from both the expectations (table 4) and from the experiences (table 6) that the most important benefits will be decreased losses and disturbances and better information and decision making including improved cost control.

Table 4. Benefits of Production Planning and Control Systems

Benefit	% mentioned in answers
Better use of equipment and capacity	61
Better cost and effectiveness control	58
Better decision making	55
More accurate and timely information	47
Increased production	75
Decreased losses and risks	37
Easy and flexible planning	18
Savings in personnel	16
Increased safety in operation	11
Reduction of time loss	3
Better customer service	3
Better inventory management	3

Table 5: Reasons not to install a production planning and control system

Reason	% from negative answers
High costs	88
Benefits are marginal only	75
Difficult & complex programming	75
Lack of models and algorithms	38
Training & Education of personnel	38
Attitutdes	25
Too complex system	13

Table 6: Experiences from the existing production planning and control systems

Benefits	% from answers
Decreased losses and disturbances	81
Better information and decision making	69
High production	44
Easier and flexible planning	44
Savings in personnel	44
Improved timing	7
Problems	**% from answers**
Updating	56
Maintenance	38
Costs	19

The more "direct" savings, i.e., higher production and savings in personnel are not at the top of the list. This also supports the fact that the pre-investment benefit calculations concerning such systems are very difficult to estimate in money.

The maintenance of the systems is clarified in table 7.

Table 7: Maintenance of the process control systems

Type of maintenance	%
Vendor (babysitter)	19
Own maintenance department	35
Babysitter & own maintenace department	45
Emergency reparations only	1

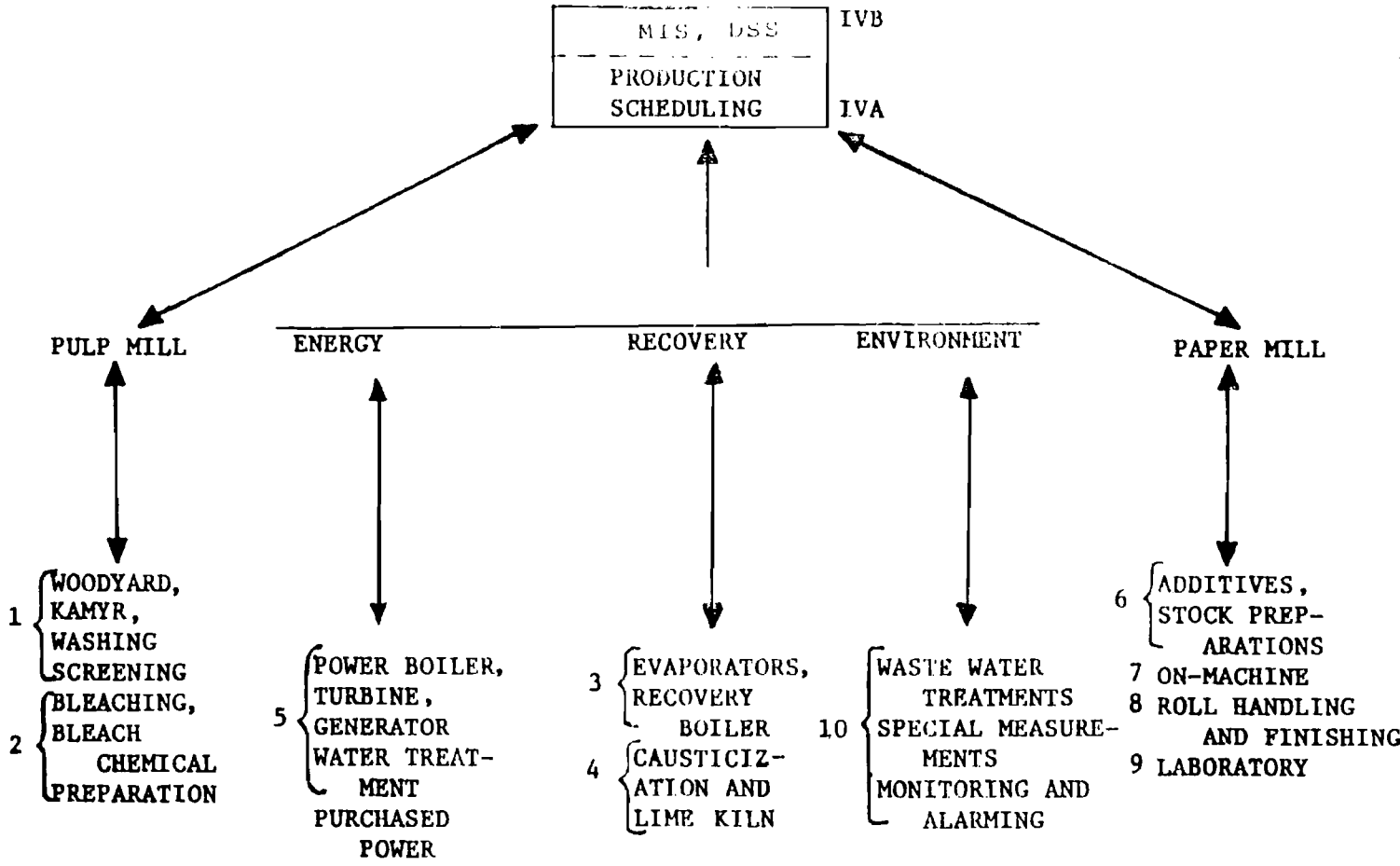
The trend here seems to go towards user maintenance. This is especially favoured by the self-diagnostic and self-checking features, the "change-the-card" hardware and similar easy to maintain properties of digital microprocessor hardware.

Concerning the future R&D in the area of process control the opinions of the users are listed in table 8.

The need for new and better sensors is obvious. It has been at the top of similar lists for years and no doubt will continue to be there, because accurate and reliable information from the state of the processes to be controlled is essential for good control. However, an important feature here is the need for better process and mill models, especially those concerned with cost and productivity. There is also need for better methods for integrating the subsystems into hierarchical structures. These are necessary for building the upper parts of the hierarchy, i.e., production planning and coordination systems as depicted in figure 3. [Uronen & Williams 1978.] It is to be noted that the production management (or area control) level must take care of the whole material handling from the purchase and transport of raw materials to the shipment and inventory of final products. A detailed discussion of the tasks at the various levels of such a hierarchy can be found in Uronen & Williams [1978].

In this connection the opinions of the users concerning the existing systems and some new trends were also explored. Tables 9 and 10 give the results.

From table 9 we can see that the users are quite happy with their existing process control systems. At the same time about half of the companies feel that their higher level systems including energy management systems are not functioning



LEVEL IV

BUSINESS MANAGEMENT
(MANAGEMENT INFORMATION
PRODUCTION PLANNING, DSS)

LEVEL IIIB

PRODUCTION MANAGEMENT
(AREA CONTROL, DETAILED
SCHEDULING, COORDINATION,
QUALITY CONTROL AND
OPTIMIZATION)

LEVELS I, II AND IIIA

PROCESS
CONTROL

Figure 3: Process Control Hierarchy in an Integrated Paper Mill

Table 8: Future R&D needs

Topics	% from answers
New sensors	61
Integration of subsystems into hierarchy	47
Process and mill models	42
Standardization	36
Man-machine interface	28
User oriented programming	22
Self diagnostics	19
Better algorithms and application of advanced theory	17
Impacts on management	3

Table 9: Users' opinions about their existing systems

System	Very good %	Satis-factory %	Unsatis-factory %
Process Control Systems	38	56	6
Production Planning & Coordination	5	74	21
Energy Management	0	40	60
Tactical Planning	8	38	54
Strategic Planning	6	50	44
Management Information Systems	9	48	53

Table 10: User's opinions on different systems

	System	Important %	Useful %	Not Useful %
A	Computerized Process Control	86	14	0
	Computerized Production Planning	43	57	0
	Computerized Order Handling	50	47	3
	Computerized Quality Control	35	59	6
	Computerized Energy Management	70	27	6
B	Computerized Coordination System	38	47	15
	Real time Management Information system	33	50	17
	Hierarchical Millwide Information and Control System	26	52	22
	Combination of MIS and Production Control System	27	60	13
C	Decision Support Systems (DSS)	14	57	29
	Fully Automated Production	0	27	83
	Electronic Office	6	59	35
	Personal Computing Tools	9	67	24

satisfactorily. This is also an expected result because the majority of experiences stem from the process control systems. This implies that the users are now aware of the possibilities and benefits that higher level systems can give.

The systems in table 10 can be grouped in three categories

Group A: Systems in use

Group B: Systems in pioneering stage

Group C: Future systems

Based on the results of table 10, it may be said that the newer the idea the less confidence in its usefulness; the trend is obvious : Group A systems are important, Group B is useful and Group C seems too theoretical so far.

MANAGEMENT SYSTEMS

The use of computer based systems in management assistance and data gathering and handling tasks is in fact older than computerized process control. As stated earlier, management systems tended to become separated from process control systems during the "second generation" and this is still very much the situation today. Most forest industry companies have quite large EDP-departments taking care of these management applications. This can be seen from table 11 which shows the number of professionals in EDP departments and in process control departments in the companies in this study.

There is a large difference in staffing between the EDP departments and process control departments. Of the companies questioned 29% answered that they do not have any professional engineers specializing in process control. This lack of professionally trained people will become a very serious problem in the building of integrated systems for the mills. It is also a demanding task of education and training at the universities. This problem has already been noted by Bialkowski, in Canada [1981].

There have been several studies concerning the extent of use and users' opinions about corporate modelling and other management systems in industry [Naylor and Schauland, 1976]. No such study specifically covering the forest industry has been published. Therefore, it was felt important that the situation in pulp and paper industries concerning the existing applications, users' experiences, benefits and drawbacks and methods used in the applications be explored. Tables 12-16 present the summary of these results. Altogether 247 applications were reported, most of them in budgeting, inventory control,

Table 11: Number of professionals in different application areas.

Number of professionals	EDP %	PC %
< 5	27	65
5-20	48	29
>20	25	6
Average	31	5

wood procurement, and transportation. Most users felt that these systems were important and useful. Further it may be noted that the applications in financial forecasts and analysis, investment analysis, profit planning and forest management are quite well used. There seems to be some sceptisism concerning the usefulness of management information systems and project management and control systems.

Applications such as resource allocation and plant location have not gained much ground amongst pulp and paper companies although these applications have been well studied and documented. Linear programming, simulation and inventory theory are clearly the most applied methods and this result supports the findings of Naylor and Schauland [1976].

According to table 14 the management applicatons should be easy to use and have good reporting and simulation possibilities. They should use high level programming languages and should work interactively with the user. The use of graphics does not seem to be very important here.

Table 12: Users' opinions about different computer based systems in management applications

	Used in % of companies	Users' opinion		
		important %	useful %	not useful %
Budgeting	75	81	19	0
Inventory Control	75	59	37	4
Wood Procurement, Inventory and Transport	53	74	26	0
Profit Planning	50	50	44	6
Financial Analyses & Forecasts	47	53	47	0
Project Management & Control	47	29	53	18
Investment Analysis	44	56	38	6
Forest Management	39	64	29	7
Management Information System	39	29	71	0
Marketing Planning	33	42	42	16
Long Term Forecasts	33	25	67	8
Corporate Modeling	31	45	45	10
Transport Planning	25	33	56	11
Purchasing Planning	25	33	56	11
Risk Analysis	19	14	58	28
Resource Allocation	19	43	57	0
Plant Location	14	45	45	10
Planning of R&D	11	0	25	75
Organization Planning	6	0	0	100

Table 13: Methods used in management systems

Method	Used in % of cases
Linear programming	67
Simulation	44
Inventory theory	36
PERT or CPM	31
Time series analysis	28
Exponential smoothing	28
Stochastic modelling	25
Determinsitic modelling	22
Integer linear programming	19
Optimal control theory	17
Box-Jenkins method	14
Other forecasting method	11
Heuristics	11
Multiobjective optimization	8
Non-linear programming	6
Dynamic programming	3
Goal programming	3
Network theory	3
Logistics	3

Table 14: Important features of the management applicatons

Feature	Mentioned % of cases
Easy to use and modify	70
Effective reporting	53
Simulation possibilities	47
Interactive operation	47
Sensitivity analysis	42
High level programming language	39
Effective database functions	33
Graphics	30
Network communications	22

Table 15: Benefits of management applications

Benefit	% of cases
More effective planning	53
Cost savings	50
Better decision making	50
More timely information	42
More accurate forecasts	42
Better understanding of business	39
Evaluation of policy alternatives	33
Optimized inventory	31
Better goal setting	25
Confirmation of other analyses	17

Table 16: Drawbacks of the management applicatons

Drawback	% from cases
Development costs	61
Long time to develop	53
Lack of necessary data	53
Training and education	44
Lack of special personnel	42
Attitudes	39
Updating and maintenance	33
Lack of models and algorithms	28
Lack of flexibility	28
Software difficulties	25
Poor documentation	14
Running costs	11
Unreliable hardware	3

Concerning the benefits (table 15), the intangible features, in money, like more effective planning, better decision making and more timely information outweigh the cost savings and optimized inventory. The most serious drawbacks and barriers for spreading these systems further seems to the the development costs, long development time, lack of necessary data and models and questions related to personnel (training and attitudes) as shown in table 16. Minor problems are the updating and maintenance. On the contrary the hardware reliability and running costs seem to present no problems.

The use of outside consultants is very common: in 70 percent of cases, outside consultants were used in developing the above applicatons. In 55 percent of the cases the applications are purchased, the share of own development being small, only 45 percent. When asked about the ongoing work in this area about 38 percent of companies were developing new applications; another 38 percent developing new algorithms and models and 24 percent had no active development work going on.

INTEGRATION OF THE SYSTEMS

Since world war II the size of the enterprises and organizations has grown rapidly. The effective management and control of large systems is very difficult because, among other things, the formulation of comprehensive models and objectives is very complicated. The large size of the system makes the communication, data transfer and the normal techniques of model solving and optimization very slow and impractical.

Further it is to be noted that a corporate and its operations are becoming more and more dependent on exogenous factors as customers, competition , availability of capital, governmental policies and regulations, interest groups, energy and labour market etc. The need for fast and reliable information systems in a corporate is essential. Several types of management information systems (MIS) have been developed and applied [Golemanov 1981] but as seen from the above questionnaire the users' experiences so far are not wholeheartedly positive.

Due to better reliability and for economic reasons there is now a general trend towards decentralized decision making, distributed computation and control and hierarchical system structures, in large-scale complex systems such as in integrated paper mill corporations. This leads to the integration of the control, information and management systems according to the hierarchical organizational and functional principles. Today, the aid of microcomputers and other distributed hardware makes this technically feasible.

The general potential benefits and advantages achieved by such hierarchical systems are [Leiviskä, Jutila, Uronen & Heikkilä 1980]:

- Easier integration of all the functions and better adaptability to existing (from their nature hierarchical) organizations.
- Flexibility and reliability
- Better utilization of resources; for example the data processing capability of individual subsystems. Then the distribution of functions, control tasks and responsibilities between different levels of the hierarchy is a key planning factor.

- Reducing complexity and thus simplifying the solution process.
- Coping with uncertainties--the decisions at each level are made at different times and thus the data at lower levels is quite uncertain when higher level decisions are made. In a centralized system all decisions should be made at the same time and thus earlier than in a decentralized hierarchy at the lower levels when the data available is more uncertain.
- The limited decision-making capabilities of an individual is extended by the hierarchical structure.
- Subsystems may be geographically far apart having limited communication with each other.
- There will always be costs, delays and errors when transmitting information. The distributed structure and decentralized decison-making will minimize these costs, delays and errors.
- In the existing system there may be local autonomy made by the subsystems and/or privacy of information. These features can be included in and coped with by the hierarchical structure.

- The technical development of the distributed hardware and databus technics [Heikkilä & Nikkilä 1980] has made the integration of the control, information and management systems attractive to build and operate both technically and economically.

In specifying and planning this kind of integrated hierarchical system there is a lot of research and development work, especially the generalities and methodology connected to planning, operation and updating of the systems. The conceptualization, theory and general advantages of hierarchical structure has been widely studied in recent years [Athans 1974, 1978, Mesarovic, Macko and Takahara 1970, Findeisen 1978, 1981]. Applications for such systems already exist, for example in the steel industry, [Mijazaki, Sakairi, Okamo, Arakawa and Suzuki, 1978], and in the pulp and paper industries [Eriksson 1978, Uronen and Williams 1978 Petersson and Rückert 1978], but the extensive implementation of the integrated system concept is just beginning. Therefore the structuring, standardizing and methodological generalities are of the utmost importance. There are several major factors and changes, especially in the pulp and paper industry, demanding and favouring the use and development of such integrated systems, for example:

- A major part, 80 percent, of the production will be run outside the normal dayshift, when top management is not on site; therefore the operators and other shift personnel need a suitable set of tools for reliable and accurate decision-making concerning the operation of the mill and planning the short term actions. This information must be stored

and later used as an historical database for checking and longer term planning.

- The mills are becoming more and more complex (the closed mill technology, larger units) and integrated (energy network, chemicals circulation, environmental protection).
- The economic factors (cost and efficiency reporting) and productivity are very important today. This development will also mean that the plant optimization will change from technological or process optimization to economic optimization thus the dimensions and the complexity of the problem will increase.
- The new developments of microelectronics and other related technology has created new possibilities. The use of computer technology in the pulp and paper industry has a certain maturity and the general attitudes are positive.

It is a well documented fact that most of the computerized unit process control systems in the pulp and paper industry have been profitable and successful investments [Keyes 1976] giving remarkable gains in terms of increased throughputs, higher yield, lower raw material and energy usage and better quality. This statement is supported by the results of this study: Most mills were satisfied with their existing process control systems.

At the higher levels of management the traditional real-time management information systems (MIS) have not been as successful as expected. The results of this questionnaire clearly support this as was shown in table 9. Parallel to the

real-time management information systems the so called decision support system (DSS) has been launched for the help of higher management in industry and business [Fick & Spraque 1981].
The most important features of these systems are:

- The system forms an effective and interactive link between computer capabilities (data) and decision maker (user);
- the system must help managers in making ill-defined, nonstructured decisions where explicit and "standard" solutions by algorithmic or other similar means are not possible.
- the system will support the judgements and human decisions.

The decision support system is a new tool for decision makers which is just beginning to be accepted by industry.

These new possibilities at all levels of industrial organizations from instrumentation to top management has created much discussion about the integration of all of these systems into a system hierarchy using distributed hardware and real time network communications [Uronen 1981, Williams 1978, 1980, Golemanov 1981, Hübner 1979, Alsholm & Haglund 1978, Eriksson 1978, Fowler 1980, Haglund & Alsholm 1980]

The development and implementation of this kind of total hierarchy is a long-term project demanding remarkable investments and planning resources. There is the theoretical and technological readiness to build these systems. The user's opinions and needs concerning the usefulness and application of these systems must be at the highest priority in order to avoid the situation where the computer technology and system vendors dictate the direction of progress. The most critical and important questions are: How much integration should be recomended and how much does it depend on local circumstances?

Is the integration of management systems with process control systems useful or advisable? How to combine the different systems and the distribution of tasks, functions and data bases? What are the effects of this kind of system on the organization and what are the most important topics for research and development work in this area? These questions were included as a central part of the questionnaire and by following the responses can be analyzed in detail.

The starting point is the existing organization of data processing activities (responsible for management systems) and process control activities inside the companies.

The result was that the existing organizations prefer to keep process control systems and data processing systems separate at all levels or organization.

The existing majority for separate organizations was, at mill level: 92% vs 8%, at division level: 79% vs 21%, and at corporate level: 92% vs 8%.

From table 17 we see that in the present situation the decentralized mill level organization for the process control area is predominant with some degree of corporate or division wide coordination. This is quite reasonable and an expected result because the technological processes and needs may vary from mill to mill. For stadardization and coordination purposes a small corporate staff is available. In the data processing area the centralized organizations are more common: 41% from the companies answered have corporate wide organizations, 19% corporate wide coordination and 24% have a mill level decentralized organization.

Table 17. Organization of the data processing and process control work in companies

System / Type of organization	Process Control systems %	Data Processing systems %
Decentralized mill level organization	53	24
Coordinated at division level	6	8
Divison level organization	9	8
Coordinated at corporate level	21	19
Centralized corporate organization	11	41

This result was also expected: The character of data processing is more general and more closely related to the corporate wide operations. Among those who are in favour of more centralization showed the most important benefits to be Common documentation, better coordination, technology transfer, staff training, lower costs, and promoting of mill wide information. However, when the opinions of the respondents concerning the organization and integration of the systems for future were asked a different opinion was given as shown in table 18.

Table 18. Integration of Process Control Systems and Data Processing Systems of the Future.

Type of organization	Yes	No
Integration at mill level	79%	21%
Integration at division level	52%	78%
Integration at corporate level	39%	61%

The trend here is clear: more integration, especially at mill level, is an important need. The main reasons opposing this development are: Different aspects and time horizon of the work, each mill has its own technical preferences and management style. The data processing people and process control people do not understand each others' work and problems, thereby showing that there is also a training and education problem.

The idea of building multilevel (3-5 levels) hierarchical integrated systems, starting from process control and including the management information system and similar functions at a high level has been widely discussed in recent years [Tinnis 1976, Uronen & Williams 1978, Ahlsholm and Haglund 1980, Uronen 1980 a, b, Golemanov 1981, Leiviskä and Uronen, 1980]. Table 19 shows the opinions of the respondents to this question.

From table 19 we can conclude that there is a remarkable interest and also ongoing work in the direction of integrated systems especially at mill level. The integration of the systems by using data base technology enables the use of common data

Table 19. Opinions about integrated hierarchy

a)

Type of hierarchy	Useful	Not important
Hierarchy at mill level	97%	3%
Hierarchy at division level	82%	18%
Hierarchy at corporate level	50%	50%

b) Benefits of this kind of hierarchy

Benefit	Mentioned in % of answers
Better decision making	78%
Better coordination	67%
Better productivity control	64%
Cost savings	61%
Faster and more accurate data	61%
Easier planning	56%
Standardization	44%
Personnel savings	22%

c) On-going developing work

System to be developed	% of companies answered
Hierarchy at mill level	44%
Hierarchy at division level	25%
Hierarchy at corporate level	22%

Table 19 contd.

d) How the management systems and process control systems should be combined

Integration	% of answers
None	8%
Same data bases	44%
Real time communications	39%
Full integration	9%

e) Future development work planned

Activity planned	% from answers
Expansion of existing MIS	30%
Developing DSS	27%
Start to build MIS	20%
Integration of MIS and production control	18%
None	5%

bases in real-time communication which seems to be the most feasible solution for the future.

Finally the recommendations and suggestions for important research topics in this area were explored. Table 20 indicates the answers.

The topics suggested indicate quite clearly the following important problem areas: Economics of automation and data processing systems, organizational effects and problems and needs for standardization and easier programming systems. Longer-term topics are DSS and fully automated production.

Table 20: Future Research topics suggested

Topics	Mentioned in % of answers
Economics of the system	39%
Distribution of decision making and its effects on MIS	39%
Mill productivity models	36%
Production scheudling and co-ordination algorithms	36%
Non-procedural programming languages	33%
Standardization	33%
DSS in forest industry	28%
Fully automated mills	19%
Corporate wide hierarchy	14%

CONCLUSIONS

There clearly exist remarkable interest and progress towards the integration of the control, information and planning systems at various levels in the pulp and paper industry. To a large extent, this has been caused by the new generation of distributed hardware capable of flexibly building of integrated hierarchical systems. The application of the new generation of these integrated information systems is now at its early stages of development without any standards or "packaged" solution. Therefore this would be an optimal time to try to develop guidelines and standards for these systems and their usage according to the opinions and wishes of the users before the market will be too much directed by the hardware and by the vendors of these systems as has been the case sometimes in the short history of the computers in the industry. Following are some critical questions to be thoroughly studied when developing these systems:

What is the reasonable sophistication of hierarchy and integration of the systems at various levels of organization i.e., mill wide, division wide or corporate wide integration? What is the "optimal" level of automatization and how much does it depend on local circumstances, mill or company size, product mix etc.?

How much standardization and general packages or modules for this kind of integrated systems can be and is feasible to develop?

Economic pay-off studies of different scenarios of integrated systems in typical mill using actual data would be important. What are the needs for new models and algorithms in these systems? The applicability of existing models and algorithms. Effects of these systems on organizations, training and education of people at all levels of organization. Based on the results of this study it seems quite obvious that at mill level the integration is feasible and advantageous and most mills are planning to implement this kind of system in the near future. The completion of this integration into division and corporate levels is not so clear and many companies do not see it as necessary. Therefore, a total system like the one depicted in figure 4 might be a general scheme for corporate wide system integration with the aid of three levels of system interconnected with data highways. In addition to these a decision support system for mill management and data link to division wide and corporate wide information systems is needed.

With this kind of development and by using digital instrumentation systems and other distributed hardware and effective video and other man-machine communications the "classical"

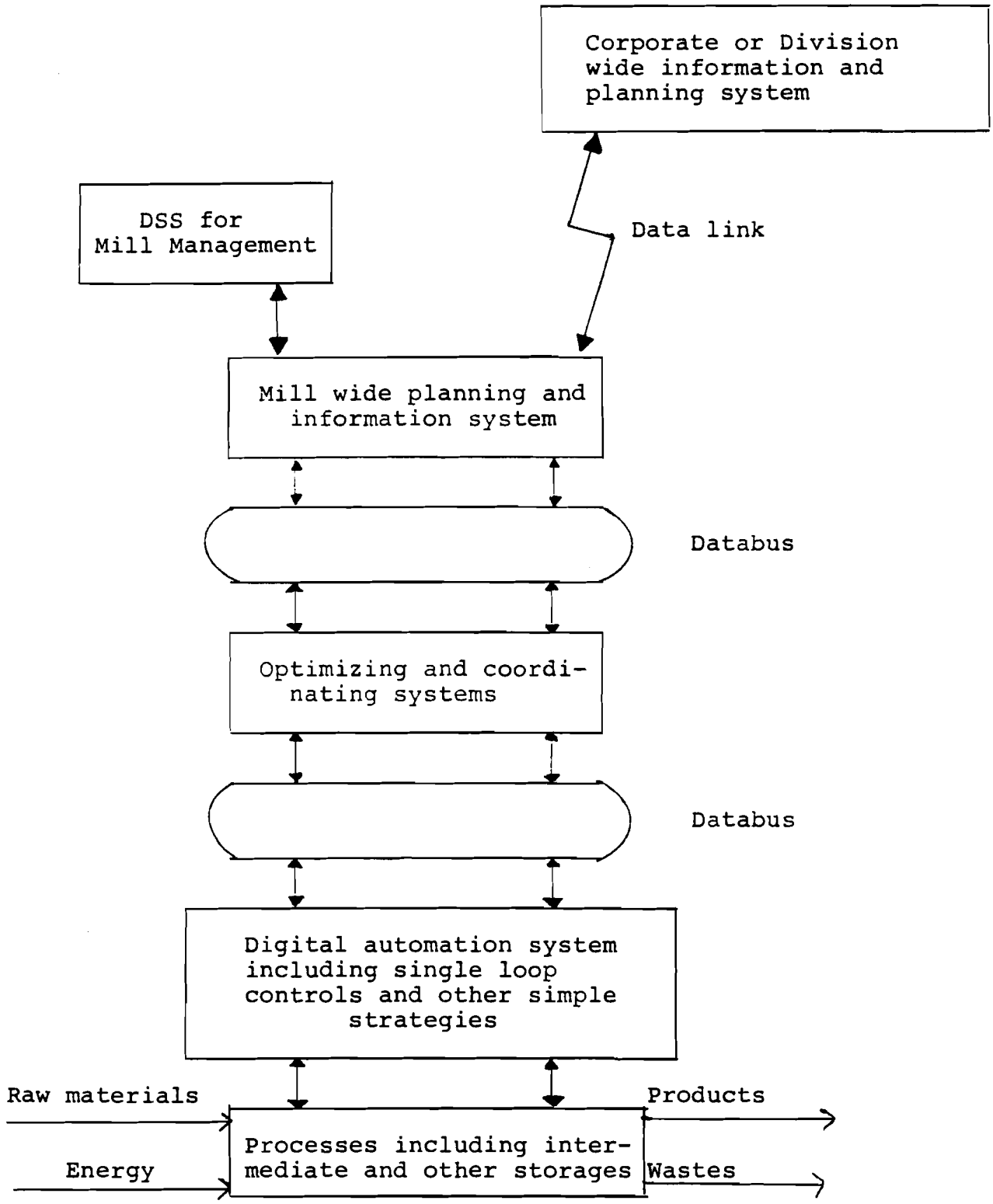


Figure 4. Proposed integrated system hierarchy

control rooms with many recorders, indicators, counters and semigraphic process flow diagrams will diminish and thus also the work of operating personnel will change remarkable. Another interesting new development area is the company intern information system similar than those operated by some public companies etc. These systems should include and handle the company intern pertinent information and it could form a first step forward in decision support systems. It is evident that the development will go in the direction of integrated information systems and this also means towards higher level of automation and already today we do have technical possibilities and means to realize a fully automated production, where operators are only in one (or in very few) control centre(s). The hardware development seems to be far ahead of the software development and there does not exist any standard solution or standards for the integrated systems. Another big problem area here will be the organizational and other man/machine effects. The future development work in these areas must be encouraged which was also clearly supported by the results of this investigation.

APPENDIX

QUESTIONNAIRE ON THE USE OF COMPUTER BASED SYSTEMS ANALYTICAL APPLICATIONS IN THE FOREST INDUSTRY

(please type or use block capitals. Tick boxes and/or delete where applicable.)

A. General

1. Name of the Company:

Main products: _____

_____

Annual capacities: _____

_____

Turnover:

<100M$ ☐

100-500M$ ☐

500-1000M$ ☐

>1000M$ ☐

Own forest lands:

None ☐

<100,000ha ☐

>100,000ha ☐

How many divisions ___

How many mills ___

How many mill locations ___

2. Organization of systems analysis work in your company.

System / Organization	Process Control Systems	Data Processing and Administrative Systems	All Systems combined together
Centralized corporate organization			
Corporate wide coordination			
Centralized organization inside divisions			
Divison wide coordination			
Decentralized (mill or plant level organization)			

Do you have plans to centralize this systems organization YES/NO

If yes, or if you already have a centralized organization, can you give some benefits which you see with the centralized system organization:

_____

_____

_____

_____

_____

3. Systems development work in your company.

Number of professionals in EDP group _____

Number of professionals in Process Control Group _____

Do you regularly use outside consultants _____

Do you have R&D cooperation with:

- Consulting companies _____
- Engineering companies _____
- Universities _____
- Research institutes _____
- System vendors _____

Have you bought most of your systems as ready products from the vendor? _____

How large, for example in %, is your own development work _____

Do you think that most "packages" available in the market do need tailoring to your company? _____

Will this tailoring be made by you, by the vendor or jointly? _____

4. Corporate wide systems.

Do you think that process control systems and management and administrative systems (EDP) should be kept fully separated:

a) at corporate level _____
b) at division level _____
c) at mill level _____

Reasons: _____

_____

_____

_____

_____

Do you think a hierarchical multilevel information and control system starting from process control and including the management information system (MIS) is useful and important:

a) at corporate level _____
b) at division level _____
c) at mill level _____

Benefits:

Standardization ☐

Common database gives more accurate and fast data ☐

Cost savings ☐

Personnel savings ☐

Better decision making ☐

Better coordination ☐

Better productivity control ☐

Easier planning ☐

Other ☐

Weaknesses: _____

_____

_____

_____

Are you building a corporate/division/mill-wide systems hierarchy in your company? _____

B. Process and Production control Systems

1. The existing systems in your mills:

	Number	Package	own development
Batch Digester Control			
Continuous Digester Control			
Bleach Plant Control			
Washing & Screening Plant Control			
Pulp Drying Machine Control			
Evaporator Plant Control			
Recovery Boiler Control			
Lime Kiln & Causticization Control			
Power Boiler Control			
TMP Plant Control			
Grinder Control			
Stock Preparation Control			
Paper Machine Control Systems			
Coater Control Systems			
Roll Handling Systems			
Quality Monitoring and Control			
Inventory System			
Trimming & Scheduling System			
Energy Management System			
Order Handling System			
Environmental Monitoring Sys.			
Production Planning System			
Production coordination & Control System			

2. What new unit process control systems do you expect and plan to install during the next 5 years in your mills:-

3. Are you planning to implement a production planning and coordination system in the near future: _____
If yes, what are the main benefits you see to be achieved with it:

Better use of equipment and capacity ☐

Increased production ☐

Decreased losses and risks ☐

Better decision making ☐

More accurate and timely information ☐

Better cost and effectiviness control ☐

Easy and flexible planning ☐

Savings in personnel ☐

Increased safety in operation ☐

Others (please specify)

_____

_____

_____

_____

4. If you think that a computer based production planning and coordination system is not useful, what are your main arguments:

High costs ☐

Difficult and complex programming ☐

Lack of models and algorithms ☐

Unreliable and non-compatible equipment ☐

Training and education of personnel ☐

The benefits are marginal only ☐

Other, (please specify)

_____

_____

_____

_____

5. If you already have a computer based corporate or mill-wide production planning system, what are your experiences:

The system was built separately without any or very little connection to the process control system ☐

The system was built by using as much as possible of the process control systems ☐

The Main benefits are:

Higher production ☐

Easy and flexible planning ☐

Decreased losses and disturbances ☐

Savings in personnel ☐

Better information and decision making ☐

Other, (please specify)

_____

_____

_____

The main problems:

Costs ☐

Training ☐

Updating of the system ☐

Maintenance ☐

Other, (please specify)

_____

_____

_____

6. Needs for R&D in this area (name 3 most obvious):

New and better sensors ☐

Development of better process and mill models ☐

Development of more efficient control algorithms and increased use of advanced control theory ☐

User oriented programming ☐

Self-diagnostics of the systems ☐

Standardization of communication and programming ☐

Better man-machine interface ☐

Methods for intergrating of the sybsystems into a hierarchy ☐

Other, (please specify)

_____

_____

_____

7. How do you maintain and update your systems in this area?

Babysitter by the vendor on-site ☐

Own maintenance department ☐

Emergency reparations only ☐

8. How do you train and educate your people in using the computer based systems?

No organized training inside the company ☐

Company organized seminars, courses, tutorials etc. ☐

Active participation in outside courses etc. ☐

Special programs designed and organized by consultants and institutes ☐

9. How do you rate your existing systems in the following areas:

	Very good	satisfactory	Not satisfactory
Process Control Systems			
Production planning and coordination			
Energy Management			
Tactical planning			
Strategic planning			
Management information system			

10. What is your opinion of the following systems?

System	Important	Useful	Not Useful
Computerized process control			
Computerized production planning			
Computerized order handling			
Computerized quality control			
Computerized energy management			
System for coordination of different departments			
Real-time management information system			
Hierarchical multilevel (3-4 levels) corporate or mill-wide information and control system			
Combination of management information and production control systems			
Use of computers at the highest level of management (Decision support systems)			
Idea of totally automated production in the Forest Industry			
Electronic Office			
Personal computing tools			

C. Management Systems

1. Which of the following computer based applications of Systems Analysis are used in your company and how do you rate them?

	Important	Useful	Not useful
Corporate modeling			
Plant location			
Resource (=Forest) Management			
Budgeting			
Marketing planning			
Investment Analysis			
Profit planning			
Long term forecasts			
Financial analyses and forecasts			
Inventory control			
Project management and control			
Planning of transportation			
Organizational planning			
Risk analysis			
Planning of R&D			
Purchasing planning			
Management information system			
Resource allocation			
Wood Procurement, inventory and Transport			

2. Which of the following systems analytical tools and methods are used in your company in the above systems?

	Used
Linear programming	
Integer linear programming	
Non-linear programming	
Dynamic programming	
Multi-objective optimization	
Goal programming	
Deterministic models	
Stochastic models	
Simulation	
Gaming	
Heuristics	
Pert or CPM	
Inventory theory	
Network theory	
Optimal control theory	
Time series analysis	
Box-Jenkins method	
Exponential smoothing	
Some other forecasting method	
Other, specify	

3. Important features of the above application:

Easy to use and modify ☐

Effective reporting ☐

Effective data base management and utilization ☐

Graphics ☐

Sensitivity analysis ☐

Effective simulation possibilities ☐

Interactive operation ☐

High level programming language ☐

Network communications ☐

4. Benefits of the applications:

- Better understanding of business ☐
- More accurate forecasts ☐
- Cost savings ☐
- More timely information ☐
- More effective planning ☐
- Optimized inventory ☐
- Evaluation of policy alternatives ☐
- Better decision making ☐
- Better goal setting ☐
- Confirmation of other analyses ☐

5. Drawbacks and reasons of the gap between the theory and practice in the use of management science and management information systems.

- Poor documentation ☐
- Lack of necessary data ☐
- Lack of necessary models and algorithms ☐
- Unreliable hardware ☐
- Development costs ☐
- Long time to develop ☐
- Training and education ☐
- Lack of special personnel ☐
- Running costs ☐
- Lack of flexibility ☐
- Software difficulties ☐
- Output format design ☐
- Attitudes ☐
- Updating and maintenance ☐

6. Do you use outside consultant, e.g., universities, software houses, computing centres etc., in the further development of your systems?

YES/NO

7. To what extent are the above applications your own development and to what extent are they purchased programs or packages?

Totally own development ☐

Mainly own development ☐

Mainly purchased products ☐

Totally purchased products ☐

8. Ongoing R&D work in this area in your company,

New applications ☐

New models ☐

New programs ☐

None ☐

9. To what extent do you think these systems should be combined with the process control and production planning systems?

Not at all ☐

Same data bases ☐

Real-time communications ☐

Full integration ☐

10. In the near future are you:

Starting to build management information systems ☐

Expanding your existing management information system ☐

Starting to study and develop decision support systems ☐

No new applications ☐

Integrating the management systems with the production planning and control system ☐

11. Recommendations for the future R&D:

Use of the decision support system idea in the forest industry ☐

Corporate wide hierarchy ☐

Production scheduling and coordination algorithms ☐

Distribution of the decision making (Corporate versus Mills) and its effects on the management information systems ☐

Economic pay-off studies of different systems ☐

Man-machine communication (non-procedural languages) ☐

Mill productivity models ☐

Fully automated mills ☐

Standardization ☐

Other, (please specify)

_____

_____

_____

12. Are you interested in the planned IIASA task force meeting planned for May 1981, where the results and findings of this questionnaire will be discussed,

YES/NO

13. Other comments and suggestion for IIASA:-

14. Name and address on the contact person in your Company

_____

_____

_____

_____

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