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Preface

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PAPER-MILL-WIDE SYSTEM DESIGN FROM THE USER'S VIEWPOINT

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ABSTRACT

The paper-mill-wide needs for process and production control and information are analyzed and synthesized in the context of a typical, rather common type of mill. It was found that the "Williams" type hierarchy provides a convenient framework for structuring of the present state of the art in paper-mill-wide systems and an extension to "business-wide" systems is proposed.

Some measurement and control problems, unique to paper-making, are reviewed in the mill-wide context. Several options for implementation, including "customized standard application modules", are briefly reviewed.

INTRODUCTION

The author, after nearly 20 years spent in research, development and marketing of process computer controls for the paper industry, had the interesting experience in 1978 to return to the industry and work as corporate technical director for a multi-mill company making newsprint, lightweight coated paper, linerboard and tissue. The major responsibilities included purchasing, deployment and performance monitoring of process computers and related automation, surveillance of quality control and process developments from a corporate viewpoint, and appraisal of capital projects.

A wide range of problems was encountered, involving many different departments in the company. These were of a short-term as well as a longer-term nature.

Information-related problems

The search for solutions often involved investigations based on data and information available from the mills or from outside the company. In addition to the first-hand experience, there were many impressions received second-hand from mill managers and their staff. Examples of information-related problems follow. These are not in order of importance.

- Daily production reports were quite often late and inaccurate even though some of them were produced by an administration computer.
- There was a considerable amount of feedback information from customers. In general, reaction to the data was on a crisis or complaint basis. There was a minimum of analysis aimed at accurate detection of significant or long-term trends.
- Very little of the data from the process computer printouts was actually used, either by manufacturing or technical personnel.
- Computer processing of production reports was supposed to reduce manpower, in fact the opposite was the case.
- Customers occasionally complained of quality variations between rolls received from different machines or different mills.
- It was very difficult and time-consuming to relate data between reels, rolls and machines, particularly when coaters and super-calenders were involved.
- There were frequent debates over the merits of different roll-numbering systems.
- Attempts to automate finished roll inventory using the existing roll handling and administrative computers were not satisfactory.
- Too often, customers seemed to receive rolls with wrong width or wrong diameter.
- Mill managers would reminisce about the graphs that they used to draw when they were superintendents in order to follow trends in the important variables in their department. They regretted that today this wasn't done, presumably through lack of manpower.
- Consultants recommended that we should implement quality control charts with action limits for many of the quality variables. This seemed to involve adding more manpower.
- Monitoring of process computer performance required many man-hours per week to do satisfactorily.
- It seemed that often, quality complaints related to the winding of the rolls rather than to the production of the jumbo reels from which the rolls came.
- The unaccounted-for losses were quite high, especially for the coated paper-mill with its re-reelers, coaters and super-calenders.

Mill-Wide Study

As a result of this type of problem, it became increasingly clear that although there were modern process computers installed on all major machines, including roll-handling, as well as computers in administration, it was still quite difficult to obtain accurate collated information. As a result, many problems which affected the company's profitability and market performance remained essentially unsolved. It seemed, therefore, that it would be worthwhile to investigate the information flow within the mills and outside the mills in terms of customer feedback, etc., to determine whether there were obvious deficiencies which might be corrected. This turned out to be a study in mill-wide control from the user's viewpoint.

There has been a great deal written about the changing times in which we live. One of the more perceptive writers in this area is Paul Hawken, author of <u>The Next Economy</u> (<u>1</u>). He describes the transition from the energy-based "mass economy" to the "informative economy". He says "One of the great myths about economic behaviour is that money is the language of economy. The language of an economy is the information that is contained in manufacturing, products and services; money is only a part of that information.... The problem with the U.S.

economy is not the lack of money, material, labour or industrial capacity. Like many of the products we manufacture, we suffer instead from a lack of information about what we are doing, what we want, and how to proceed from here."

In the case of the paper industry, the "lack of information" is often not a lack of basic knowledge. The problem often seems to be that the knowledge is not brought to bear consistently. Spending a lot of money on equipment does not guarantee that it will be used correctly. One potential of the mill-wide system is to embed that knowledge in a so-called "expert system" so that available measurements are used consistently and correctly in decision-making.

MILL-WIDE STRUCTURE

Information and control problems within the mill seem to be so widespread and diverse that it is often difficult to know where to start. Perhaps we could draw a parallel with the development of process-control computers in the very early 1960's. Process computers had just become available and we were trying to find a meeting ground between the new, and in retrospect, rather simple-minded solutions, and the actual, very complex needs which could not be expressed too clearly. Today, of course, the new technology is the microprocessor and the communications network. The messages of systems engineering were then coming into vogue and they are probably still applicable today.

Drawing the boundaries

Perhaps the most critical message and the one requiring the most intuitive skill to implement is how to define the boundaries of the problem to be attacked. The second message is that it is necessary to establish a structure within the boundaries. The mill-wide problem is potentially so large that it is advantageous to be able to subdivide it into smaller structures which are as much as possible self-contained. It seemed appropriate to choose newsprint as the starting point because this was the major grade made by the company. In addition, newsprint is extremely important in the Canadian economy. We are fortunate to have a large group of mills in Canada with similar control problems.

Canadian Newsprint

The newsprint industry consists of roughly 40 mills with about 140 machines, and it produces half the world's supply. Newsprint mills are distinguished by:

- all production is rolls
- rolls produced to customers' order
- 1,500 to 3,000 rolls per day
- several machines
- long grade runs
- simple quality specifications

It is always easier to design an information and control system for a process which is essentially in a static state of development. Despite enormous changes in paper-making technology over the last thirty years, newsprint manufacture still depends on the basic processes of sheet-forming, pressing, drying, calendering, reeling, slitting, winding and finishing, storing and shipping, and is likely to do so into the forseeable future.

For the purposes of this paper, the process boundary was drawn arbitrarily between the paper-mill and the pulping and energy departments.

Information Boundary

Once in the paper-mill, the most difficult boundaries to choose seem to be not so much a process boundary but rather an information and jurisdictional boundary; namely, that with the mill computer department. The data processing being done by these departments relates to administration as well as to production. How much of this responsibility should actually be part of a mill-wide system?

An overview of this relationship was obtained by preparing a large table with all major information-processing activities, whether computerized or manual, listed along both the rows and columns. The off-diagonal elements in the table showed whether or not there was an information flow from one activity to another and if so, whether the information could be categorized as related to material, service or money. For example, material-related information from order entry passes to scheduling and trim, as well as to labelling, roll-weighing, bill of lading and shipping. Invoicing receives information related to money from the order-entry activity.

By rearranging the rows and columns, it was found possible to partition this table in such a way that there was a section of the table where the elements contained only material-related information. This is not to say that economic considerations were to be excluded, but rather that where money is involved, it would be related to cost-accounting rather than to financial accounting. The mill-wide system boundaries were drawn round this section. The applications range from Order-entry through to Analysis for production and quality.

Functional Model

The information activities seem to lie in several related areas, as shown in Fig. 1:

- Production
- Customer
- Efficiency
- Quality
- Usage of materials and energy, including discharges.

By including the customer in the scope of the mill-wide system, we are in fact extending it to become a "Business-Wide" system (2).

BUSINESS-WIDE SYSTEM FUNCTIONS

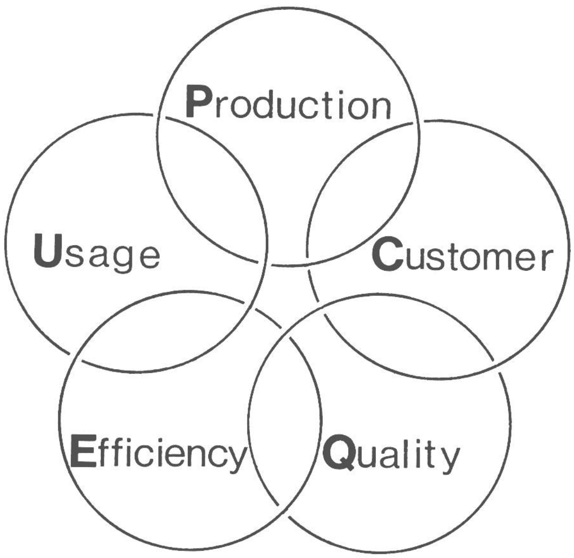

Fig. 1: Scope of "Business-Wide" system links five functional areas

Although Fig. 1 shows all these information activities as related, it does not show the extent of these relationships. The information flow between each of the activities is shown by the arrowheads in Fig. 2. It can be seen that there is much interaction between the functional areas, which leaves no question about the needs for integration in a mill-wide system.

THE HIERARCHICAL MODEL

These rather simple conceptual models provided a broad overview from a functional standpoint. They did not, however, show how the mill-wide system should be related to the process or to the organization which runs the mill, both of which seemed to be necessary for long-term design or planning.

Organizational Structure

The hierarchical line organization is generally recognized to be the most suitable for management of mature, well-defined operations. Each level in the hierarchy from operator to mill manager has its own specific responsibilities.

Williams (3) has shown that computer systems for mill production also need a hierarchical structure so that all parts of the system work towards meeting the mill's operating objectives. These concepts have been applied with some modifications to newsprint, (2), (4), with the result shown in Fig. 3.

BUSINESS-WIDE FUNCTION INTEGRATION

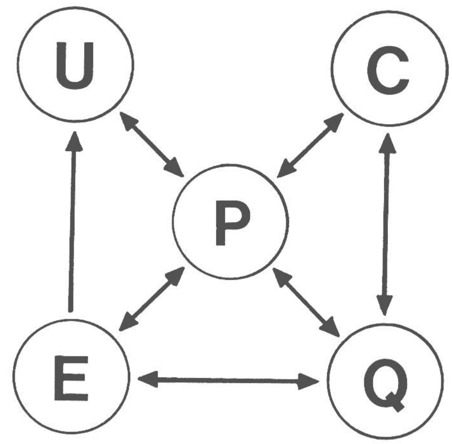

Fig. 2: The arrows show the information flow (integration) between "Business-Wide" functions

The pyramid-like structure for the mill-wide system has five distinct levels with the information flow between each level indicated by arrows. All communications between functions at a particular level pass through at least one higher level.

The highest (EXTERNAL) level communicates primarily with the world outside production. It exercises no process control as such. The MILL and AREA levels (3 and 4) perform production scheduling, inventory control, quality control and reporting tasks. The UNIT and GROUP levels (1 and 2) perform direct process control and data acquisition.

Mill-wide systems therefore generally have the following important characteristics:

- <u>Horizontal Span</u> across several production areas or groups;
- <u>Vertical Reach</u> from order entry down to direct unit control;
- <u>Integration</u> both vertically and horizontally.

Inventories determine structure

There are several inventories shown in Fig. 3 which have an important bearing on the control and information system. These inventories are both forward-direction inventories and recycle (broke) inventories. By putting stock preparation in "reel-making", we have in effect hidden the stock inventory, including wet broke. Control of this inventory should not be simple level control, but is a co-ordinating function carried out at the Area level. When the process changes from being continuous to being discrete at the machine reel, inventory control becomes more complex and involves tracking of jumbos and rolls.

We could easily amplify the model by moving stock preparation to the Group level, separated from reel-making by the stock chest inventory. The new unit level controls would include proportioning, refining, blending, etc. It can also be seen that it is relatively straightforward to extend this model to include, for example, off-machine coaters or super-calenders, as well as into sheet-finishing, etc.

Details of the functions at each level can be found in (2) and (4).

THE STATE OF THE ART IN CANADIAN NEWSPRINT

It is worth examining how far the Canadian newsprint sector has progressed with computerization in relation to this paper-mill-wide hierarchy. In 1982, over 95% of machines had process computers at the reel. By the end of 1984, the majority will also have cross direction controls. Over 95% of mills also have computers for roll-handling.

Roll Computer Systems

There is some variation of the scope of roll handling computers between different mills but the most complete systems include the following functions (4):

- External Level: Order receipt and status; invoicing. Several companies have centralized order receipt with allocation to mills.
- Mill Level: Order processing; machine scheduling; winder trimming, naked roll inventory, reports (roll shipments, production, inventory, quality rejects, etc.)
- Area Level: Wrapped roll inventory; shipment planning.
- Group Level: Winder patterns; roll classification; finishing co-ordination; shipping co-ordination.
- Unit Level: Identify roll by customer order, measure (diameter, weight, width), wrap, label, stencil, load, documents.

Roll systems therefore have the characteristics of mill-wide systems as shown by the unshaded area on the upper levels and right-hand side of Fig. 3. They meet the three criteria:

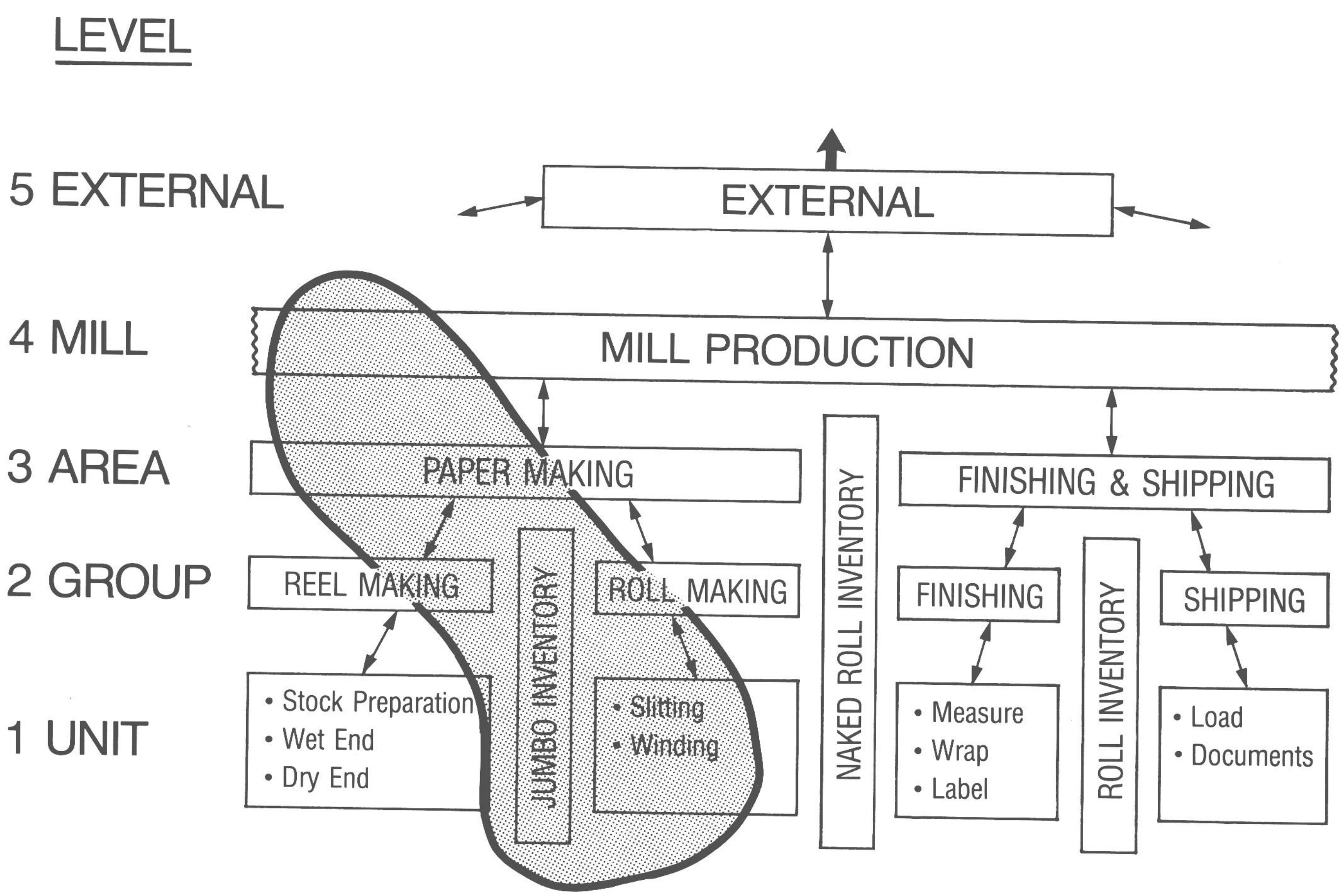

Fig. 3: Paper-mill-wide information and control system can be modelled as a multi-level hierarchy. Computerization in the Canadian newsprint industry is quite extensive. On-machine computers implement the lower left-hand corner and roll-handling computers the larger unshaded area on the right. The shaded area is the "missing link".

- Horizontal Span from roll-making to shipping;
- Vertical Reach from external to unit level;
- Integration both vertically and horizontally.

These systems have achieved considerable benefits:

- Reduced fixed costs: Operating and clerical labor savings, reduced inventory carrying costs and faster invoicing;
- Increased efficiency: Reduced losses due to trim, overruns, down grades and inventory spoilage;
- Improved quality and customer service.

Many of these benefits accrued because of integration: For example, to gain the full benefits of computerized labelling requires computerized scheduling and trimming which in turn depends on computerized order processing. Without the integration, the same data would have to be entered by different clerks and shift operators.

Jumbo reel computer systems

On the other hand, on-machine (reel) computer systems have also brought important benefits in terms of:

- Increased profit margin by increased moisture;
- Increased efficiency and productivity by reduced rejects and increased basis weight and in some cases by reduced breaks and increased speed;
- Improved quality by reduced variability;
- Fixed costs have generally increased, however, because service is generally contracted to the computer supplier.

The benefits of reel computers were obtained by direct process control, primarily at the unit level in reel-making, shown at the lower left corner of Fig. 3. However, reel computer systems do not have mill-wide characteristics; they have neither horizontal span (in two dimensions) nor vertical reach; also, they are not integrated horizontally or vertically.

The Missing Link

So, in the paper-mill at least, a large part of the mill-wide system is already in place and substantial benefits have been gained not only from individual control functions but also by integration of functions on a hierarchical basis. Important parts are however still missing, with serious consequences. The shaded portion of Fig. 3 represents the missing parts of the hierarchical control system organization.

The structural defects due to this "missing link" and the probable benefits from completing the structure have been reviewed in (4). Important measurements of quality and quantity either do not enter the mill-wide system or in the case of the reel computers are discarded at the unit level of reel-making. In addition there is no control at the unit and group level of roll-making and the jumbo reel inventory is not controlled. Area control of paper-making does not exist. There are important integrating links missing.

PEELING BACK THE LAYERS

The mill-wide characteristics of reach, span and integration are very important. So far, we have been looking at mill-wide systems from a "top-down" vantage point. It is worth looking at an example which will illustrate some of the characteristics of mill-wide. This involves the material balance downstream from the point where production ceases to be continuous and becomes discrete. This point is the machine reel.

Material Balance

Let us review the measurement and optimization of the material balance between the machine reel and the shipping scale. Note from Fig. 3 that this problem has horizontal span from reel-making to finishing and vertical reach from unit level to mill level and back down to unit level.

PRODUCTION BALANCE

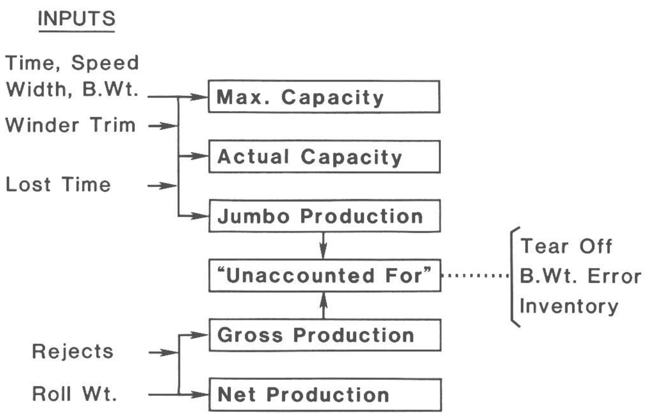

Fig. 4: Material balance from turn-up of jumbo to roll-weighing

The balance is shown in Fig. 4 in terms which are common within the Canadian newsprint industry. The basic measurements are made at two points: reel measurements are the basis for downstream calculation. Wrap-line measurements are used to calculate upstream. Supplementary measurements are made at the winder. At the reel, computer measurements of average basis weight (end-of-reel grab samples are not recommended), and average speed are taken over a given time period. These data are used together with the paper machine width to calculate the maximum capacity in tonnes. The actual capacity is found by subtracting losses due to actual average winder trim. There is lost time due to breaks and maintenance which when pro-rated out leave tonnes of jumbo production. From the wrap-line, the weight of rolls during the period gives the net production. Gross production is obtained by subtracting rejected rolls. The difference (jumbo production minus gross production) is "unaccounted for" - which amounts to 4 to 5 percent in many mills (5). In fact it consists of the following assignable components:

- "Tear-off", i.e. sheet length losses between turn-up of the jumbo and roll-weighing;
- Increase or decrease in inventory of jumbo reels and naked rolls;
- Error in basis weight measurement.

Determination of tear-off involves measuring jumbo sheet length during reel-making, tracking this value through jumbo inventory and measuring set sheet length and any roll slab-off in roll-making. Increase or decrease of inventory requires tracking of both jumbo and naked roll inventories.

Provided that the tear-off and inventory functions are implemented correctly, and the roll scales are correctly calibrated, which must be done to satisfy government regulations, then any persistent positive or negative unaccounted-for must be due to basis weight sensor calibration offset.

In the author's experience (6), the majority of mills do not pay adequate attention to sensor verification. The recommended method is the roll weight/mileage method. In one of the better managed mills, where dynamic verification is performed routinely, the results of 70 sequential tests over 12 months on one machine showed that the sensor averaged 0.3% low with a variation of ±0.8% (2 sigma). For an average newsprint mill, the error of 0.3% would cost nearly $200,000 per year.

The mill-wide system would perform this verification automatically at a rate several times greater than is practical with the manual method. As a result, calibration errors can be detected in a matter of hours rather than weeks and basis weight can therefore be optimized. Automatic recording of tear-off with associated reason provides a means to reduce this loss by determination of cause, operator-training and follow-up.

Quality Control

The whole question of quality control is another good example of a problem with mill-wide characteristics. Measurements for quality control are made at several locations. These include:

- pulp samples
- process computer at the reel
- paper samples from jumbo
- inspection of reels and rolls
- measurements at the wrapline
- checking on loading

The "span" of quality control is therefore across the whole mill, in fact, it should extend to the customers' plant and back so that full use can be made of product performance data. This means that the "reach" should include all levels from unit to external.

Hierarchical model proves useful

The author has found the hierarchical structure to be very valuable for analyzing the needs and deficiencies of mill-wide systems. Many examples of potential sub-systems and their benefits are given in (2) and (4). Unfortunately, it was only possible to scratch the surface in terms of detail.

According to H.F. Judson in The Search for Solutions (7), "Models are provisional structures, subject to change. They should not be complete; they must prove useful...." The modified Williams model, we believe, has met all of these criteria.

IMPLEMENTATION TRENDS

Embryonic Market Development

Judging by published reports, paper-mill-wide systems of the scope described in this paper are still very much in their infancy. One of the earliest at Varkaus, Finland (8), was an "in-house" system. More recently, systems have been reported in the U.S. and overseas which were implemented by multiple vendors (9), (10), (11). There are many more systems in Europe which have been developed by a combination of vendor and in-house.

In comparison with Northern Europe, North American mills are run with fewer technical staff and tend to rely more on vendors and "packages".

The market place for "jumbo reel" computer controls has been completely dominated by the package system for all types of machines and grades of paper in most countries. The author believes that this occurred because the vendors paid attention to all aspects of the innovation process (12). They not only recognized the users' needs but also the technical capability which had become available in the late 1960's in the form of the low cost mini-computer. They pursued the innovation process by establishing the validity of the need and at the same time achieved satisfactory technical performance. There was no question that user education was a vital ingredient in taking the innovation to a successful conclusion.

In the mill-wide area the vendors (13) are perceived, in general, to be approaching the mill-wide market by concentrating more on promoting hardware technology than on developing systems to satisfy the needs of the paper industry. That sort of approach could, on the one hand, delay establishment of the validity of the needs and on the other hand increase the time before adequate technical performance, at a justifiable price, is demonstrated.

Most vendors have made major investments in general purpose hardware and software for mill-wide control. To turn this into a successful "package" for paper-mill-wide control requires the development of "customized standard application modules" which must demonstrate the validity of the need in a cost/effective manner. These modules, although largely standardized and based on the first principles of the application, must be capable of customization to a greater or lesser extent depending on the varying needs of each customer. This level of customization will be much more extensive than has been the case for previous package systems. This will be a challenging assignment, requiring not only an in-depth knowledge and experience of paper industry operations but also product development and application experience of computer systems covering all levels of the hierarchy. The latter multi-level experience may be particularly difficult to find. Computer expertise seems to have polarized into "real-time" process control on the one hand and "transaction-based" data processing on the other. In the paper-mill-wide systems these neat compartments may no longer be appropriate. Integration has the potential to create a hybrid of "real-time transaction processing" which may require rather careful design and application trade-offs to be fully cost effective. It will also demand higher standards of reliability, accuracy and data integrity than we have become accustomed to with package systems to date.

Planning for Existing Mills

The major market for paper-mill-wide systems is the existing mills. Mills must, where feasible, build on what is already installed. Implementation should be incremental, otherwise the requirements for detailed design, changeover and training may be too demanding for success. This implies a fair degree of planning.

These plans should be based on need rather than hardware. The basic needs are likely to change much more slowly than the availability and cost of hardware and software. If it is only cost-effective to implement part of the plan, go ahead. There is a high probability that the price/performance of the hardware will improve markedly with time. Do not overplan, allow for innovation both from within and outside the mill.

The order of implementation is quite important. The precepts of top-down planning and bottom-up implementation may not neatly apply to paper-mill-wide systems. It seems that a lot of bottom-up knowledge is needed to develop the top-down plan. In addition, the optimum order of implementation does not necessarily mean starting at the unit level. One roll-handling system vendor found that in order to standardize, the system could be decomposed into several application modules as shown in Fig. 5.

This diagram is arranged to show the preferred order of implementation (2). Order Processing, which is an External level

PROFINET FUNCTIONAL STRUCTURE

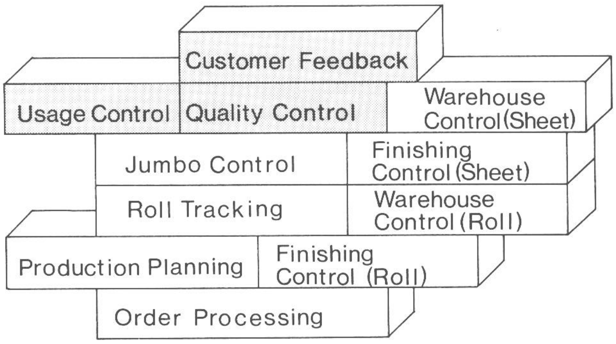

Fig. 5: Paper-mill-wide application functions build upon each other for ease of integration.

function, should be implemented first, followed by Production Planning (Mill Level), and Finishing Control (Area, Group & Unit). The shaded functions were specified by the author to complete the paper-mill-wide system. They are again shown in building block sequence. Jumbo Control provides the "missing link" between the paper machine and the winder, which is the foundation for effective Quality Control, Usage Control and Customer Feedback.

Do not equate 1:1 the paper-mill-wide levels with hardware solutions, for example the Unit level involves data acquisition and process control. Distributed Control Systems and Programmable Logic Controllers involve data acquisition and control. If the Canadian newsprint sector is typical, less than 5% of machines have DCS's. They are nice to have as a basis for paper-mill-wide, particularly if their architecture permits collection of all the types of data needed such as laboratory test results, roll numbers, sheet length in the jumbo or roll, time and duration of breaks, etc., as well as the more usual digital and analog inputs. If they do not have these features, then you could look at the increasingly wide choice of relatively inexpensive programmable input/output systems with communications capabilities. On the surface, this may look as though it would create network communications problems. According to Fadum (13), the network difficulties tend to be concentrated more at the Unit level where most suppliers have proprietary protocols. The higher level communications will most probably become an open standard.

CONCLUSIONS

The needs for a paper-mill-wide system were illustrated in terms of several rather common information and control-related problems. From a conceptual viewpoint, these problems related to a "business-wide" system whose functional elements were highly inter-related. A modified Williams multi-level hierarchy was developed for the paper-mill-wide system which has the characteristics of horizontal span, vertical reach and integration.

The current state of computerization for the Canadian newsprint industry in this context is quite extensive although it was shown that in all mills a "missing link" exists between the machine jumbo reel and rolls off the winder which has quite serious technical and economic consequences.

It was concluded that there are only a few North American mills which presently have installed paper-mill-wide systems. Planning for mill-wide systems should be done relative to the need, rather than from any specific hardware base, and should follow a rather specific path for ease of future integration.

REFERENCES

1. Hawken, P., The Next Economy, Holt, Rinehart and Winston, New York, 1983.

2. Brewster, D.B., Preprints, CPPA/ISA Process Control Symposium, Vancouver (1983), p.183.

3. Williams, T.J., Proceedings: Control Systems in the Pulp and Paper Industry, EUCEPA, Stockholm (1982), p.61,

4. Brewster, D.B., Pulp & Paper Canada, 84:10 (1983), p.35.

5. Mardon, J., Vyse, R.N., Pulp & Paper Canada, 83:10 (1982), T289.

6. Brewster, D.B., Pulp & Paper Canada, 81:8 (1980), T177.

7. Judson, H.F., The Search for Solutions, Holt, Rinehart and Winston, New York, 1980.

8. Strom, U., PIMA (1979), Feb. p.34, Mar. p.15, Apr. p.15.

9. Anon., Tappi Journal, 65:12 (1982), p.37.

10. Horelli, J., Pulp & Paper, 57:2 (1983), p.121.

11. Rice, G.F., Fourie, A., Tappi Journal, 66:10 (1983), p.59.

12. Jervis, P., Physics in Technology, (July 1975), p.38.

13. Fadum, O-K., Pulp and Paper Journal, (April 1984), p.12.

A STRUCTURED APPROACH TO MILLWIDE AUTOMATION

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INTRODUCTION

Millwide automation is more of a philosophy than reality at this point in time. It can be thought of as a goal to strive for that will be implemented in a stepwise fashion over several years. Millwide automation, therefore, requires a top-down plan. This will assure that equipment and application packages purchased today will integrate together in the future and make millwide feasible. It will also assure that purchases are driven by needs rather than available technology.

Planning for millwide can be supported by tools such as structured analysis. A Mill Automation Plan (MAP) based on structured analysis has been developed by Fadum Enterprises for the pulp and paper industry. This method has several advantages. It focuses on a top-down structure where the top levels are suitable for presentation to management and the lower levels are suitable for implementation. The method supports both a hierarchical system architecture as well as a totally distributed system architecture. With the latter approach the hardware has no hierarchy, thereby making communications easier, and fewer computers are required. The information structure can, however, still be structured hierarchically as the manager's information needs are different than those of the operator. Alternately the MAP approach supports a mixture of distributed control and hierarchical control.

The reason for developing the mill automation plan was to come up with a formalized way that would give a mill several choices in configuring their control system. Up until now, the only available method has been the hierarchical hardware and software structure as proposed by T.J. Williams and P. Uronen (Purdue Report No. 111). The MAP encompasses this as one of its configurations but also offers several alternatives, especially in the configuration of the hardware.

The distributed (or network) architecture made possible through MAP is one of the most important alternatives to the hierarchical architecture. It is consistent with existing distributed control system offerings as well as emerging communication technologies that center around the use of a bus or a ring architecture. It is also consistent with new thinking in the area of organizational theory where there is a move towards distributed responsibilities (peer-to-peer) as compared to hierarchically defined responsibilities.

According to J.Naisbitt in Megatrends, "There are three fundamental reasons why networks have emerged as a critical social form now: (1) the death of traditional structures, (2) the din of information overload, and (3) the past failure of hierarchies. -- the hierarchial method that was so effective in the past is no longer workable, in part because it lacks the horizontal linkages ---In the future, institutions will be organized according to a management system based on the networking model ---In an information economy, rigid hierarchical structures slow down the information flow - just when greater speed and more flexibility are critically needed."

T.J. Peters and R.H. Waterman treat this same subject in "In Search of Excellence" as follows: "The military metaphor (hierarchical organizations) is a bad choice because people solve problems by analogy, and as long as they use the military analogue, 'it forces people to entertain a very limited set of solutions to solve any problem and a very limited set of ways to organize themselves'."

It should be noted that the hierarchical organization will not disappear but rather that it will be changing and that from a computer hardware/software architecture that we need alternative choices in structuring the best millwide automation plans.

Another important feature of MAP is that it defines the information and control needs of the mill before the hardware and the software architecture is "overlaid" to meet these needs. This also solves the problem of "missing levels" that occur with a formalized hierarchy.

THE MILL AUTOMATION PLAN

Structured analysis has been widely used in the data processing field to define software projects (Ref. 1,2). Recently it has also been used by several of the control system suppliers as a tool for system development. Several paper companies have also used the method and then primarily to define software projects. Fadum Enterprises has used this method to define mill automation plans that meet the user's needs.

The benefits of the mill automation plan (MAP) are as follows:

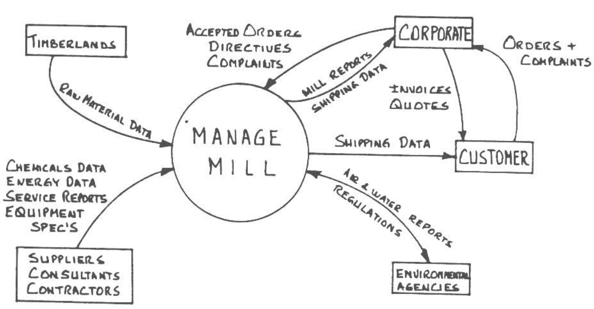
1) It is a graphic procedure which makes it easy to discuss and agree on (walkthroughs). Graphics make it easy to detect errors and reduce or eliminate wordy specifications.
2) The top-down approach makes the top layers easy to present to management whereas the bottom layers can be used for implementation.
3) Millwide automation can be divided into manageable segments for implementation over time. In addition to defining the segments, the technique also defines the communications between the various segments.

4) The method is implementation-free, which means that it can support various suppliers and technologies as they change over time.
5) The method is concise and eliminates redundancy which makes modifications easy.
6) A network orientation reflects the general structure of a mill with its production units and product flows.
7) Information flows as well as control flows are shown.
8) Supports both a hierarchical and a totally distributed architecture as well as a combination of the two.
9) Defines mill information and control needs before the hardware architecture is overlayed.
10) Defines the data bases, their location and interaction.

A MAP FOR AN INTEGRATED PULP AND PAPER MILL

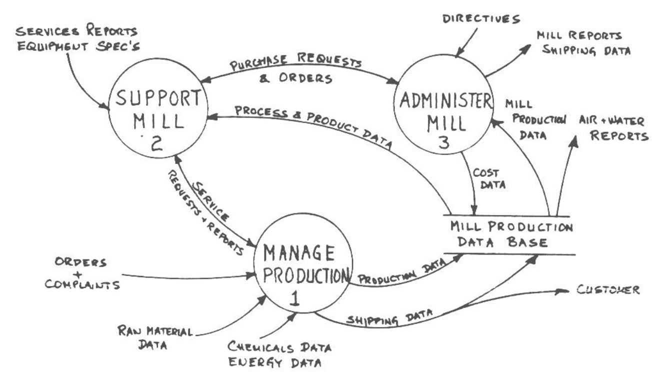
The analysis starts with an overview of the area to be investigated such as Manage Mill (Fig. 1). This is shown as a circle on the CONTEXT DIAGRAM with interacting areas such as corporate, customer, timberlands, environmental agencies, as well as suppliers, consultants and contractors shown in square blocks, meaning they are outside the scope of study. The lines drawn between the various functions (shown as circles) represent information flows. This is why these diagrams are often referred to as data flow diagrams. The reason for starting at the Manage Mill level is to trace the order as it is received from the customer at the corporate offices through to when the finished product is shipped to the customer from the mill.

FIG. 1 THE MILL AUTOMATION PLAN : "CONTEXT DIAGRAM"



The MANAGE MILL (Fig. 2) diagram shows the interaction between the three major functions such as (1.0) Manage Production, (2.0) Support Mill and (3.0) Administer Mill. The mill production data base is also shown. The Manage Production function can be thought of as Computer Aided Manufacturing (CAM), the Support Mill function as Computer Aided Engineering (CAE) or Computer Aided Technical Services (CATS), and finally the Administer Mill function as Manufacturing Resource Planning (MRP). The orders enter the Manage Production function where it is converted to shippable products. Also entering Manage Production is information relating to raw materials received as well as chemicals, energy and equipment. Work orders and requests are sent to the Support Mill function and a record is kept of maintenance performed as well as services rendered. Information is also sent to the Mill Production Data Base relative to production rates, inventories and shipped products. The Support Mill function consists of maintenance, engineering and technical services. This support function generates the requests for purchases and receives purchase orders from the Administer Mill function. The Administer Mill function receives directives from the corporate office and sends information relative to mill operations back.

FIG. 2 THE MILL AUTOMATION PLAN : "MANAGE MILL" 0.0



The MANAGE PRODUCTION (Fig. 3) function can further be broken down into Manage Paper Mill (1.1), Manage Pulp Mill (1.2) and Manage Power House (1.3). (For simplicity the Environmental Area has not been shown.) The Manage Paper Mill receives the orders and provides information relative to orders shipped. The production and quality demands are sent to the pulp mill who sends back information relative to the actual values on production rates and quality. The paper mill production schedule is also sent to the power house. The Manage Pulp Mill receives information relative to incoming raw materials, chemicals and energy. It provides information relative to waste water amount and quality. It also sends information relative to the pulp mill production schedule to the power house to minimize upsets. The Manage Power House function receives information relative to incoming energy amounts and quality. It also keeps track of energy consumption in the pulp and paper mill.