AGILE MANUFACTURING: ENABLING OPTIMAL VALUE CHAIN MANAGEMENT THROUGH NEW PRODUCTION TECHNOLOGY

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ABSTRACT

Agile manufacturing is an operations management concept that brings flexible manufacturing, Just-In-Time inventory management, Total Quality Management and an overall customer focus in day-to-day operations. It has important implications for the choice of manufacturing technology. Business and financial justification for agile manufacturing has to include the value of agility (flexibility), and has to be based on the valuation of Real Options.

INTRODUCTION

Agile manufacturing consists of several operations management concepts launched in the last fifteen or twenty years. These concepts include Just-In-Time (JIT) inventory management, lean manufacturing, flexible manufacturing, and Total Quality Management (TQM). Agile manufacturing provides the operational and business tools to implement and take advantage of the business opportunities of electronic commerce. It has been developed to a large degree in the machinery industry, and the challenge for the paper industry is to apply its principles to the industry's technological and operational framework.

Agile manufacturing has an important impact in the choice of production technology. It places heavy emphasis on operational flexibility. Fast grade changes on the paper machine without large quantities of off-specification product are essential. Additionally, the paper machine has to have the ability to use a wide variety of raw materials in order to optimize the properties of the sheet, to minimize manufacturing costs, and to accommodate legal or client stipulations regarding the contents of the product.

A key challenge for paper manufacturers is to take right capital investment decisions. In a context of a changing competitive environment, societal values, law and production technology, the value of business and technological flexibility has to be considerable. This value of flexibility is not explicitly included in the commonly used capital budgeting decision-making tools, for instance, Internal Rate of Return (IRR), Net Present Value (NPV) and their derivatives. The Real Options Theory (ROT) provides here a robust quantitative and qualitative framework to assess the value of flexibility.

TECHNOLOGY AND COST COMPETITIVENESS OF THE NORTH AMERICAN WCC PAPER INDUSTRY

The need for agile manufacturing is underscored by the North American coated papers producers' have clearly lower production capacities than their European counterparts, see **Table 1**. In the case of commodity woodfree coated (WFC) grades, the European paper machines have a 76% higher production capacity, and in the case of the commodity wood containing coated (WCC) grades it is 49% higher.

	North America	Europe
WFC	90,000	158,000
WCC	104,000	155,000

Table 1. Average production capacity of North American and European WCC and WFC machines in 1998 (in FMT per annum).

The main reason for this are the higher design speeds of the European WFC (**Table 2**) and WCC machines (**Table 3**). This means that the European producers have a potential competitive advantage in all costs dependent on the number of paper machines rather than their size, e.g., labour costs.

	North America	Europe	Difference
Trim Width (cm)	429	465	+8.39%
Design Speed (m/min)	588	864	+46.9%
Capacity (FMT/year)	90,000	158,000	+75.6%
Productivity (FMT/d/cm)	0.59	0.85	+44.1%

Table 2. Average paper machine productivity and dimensions of WFC paper machines in Europe and North America in 1998.

	North America	Europe	Difference
Trim Width (cm)	508	585	+15.2%
Design Speed (m/min)	784	1051	+34.1%
Capacity (FMT/year)	104,000	155,000	+49.0%
Productivity (FMT/d/cm)	0.57	0.70	+22.8%

Table 3. Average paper machine productivity and dimensions of WCC paper machines in Europe and North America in 1998.

The larger production capacity, higher design speed and greater trim width of the European WFC and WCC paper machines have an important implication for the installation of new production technology: It is easier to justify new technology. The installation of a shoe press increasing the sheet solids level from 45% to 50% going into the dryer section does not cost as much per FMT per annum on a large paper machine than on a smaller machine. There are two main reasons for this. First, the full investment cost of the show press does not rise are rapidly as the paper machine's speed and trim width. Second, newer machines may have been designed to allow for the installation of new unit operations.

A higher production capacity paper machine has therefore a valuable real option, i.e., it is easier to justify an investment of new technology that reduces cash manufacturing costs. Consequently, the installation of other technological innovations later that further reduce the cost on the larger paper machine thus increasing the gap between newer and older paper machines. In other words, a higher production capacity paper machine may have more (future) technological flexibility.

Labour costs are clearly lower among the European mills producing WFC (**Table 4**) and WCC (**Table 5**) paper grades than among their North American counterparts. This is a function of the wider and faster European paper machines, but recovery after breaks is usually faster among the European producers as well.

	North America	Europe	Difference
Fibre	211	242	+31
Chemicals + Fillers	151	137	-14
Fuel	43	49	+6
Electricity	13	14	+1
Labour	133	81	-52
Other	74	57	-17
Total	625	580	-45

Table 4. Major cost components in WFC production (in US$/FMT) in 1998.

	North America	Europe	Difference
Fibre	140	213	+73
Chemicals + Fillers	153	110	-43
Fuel	26	22	-4
Electricity	39	44	+5
Labour	150	77	-73
Other	74	53	-21
Total	583	518	-65

Table 5. Major cost components in LWC production (in US$/FMT) in 1998.

These two tables show that the North American mills have a fibre cost advantage. For the time being, the vertically integrated mills have a cash manufacturing cost advantage (although the costs associated with distribution logistics may change this), and the North American mills are more vertically integrated than their European counterparts (**Tables 6** and **7**). The term "vertical

integration" is here reserved for integration at the same site of a chemical pulping operation and a papermaking operation owned and operated by the same company. From the standpoint of raw material agility, and the optimization of the papermaking furnish a grade, vertical integration may be a drawback, because it may limit the paper mill's factual degrees of freedom to use the optimal fibre rather than the internally produced one.

	North America	Europe
BSKP	19%	8%
Purchased BSKP	11%	30%
BHKP	37%	10%
Purchased BHKP	14%	22%
Bleached Sulfite Pulp	0%	13%
PGW + SGW	0%	4%
TMP + RMP et al.	0%	0%
Recycled Fibre	6%	1%
Fillers	12%	12%

Table 6. Production capacity weighted average WFC furnishes in North America and Europe in 1998.

	North America	Europe
BSKP	20%	5%
Purchased BSKP	17%	38%
BHKP	2%	0%
Purchased BHKP	2%	0%
Bleached Sulfite Pulp	2%	1%
PGW + SGW	31%	26%
TMP + RMP et al.	15%	19%
Recycled Fibre	1%	3%
Fillers	10%	8%

Table 7. Production capacity weighted average WCC furnishes in North America and Europe in 1998.

The value of the (real) option of buying or not buying pulp from the vertically integrated chemical pulp mill should be determined as well. The result of this analysis will partially depend on the assumed friction factor associated with switching from buying from a company internal supplier to another supplier. This again depends on the chemical pulping operations ability to find and sell to other clients, e.g., does the pulp mill have a pulp dryer? Additionally, the management strategies and systems adopted by the company may influence the severity of this friction.

Considering the cash manufacturing cost advantage of the European producers, do they have a competitive advantage in the North American markets? The delivered cash costs for North American and European mills to Chicago were estimated, a major market for coated papers in North America. The results show for both WFC (**Figure 1**) and WCC (**Figure 2**) grades that several European mills could mount a strong challenge to the North American coated papers industry in the Chicago market. Today and in the future, this challenge could be even more

formidable, because several new paper machines were not included in this analysis, e.g., Haindl's new LWC machine in Augsburg and Cartiere Burgo's LWC machine in Verzuolo. Additionally, the U.S. dollar has appreciated against the Euro in the last year.

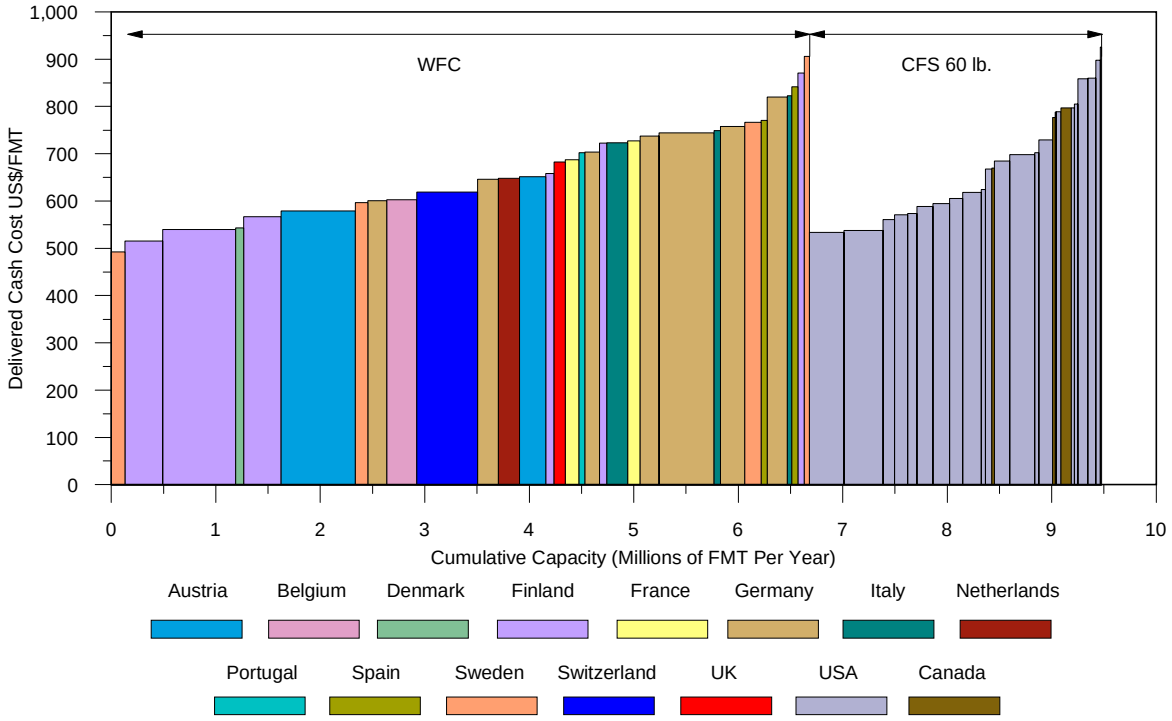


Figure 1. Combined cash manufacturing and transportation costs of North American and European WFC producers in Chicago in 1998.

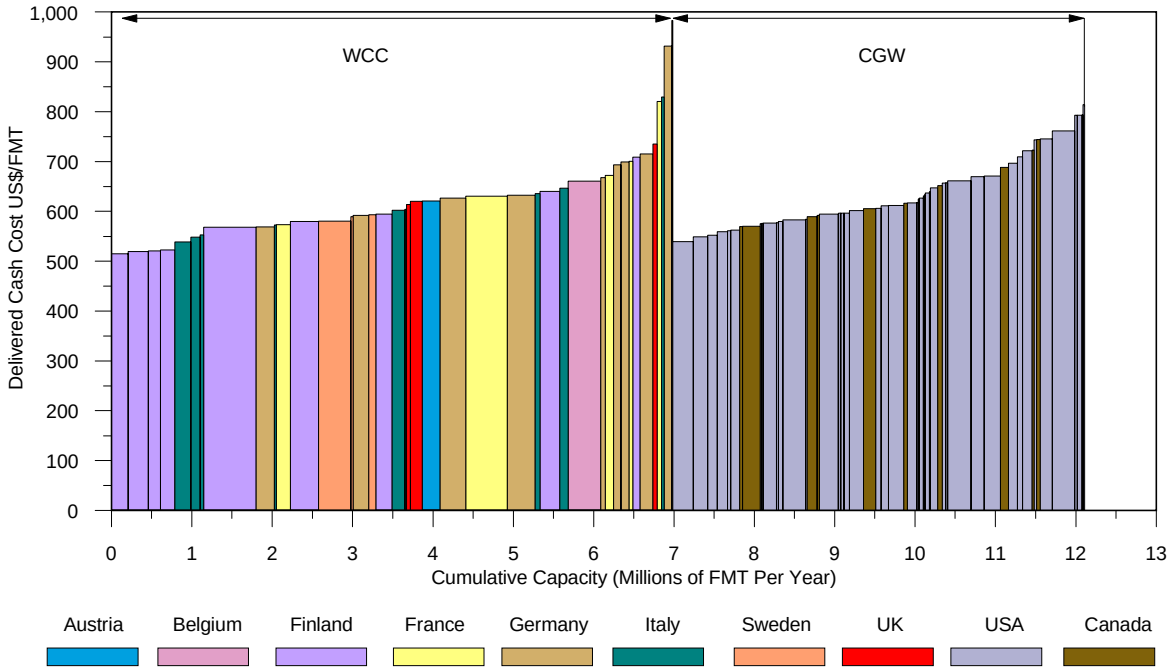


Figure 2. Combined cash manufacturing and transportation costs in the Chicago market for all WCC grades (in US$/FMT) in 1998.

AGILE MANUFACTURING CONCEPT AND ENABLING TECHNOLOGY

The North American WFC and WCC industries are facing the potential of stiff competition from European producers in North America. Occasionally, a company may need to supply both the European and the North American markets after starting up a new coated papers machine, because the sudden increase in annual supply by roughly 500,000 FMT could cause severe interruptions in the market place.

Supplying markets with different specifications for similar paper grades requires that the WFC/WCC machine is capable of producing a wider range of paper grades with different properties and from different papermaking furnishes. This requires operational agility. Simultaneously, the increasing importance of home office laser and ink-jet printers along with digital printing raises the spectre of diverging specification from users and manufacturers of printers in terms the sheet's physical strength, absorption and optical properties. Again, this would require that a paper machine is capable of producing a wide(r) range of paper grades, i.e., it has a high(er) level of operational agility.

These goals of operational agility and economies of scale are not necessarily mutually exclusive. Using design criteria taking the requirements of agile manufacturing into account may result in large paper machines becoming (more) agile, i.e., less specialized.

In an agile value chain, the customer is fully integrated into the production, design and development of the product and service (Boutellier[1]). In the literature, the need for agility in terms of the customer is generally stressed, but agility vis-à-vis the raw material supply is also important. Designing the production facility and the value chain in such a way that the technological and cost potential of the raw materials are fully leveraged thus adding value to the facility's value chain partners and customers.

The principles of agility include the following aspects (Oleson[2]):

- *Value Chain Management*: The value chain has to satisfy the customer's needs, wishes and preferences. The value chain includes all the providers of materials, equipment and services that are part or determine the product's properties, its production and development. The flow of materials and products on the one side, and the flow of information for operations management purposes on the other hand, are usually counter current.
- *Production Capability*: The production facility is capable of producing customized products at low volumes without losing the *economies of scale*. This is often referred to as *mass customization*. This means that the production facility and the different unit operations have to be designed in such a way that switching between production runs can occur without time, material and economic loss, i.e., the amount of transition product is minimized. For instance, the equipment chosen for a press section may have to produce paper grades with different bulk levels requiring the agility to vary the nip pressure considerably.
- *Automation*: The reduction of transition product makes the use of process automation is necessary, because it may allow for optimization of the process from production run-to-production run. This requires first rate instrumentation (on-line gauges, analyzers, scanners, etc.) and software. The in-depth knowledge of the papermaking process is critical for the successful development and implementation of process automation.
- *Information Systems*: Whereas automation deals with the internal papermaking process, information systems are required for real time information flow between the various parts of the value chain. Having real time information allows faster execution of production, process

and product development, and the reduction in cost by more efficient inventory management throughout the value chain, and by the improved co-ordination of the activities of the different parts of the value chain.

Incorporating operational agility into a coated papers machine may increase the capital investment requirements. In a world with standardized paper grades being sold at huge quantities, spending the additional money would make only sense, if several paper grades have different pricing cycles. However, agile manufacturing opens up the potential of two other business benefits: More stable business relationships and increased raw material flexibility.

The Real Options theory is a powerful tool in identifying and quantifying the benefits and drawbacks of capital investments in increased operational flexibility. This theory draws both from the valuation of financial options and from game theory.

REAL OPTIONS THEORY AND APPLICATIONS

Making major capital investment decisions is arguably one of the most important strategic decision-making situations in the paper industry because of the industry's high capital intensity. Using the right analytical tools is therefore of utmost importance in order to avoid poor decision-making.

Modern corporate finance theory favours Discounted Cash Flow (DCF) -based criteria, the most important of them being the Net Present Value (NPV) rule. It is based on three key assumptions (Brealey[3]):

1. *Time Value of Money*: An amount today is worth more than the same amount tomorrow, because it can start earning risk free returns immediately.
2. *Forecasted Cash Flows and Cost of Capital*: The NPV rule looks only at the proposed projects, their cash flows and the cost of capital at a rate reflecting the risk of a project.
3. *Additivity*: The results of an NPV analysis are expressed in today's monetary value and can therefore be added up.

It has to be added here that having the NPV for all projects under consideration helps in comparing them. The NPV rule may be expressed mathematically as:

$$NPV = C_0 + \Sigma (C_t / (1 + r_t)^t \qquad (1)$$

where C_0 is the initial investment (out flowing money is negative, inflowing positive)
C_t is a cash flow at the point of time t
r_t is the risk-adjusted discount rate

A common mistake made in evaluating capital investment projects is that the investing company's average cost of capital is being used. This contradicts the second assumption presented above. Instead, the risk-adjusted discount rate has to be arrived at based on the projects riskiness, which may be substantially different from the company's average cost of capital.

The word "risk" has been used frequently above. The risk may be associated with (Finnerty[4]) no completion of the project, technology, raw material supply, economic factors, currency

fluctuations, political factors, environmental issues, and *force majeure*. However, higher risk means the potential of a higher profit in a risk neutral setting. The NPV rule requires for a riskier project a higher discount rate.

Risks pose opportunities as well (Amram[5]). Every one risk may be considered a business opportunity for a producer who is agile (flexible) enough to take advantage of it, assuming that an investment has or is being made, and that it is irreversible. Brekke[6] points out that "[w]hen investments are irreversible and the economic environment is stochastic, the option value of maintaining flexibility is important."

Although the NPV rule allows for the comparison of different capital investment alternatives, it has a major weakness in not taking the synergy effects of two or more capital investments into account. To quote Trigeorgis[7]: "... the basic inadequacy of the NPV approach and other DCF approaches to capital budgeting is that they ignore, or cannot properly capture, management's flexibility to adapt and revise later decisions (i.e., review its implicit operating strategy)."

Building on Castelo's[8] analysis of first investor advantages, a second investor is more cautious the greater the investment (or capital intensity) and the lower the first investor's unit production costs. As seen earlier in this paper, the European producers of coated papers have lower cash manufacturing costs thus discouraging investments in North America. This is particularly true in times of an overvalued U.S. dollar vis-à-vis the Euro based on the Purchasing Power Parity.

A paper machine that has to be agile to be rebuilt using emerging best available technology and to satisfy emerging business trends, has an in-built additional value compared to a machine that can produce one product. Technological agility means that:

- *Paper Machine Design*: In the design of a paper machine steps are taken to allow for cheaper paper machine rebuilds without loss of runnability. For instance, this involves avoiding cramped spaces which would increase the cost of adding new equipment or modifying existing equipment. A paper machine designed for technological change would therefore have a valuable option included.
- *Paper Machine Size*: The size of the paper machine is an important factor in the performing the financial justification of a paper machine rebuild, because the cost of the rebuild is compared against the (increased) cash flow generated by it. If the cost of the rebuild increases more slowly than the incoming cash flow due to the rebuild, a larger and/or faster paper machine has an advantage. An analogy here is Lambrecht's[9] analysis of patent exploitation, because the existing capital investment like a paid fee that is a financial incentive to use its full potential for revenue generation (the bigger the investment, the bigger the incentive). This potential in the case of a new paper machine is to reduce its variable costs. (These are important factors in explaining why the European paper producers are able to justify major paper machine rebuilds and the installation of new papermaking technology whereas the North American producers are not.)

A Real Options analysis requires thus that all the potential technological, regulatory and other risks (opportunities) are qualitatively identified and quantified. This may require the use of a wide range of research methodologies, e.g., the Delphi Method. It is critical for the reliability of the analysis that it is performed in such a way that the technological, regulatory, social and other factors affecting the coated papers industry are constantly kept in mind.

CONCLUSIONS

Agile manufacturing allows a production facility to produce a wide range of products, or in the case of the paper industry, a wide range of paper grades. This may be important in order to maximize the company's client relationships and marketing in markets with different customer specifications. Furthermore, increased agility may be required because of the rapid growth in the number of printing facilities, both at home in the form of home office printers and at facilities using digital printing. This fragmentation of printing may result in the fragmentation of product/grade specifications.

The traditional capital budgeting decision-making rules (e.g., NPV and IRR) do not take into account the value of operational flexibility (agility). The Real Options theory offers a robust qualitative and quantitative framework for the analysis of the sources and value of operational agility. Capital budgeting should take this value into account.

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[1] Boutellier, R., Schuh, G., Seghezzi, H., in Komplexität und Agilität (G. Schuh, H. Wiendahl, Eds.), Springer, Berlin, 1997, pp. 37-64.

[2] Oleson, J., Pathways to Agility, John Wiley & Sons, New York, 1998, pp. 47-129.

[3] Brealey, R. A. and Myers, S. C., Principles of Corporate Finance, McGraw-Hill, 1991, pp. 73-94.

[4] Finnerty, J. D., Project Financing, John Wiley & Sons, 1996, pp. 34-52.

[5] Amram, M., and Kulatilaka, N., Real Options, Harvard Business School Press, 1999, pp. 29-45.

[6] Brekke, K. A. and Schieldrop, B. in Project Flexibility, Agency, and Competition (M.J. Brennan and L. Trigeorgis, Eds.),Oxford University Press, 2000, pp. 34-49.

[7] Trigeorgis, L., Real Options, The MIT Press, Cambridge, 1999, pp. 121-150.

[8] Castelo Joaquin, D., Butler, K.C., in Project Flexibility, Agency, and Competition (M.J. Brennan and L. Trigeorgis, Eds.), Oxford University Press, 2000, pp. 324-339.

[9] Lambrecht, B., in Project Flexibility, Agency, and Competition (M.J. Brennan and L. Trigeorgis, Eds.), Oxford University Press, 2000, pp. 297-323.

Received: June 8, 2000
Accepted: June 14, 2000

This paper was accepted for abstracting and publication in the December 2000 issue of *TAPPI JOURNAL*.

TAPPI Website: www.tappi.org