Today’s paper industry depends on a long integrated supply chain, starting in the forest and ending as products consumers use every day. The lead time across this supply chain is typically long and involves many steps performed by several companies. Knitting together manufacturing information that tells the true picture of product cost is complex and many gaps remain. This article will help the reader understand how the large amount of unutilized data can be used to make timely decisions and reduce overall variable costs across his value chain.

Three case studies are included to illustrate different operational tactics to increase profitability. Pulp mills, paper mills, power producers, and converting operations can all leverage and share information captured by their real-time data systems to reduce manufacturing costs, increase energy efficiencies, and achieve business objectives.

INTRODUCTION

The paper industry plays a significant role in both the North American and the world economies. According to the 2000 Paper and Forest Products Industry Survey, this sector’s global annual revenue from sales of over 300 million tons of products exceeds 500 billion U.S. dollars, over one-third of which is attributable to the U.S. and Canada [9]. Paper manufacturing plays a critical role in the local economies of virtually all regions of the United States and Canada; yet during the last 15 to 20 years, the industry has been overcome with economic and financial problems that these companies have found difficult to address. Among these chronic problems are over-capacity, weak prices, low profit margins, strict environmental regulations, high energy prices, and overall deteriorating shareholder value. Faced with growing competition on many fronts, the North American paper industry has tried to respond with redoubled efforts to achieve greater economies of scale—a strategy that relies on major capital investments that tend to compound the industry’s problems of over-capacity and weak pricing. Even the wave of mergers and acquisitions over the last decade, coupled with the synergies they have provided, have not yielded the levels of profitability realized in other basic materials industries. In a CPBIS Pulp and Paper March 2008 magazine article entitled “Lessons from the Past” [7], the author Jacquelyn McNutt succinctly summarizes what critics say about the paper industry. “The industry is mature, capital-intensive, extremely cyclical, seriously affected with failing performance and returns, monolithic, and slow to change. Substantive assets are underutilized and under-performing. Leadership seems largely to lack adequate vision, innovative thinking, and a good solid understanding about the character of value.”

BIG DATA

The amount of data in our world has been exploding, and analyzing large data sets, so-called “big data,” has become a key basis of competition, underpinning new waves of productivity growth, innovation, and consumer surplus. Increases in employee performance in manufacturing resulting from thorough use of plant information range from 5% to 24% [1] [4], depending on the source of the study. Plant data are typically collected and stored across pulp and paper manufacturing and converting operations to give operators and managers insight leading to action across their operations. Insight: the ability to see clearly and intuitively into the nature of a complex situation and the power to discern the true nature of a situation. Action: the ability to achieve a purpose or a goal and the power to redirect and control the outcome.

With the advent of mill process historians, ERP systems, MES systems, and access to data outside the traditional supply chain, corporate-wide information has gone from scarce to superabundant. That brings huge new benefits, but also big headaches, hence the “big data” dilemma.

As defined by McKinsey Global Institute (MGI) in their 2011 report, “Big Data: The next frontier for innovation, competition, and productivity” [4], the term “big data” refers to data sets of a size beyond the ability of typical warehouse database software tools to capture, store, manage, and analyze. A typical mill archives event
data at a rate of 100,000 events per second. With an event data size of 16 bytes, this means that approximately 10 terabytes are captured every 72 days. This is the very definition of “big data” and recurs five to six or more times per year.

One 2011 report from the Corporate Executive Board (CEB) [3] concluded that most employees struggle to apply judgment to data. Their survey of 5000 employees at 22 global companies showed that only 38% of employees (and 50% of senior managers) have the ability to make good decisions based on data, 19% of the employees seldom trusted data and made decisions unilaterally, and the remaining 43% were “unquestioning empiricists who trusted data over judgment.” According to CEB’s findings, most employees are now considered “knowledge workers” and spend on average 36% of their time collecting and analyzing information. Corporate IT should be strategically involved in translating mill-wide data into actionable information. However, IT tends to invest in tools to provide business intelligence about customers and suppliers that does not necessarily profit the business. When corporate IT does not engage with mill operations, their data set is limited to enterprise and transactional data. Moreover, the primary focus of mill IT is limited to hardware and software infrastructure. Somehow, “ownership” of operational data too often remains in the hands of process engineering, and the data are never linked to or integrated with the mill’s balance sheet, except at the order header level.

CEB’s statistics further showed that half of employees found that information was in formats that they could not use, and two-thirds reported spending time on unproductive data analysis. Of all the information in a company, approximately 85% is unstructured, and much is unusable. However, the most important quantitative finding was CEB’s conclusion that overcoming the data insight deficit had a significant economic payoff: employees with the highest data insight ability performed, on average, 24% better than their peers across a wide range of metrics, including effectiveness, productivity, employee engagement, and market share growth [3]. In an MIT Center for Digital Business document entitled “How Does Data-Driven Decision-Making (DDD) Affect Firm Performance?” [1], the authors calculated that firms that adopt DDD realize a 5%–6% improvement in productivity because of their investment in and use of technology. They modeled this improvement as follows:

\[ MV = \sum_{i=1}^{n} A_i + DDD \times A_i \]

where MV is the market value of the financial claims of the firm represented by the sum of each of its n assets (A) plus DDD (an index with a mean of 0 and a variance of 1) times A (assets). The authors found that DDD is most highly correlated with market value when it is “scaled by a company’s IT employment,” yet one can argue that DDD is also related to IT spending as a percentage of company revenue. The consistent conclusion among those who study and document the benefits of real-time data use in manufacturing is that using informed actionable data positively impacts a company’s bottom line.

The increasing volume and detail of information captured by enterprises, coupled with the inter-company communication required by the commerce of the future, will help fuel exponential growth in data collection for the foreseeable future. According to the MGI report [4], the use of big data will become a key basis of competition and growth for individual manufacturing companies. Gains in profitability will come from improved operational efficiency, improvements in product quality, and ability to meet customer needs better through more precisely targeted products and effective promotion and distribution. “From the standpoint of competitiveness and potential value, all companies need to take big data seriously. In most industries, established competitors and new entrants alike will leverage data-driven strategies to innovate, compete, and capture value from deep and up-to-real-time information.” One example MGI provided of “big data” in manufacturing was the increase in “sensor-driven operations.” MGI calls sensors and devices embedded in the physical world and connected by networks to computing resources “the Internet of Things.” The proliferation of manufacturing sensors in this Internet of Things enables manufacturers to optimize operations by embedding real-time, highly granular data from networked sensors in the supply chain and in production processes. These data enable process control and optimization tools to reduce waste and to maximize yield or throughput. Pulp and paper companies with connectivity to a myriad of sensors and control devices are typically storing this real-time data in vast process data historians at very high resolution. However, until these data can be put into a meaningful context, they have little measurable value in their raw form.

Because a proliferation of data already exists today across most paper industry supply chains, locked away in several different data stores, companies that can leverage this data into actionable information with easy access across their information landscape will benefit the most from the data explosion. Value-chain optimization, as seen in Fig. 1, will occur only when raw data are readied for seamless access across many platforms and protocols. Real-time information systems that cannot only store real-time process data, but also unite these data with external mill sources without duplicating these other data sets will prove to be the most efficient data stores for maintainable and extensible information use.

Paper industry critics from financial institutions, consultant services, shareholder groups, customers, government agencies, and environmentalist organizations often give advice on efficient manufacturing practices that is too simplistic and fundamentally contradictory. Too often, the advice or regulation imposed is ignorant of the process understanding that can be derived from the mill’s real-time data store. Take, for instance,
environmental regulations. The relationship between environmental regulations and paper-industry competitiveness has normally been thought of as a trade-off between social benefits and industrial expenditure. However, effective use of mill data can reveal that under certain conditions, process efficiency gains can also be used to reduce emissions. Uninformed advice lacks meaningful and workable recommendations for sustainable, measurable performance improvements.

The paper "value chain" grows as biorefining, co-generation, and fluctuating product demand give paper companies many options for routing materials and energy. The information value chain also grows to encompass the sum total of the real-time data existing across these environments, such as products being manufactured, raw material consumptions, energy consumptions, line speeds, and tons produced. Some of the variables needed to turn data into information are cost of power, cost of raw materials, selling price of manufactured product, and lost time on the production line. The goal of value-based manufacturing is to collect as much of these data as economically possible across the supply chain (without getting lost in the "weeds") and to use them to make actionable decisions to maximize profits while reaching quality and production targets. Paper companies can leverage information captured in their real-time data store to accelerate and sustain improvement initiatives and to achieve business objectives.

To transform the traditional business model of the paper industry and to create new opportunities for profitability, companies must leverage process information across their supply chain. They must seek new ways to use their vast data stores to have a positive impact on their bottom line.

**QUANTIFYING THE VALUE-CHAIN DILEMMA**

In a February 2008 *PaperWeek* presentation [8], Jacquelyn McNutt reported that the paper industry’s return on capital is less than 5%, while its cost of capital is around 12%. Investors shy away from an industry where stocks have gone nowhere in almost two decades and where technology advancements are almost nonexistent. A new integrated mill has not been built in North America in 15 years, yet a new mill comes on-line elsewhere in the world almost every month. Many pulp and paper mills are small and old and have not benefited from the capital expenditure required to modernize them to compete with more modern mills coming on-line in other parts of the world. However, the possibility still exists for the North American pulp and paper industry to turn itself around. North America has stable governments, sustainable forestry practices, and a large source of economical fibre. It also leads in most areas of computerization and information technology. North Americans are on the forefront of implementing new concepts such as forest biorefining and nanotechnology for cellulose fibre manufacturing. Therefore, the strategy to balance existing profit margins, keeping variable costs low while also reacting to fluctuating consumer demand, may be locked away in the supply-chain data store. Acting on information to maximize profitability is a major component of value-chain optimization. The ability to collect and see variable costs in real time and to react by making process changes that reduce costs will play a key role in industry sustainability.

CIRRELT, the Interuniversity Research Center on Enterprise Networks, Logistics, and Transportation at Laval University [2], has proposed the concept of the paper industry supply chain shown in Fig. 2.

1. How much profit did I make shipping Order 123 to the customer today?
2. Is my cost of manufacturing for Product ABC less in my mill in Maine or in Quebec?
3. Should I burn wood or make pulp this month?
4. Should I run my paper machine at capacity tonight or curtail production and sell electricity back to the power grid?
The cost of paper can vary by hundreds of dollars depending on the economics of process decision-making (especially to avert paper machine lost time or when trying to maintain export orders), any real-time decision supported by timely information can conceivably impact profitability, saving or generating millions of dollars over the course of a year. We call this flexibility “value creation.” Emerging economies’ huge appetite for commodity pulp plus rising shipping costs (energy) places the North American paper industry in an unprecedented situation. It is now more expensive to import many types of finished paper products from Europe and Asia than to manufacture them domestically. These two facts provide the impetus for North American manufacturers to be creative in acting on value-chain information. The following case studies show examples of how some North American paper companies have profited from data in a downturn economy by focusing on areas where improvement is possible.

**CASE STUDIES #1 & #2:**

**Optimizing Boiler Usage Translates into Optimizing Profit, a.k.a. “Buy Low, Sell High”**

Although many paper companies balance their steam and electrical generation with purchased power from the grid, two companies actually stand out in this area: Papiers White Birch in Quebec City QC and Smart Papers in Hamilton OH. Both these companies were able to operate several years beyond their predictable life by using data to optimize profitability. Although both paper companies have recently closed, their data model for profitability is considered by many to have been transformational in the paper industry.

In a PaperWeek Canada presentation in 2011 [5], Papiers White Birch told the story of how they used millwide data for decision support to reduce overall energy costs across the entire mill complex. The story started...
with the conversion of a boiler to waste sludge biomass in 2006, which increased the complexity of operational steam balancing. Operators who were tasked with making steam production decisions lacked timely information about the cost of fuel and the interaction of the various boilers. Company engineers created a simple data model of their thermal power plant operations, taking into account the various economic factors. The result was a control-room display that showed the operators the real-time costs of steam, taking into account the various economic factors. The result was a control-room display that showed the operators the real-time costs of steam, taking into account the various economic factors.

- The cost of the various fuels (bark, natural gas, oil)
- The cost of sludge disposal (de-inked, processing secondary sludge)
- The cost of purchasing steam.

Normally, when production of steam decreased, another boiler had to be started to compensate for the loss. Without real-time cost measurements, operators were frequently maintaining the production of steam at a cost higher than the sale price of containerboard rather than curtailing production on the board machine. Data, once locked away in a mill-wide real-time database, were used to establish a basis for comparison between the costs of use of the biomass boiler and the purchase price of steam from the City of Quebec. This historical use served as a basis to renegotiate the steam purchase contract with the Quebec City Incinerator and to strike a balance between the costs of sludge disposal and the minimum cost of using the biomass boiler to burn the sludge. This approach enabled Papiers White Birch to operate at its minimum production threshold in the winter, even though this created a negative impact on the efficiency of board machine operation. Measuring all flow rates and converting them into their equivalent dollar amount enabled easy comparison of the cost per ton of paper and the cost of steam production. This “Apples with Apples” approach uses real-time data to drive additional awareness of tangible production cost reductions and to give operators real-time cost information, enabling them to make quick, cost-effective decisions.

Another example of turning data into action centres on a former Champion Paper mill in Hamilton, Ohio [6]. Champion closed this mill, but it was resurrected in 2006 by an investment firm both as a profitable power company and as a paper company. To “split” industry allegiance within a single operating environment took some innovative thinking about value-chain optimization. Smart Paper Holdings, LLC, consisted of two distinct operating units: Smart Paper and Smart Power. Although Smart Paper closed its doors at the end of 2011, the power side of the business will likely remain in operation, although its paper brands and production facilities have been sold to another manufacturer.

Smart Paper Holdings found value in marketing electricity produced by its two coal-fired boilers to the Midwest electric utility grid. Smart was on the cutting edge of a concept that puts smaller pockets of electricity generation closer to where the power is needed, as shown in Fig. 3. Advocates say that this approach, known as distributed generation, takes stress off transmission and distribution lines and puts additional electricity supplies near where they are needed. Although many paper companies participate in active energy distribution, few actually license their powerhouse operations as permitted smart-grid electrical distribution facilities.

![Fig. 3 - The unique supply chain for Smart Paper Holdings, LLC (6).](image)

Smart actually established itself as a competitive energy supplier, actively monitoring price swings looking for opportunities to turn up its steam generators to produce more electricity to take advantage of price spikes.

“This concept gives us maximum control over our energy costs,” said Smart Paper’s COO, Dan Maheu. Because the Hamilton plant’s boilers burn lower-priced coal, this approach also gives the company the opportunity to make money off its electricity sales [6].

The plant used steam in the paper-making process. Some of the pressurized steam was piped across North B Street to two new electric turbines, from which the output could flow back across the street to Smart Paper’s plant, where it was used to power the paper-making machines, keep the lights on, and run the computers. The excess electrons flowed onto the grid through local transmission lines. The turbine operator in Smart Paper’s powerhouse not only monitored temperature and pressure data in the data historian, but also kept an eye on a computer screen which tracked current wholesale electric prices in five-minute increments across the Midwest using a data interface to the Web. A calculation produced the necessary information for operators to respond in a matter of minutes to changes in electricity prices with respect to boiler operations. When the price of electricity started to tick upward, the turbine operator told the boiler room to feed more coal into the plant’s steam boilers. This is yet another example of turning data into action across the supply chain.

**CASE STUDY #3:**

**Take and Make an Order or Not**

In an April 2007 Supply Chain edition of *Pulp and Paper Magazine* [10], Mike Paulin, a corporate business process engineer at Sappi Fine Paper North America, described his company’s experience with an information technology project to manage raw materials planning and costing. The project was implemented in 2007 to optimize their use of information technology and process control data from their corporate-wide data store to provide near-real-time information to operations on
Typically, the paper industry focuses on information technology projects that better integrate and optimize diverse systems. However, these projects often focus on the visibility of finished goods in the supply chain and have not taken full advantage of the capabilities for raw materials planning, consumption reporting, and real-time costing for paper products. Although finished goods are definitely a component of supply-chain cost, they are arguably not the highest variable cost. Sappi Fine Paper North America executed an IT optimization and reorganization effort called “Project Impact.” Project Impact integrated and optimized raw materials planning and costing with process control systems at the grade/basis weight/asset level, as depicted in Fig. 4. In addition, because of the “real-time” information derived from the product costing system, Sappi was able to take advantage of their ERP’s demand-based raw materials planning tool to automate the mill’s raw material reorder and delivery process. Sappi’s raw materials planning and costing project offered valuable lessons related to integrating its ERP and shop floor information systems, according to Paulin, business process engineer. Many of these lessons related to the following areas:

1. **Master data maintenance:** With any information system, particularly ERP systems with tight integration between modules, the data it provides are only as good as the data put in, says Paulin, and this calls for strict business procedures. “Our business procedures related to the system help us keep the master data maintained properly, so there are very specific steps about what is maintained, when it is done and by whom, as well as how to do that in the system,” Paulin explains. “We developed the procedures early on, but they’ve evolved as we learned through installing the systems and modules related to the project at the various mills.

If you don’t maintain the master data, the whole process falls apart.”

2. **Accuracy of the information stream:** When using the systems for planning and costing, Sappi discovered data in the information stream that were not accurate enough for what the process demanded. “In certain cases, the absolute numbers we were getting from shop floor instruments and how they were treated in the shop floor system weren’t giving us an accurate enough portrayal, so we’ve improved the quality of those data by fine-tuning some instrumentation and the calculations associated with it,” said Paulin.

3. **Bill of materials methodology:** Sappi discovered that its methodology for developing the standard bill of materials did not always provide an accurate portrayal of expected consumption. To improve the methodology, Sappi “tightened up the data stream.”

Comparing the raw materials budget
against actual consumption has helped mill personnel adjust the process to become more cost-effective. As an example, Paulin cited a reduction in the use of a very expensive chemical at one mill that removed several million dollars of production cost. “By isolating the costs for this chemical, the system helped us evaluate its cost impacts, leading to a process change,” he said.

Every paper grade has a distinct bill of materials (BOM). As with most paper companies, raw material consumption is posted daily or weekly as if the product were made exactly as the recipe read on the bill of materials. At month end, the consumptions are reconciled with actual or physical inventories, and the books are balanced. With a real-time costing method, actual process data flows are mapped to line items in the bill of materials and recorded at the end of each production run. The complexity of the raw material recording can be only as detailed as the bill of materials, meaning that if management wants to monitor water and electricity consumption by grade, then these items must also be on the grade recipe (or BOM). At the most detailed level, a company can gain complete visibility of their variable material costs to manufacture each grade. By adding the factor of process time shifts, such as high-density tank storage and bleaching retention times, a full profile of wood-to-paper can be mapped for near-real-time costing of paper manufacturing. By doing this, companies can readily decide which assets perform with more efficiency on certain grades and schedule accordingly. The findings for real-time product costing are not limited to these few examples; there are many additional process lessons that can be learned when companies use real-time mill data for decision-based support.

CONCLUSION: USE DATA, TAKE ACTION

Although economic pressures continue to wreak havoc on the forest product industry and its supply chain, companies can leverage a balance of culture, process, and information technology to transform their balance sheets. Similarly, across all process industries, a wealth of information can be found in collected data, just waiting to be leveraged.

In a 2001 OSIsoft User Conference presentation by Shell Global Solutions’ Manager of Statistics and Risk [11], David Stockhill used the example illustrated in Fig. 5 to illustrate how tank level data stored in their time-series process historian could be sorted statistically to provide a view of the data that was more convincing to accountants, who were working to provide a way to monitor and quantify all oil stock transfers and to derive monetary benefits from the ease of use of data in this format. Stockhill made three claims that are also applicable to any paper company anywhere:

- “We are in a data-dominated world – all parts of our business have information?• There is a clear change to a risk-based approach. For example, in plant maintenance, the days of rule-based activities are gone—the focus is now condition-based maintenance. We need decision support tools to help us decide when to maintain or service. This needs some statistical benchmarking and a framework.
- Capital expenditure is still tight. “Sweating the assets” is common jargon. Yet if we are really to understand the operation and behavior of our existing assets, then our prime window through which to observe them is via the process measurements and the historical records of plant performance.
His conclusion is to direct data analytic effort towards process historians and to look for reliable techniques to help analyze these data and to transform them into actionable information [11].

The paper industry value chain is a physical representation of the various processes involved in producing goods and services related to the sales and delivery of each intermediate component, starting with raw materials and ending with the delivered product. The information value chain is based on the notion that additive access to all stores of information at each manufacturing stage increases the value of total product information. When raw data are turned into operational efficiency metrics and then linked to actual financial performance, “data” become actionable.

Improving manufacturing performance on a continuous basis across the supply chain is a key business strategy for manufacturers in all industry sectors, not just the paper industry. Achieving high levels of value-chain efficiency requires a business model that is more flexible and more responsive to market changes than whatever the competition has. Paper companies that invest wisely in information technology to deliver value-chain improvements will excel in a competitive environment. Marginal ROI improvements can mean the difference between continuing to operate or shutting down a facility. Whether companies structure their utilities plant to buy or sell power to the electrical grid, or whether they use real-time information to report manufacturing grade costs accurately, marginal economics may be the life-line of the paper industry. Turning data into actionable information is a key component of paper supply-chain optimization.

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