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KSH CONSULTING
A CONSULTING CONCEPT

**FURNISH DESIGN AND
COSTS OPTIMISATION**

KSH
Consulting



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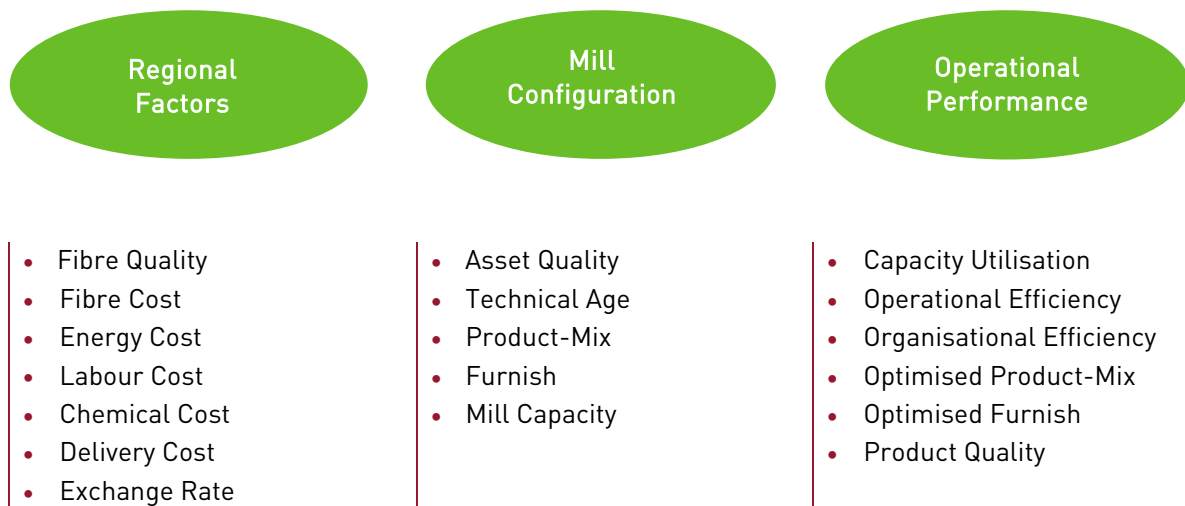
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BACKGROUND

Three main drivers have an impact on cost performance: regional factors, mill configuration and operational performance (Figure 1). Regional factors typically determine 15% to 25% of the cost variability between different operations. However, a company has little control on it since it is driven by the plant location. Operational performance is typically the smallest cost determinant, representing another 15% to 25% of mill-to-mill cost differences. The biggest driver of cost performance is the mill configuration, which typically accounts for more than 50% of mill-to-mill differences. The furnish as a key element of the mill configuration, has a profound impact not only on the capital investment but also on the operational performance and profitability of the mill.

Figure 1
Drivers of Cost Performance



In fact, paper manufacturing costs are heavily influenced by furnish design, or more specifically, by the combination of pulps and fillers used to make paper. Three very important properties producers must satisfy are strength, brightness and opacity. A mill must not only produce a sheet just strong enough to run through the paper machine and printing press but also a sheet that has marketable optical characteristics.



The key words here are “just strong enough”. Paper producers must continuously seek the proper combination of fibres and fillers capable of meeting end-use requirements at minimum cost, taking into consideration regional factors (fibre quality, availability and cost, energy, etc.). For example, non-integrated mills producing LWC and SC-A, usually try to minimize the use of high-cost purchased softwood kraft. According to KSH’s pricing data, the long-term trend of northern bleached softwood kraft (NBSKP) is about US\$600/ADt in 2001 dollars. At this price, efficient use of purchased kraft is essential.

KSH has developed a paper furnish model that links fibre characteristics and pulping processes to key paper properties and furnish costs. This model has been used for several years for a variety of paper grades including newsprint, coated and uncoated groundwood, coated and uncoated freesheet, solid bleached board, folding boxboard and tissue.

In addition, we have dealt with many of the world’s pulp species and non-wood fibres such as bagasse, bamboo and wastepaper and pulping processes ranging from stone groundwood, TMP, kraft to little-known proprietary technologies. But most importantly, this model has provided KSH’s clients with valuable economic insights.

OBJECTIVES

The paper furnish model has been used successfully to:

- Design the optimal furnish given a fixed fibre resources and a series of market-driven paper specifications.
- Design a cost-effective paper furnish in light of various pulping process alternatives and species-mix. A common example is the debate between TMP and PGW/SGW as the mechanical pulping process for LWC manufacturing.
- Test technical and economic sensitivities of furnish design to modifications in paper characteristics (i.e. brightness, opacity, tear) as a result of market changes or due to a strategic decision to move up (or down) the value-added ladder.
- Test the viability of using innovative furnish materials to manufacture standard or leading edge paper products. Several newly developed and innovative pulps and pulp substitutes have been tested with this model.
- Test the end-use value of competing furnish components.
- Define the lowest basis weight sheet given a series of furnish constraints.

Troubleshoot and test solutions to paper quality problems at mills.



METHODOLOGY

Linking pulp properties to key paper properties is a technique for determining the utility and cost effectiveness of paper furnish alternatives when a paper specification is known. By using such a method, the papermaker or pulp producer would be able to identify the theoretically optimal combination of fibres and fillers for a desired set of paper characteristics.

If one knows the percent content and properties of each furnish component, four paper properties can be predicted by using the weighted-average method. These are tensile strength, tear strength, brightness and opacity. Our model can also integrate the negative impact of clay and calcium carbonate fillers on the overall sheet strength. Brightness and opacity are estimated by using Kubelka-Munk formulae. KSH has built up over the years an extensive database of strength and optical characteristics of various wood and non-wood pulps ranging from mechanical pulps (TMP, SGWD, BCTMP) to chemical pulps (sulphite, kraft etc.).

EXAMPLE: OPTIMUM BASE SHEET DESIGN FOR A LWC PRODUCER

To illustrate possible applications of the model, we designed the optimum furnish using local wood species from a South American paper producer (Company X). Because this paper mill would compete domestically with imported paper and export into the U.S., it would need to produce LWC having paper characteristics (tear and tensile strength, brightness and opacity) similar to those found in North American paper markets.

A typical North American 40 lb. (59.3 gsm) LWC sheet made from softwood kraft pulp and a mechanical pulp such as PGW (pressure groundwood) would have furnish composition and base sheet characteristics as shown in Table 1.

Due to an abundance of softwood chips (i.e. a sawmill was located near by), Company X selected TMP as the integrated mechanical pulping process. As well, our illustrative mill has a plan to use locally produced softwood kraft as the reinforcing pulp and *regular* filler clay as the base sheet opacifier. The initial furnish design and predicted base sheet characteristics are shown as Design 1 in Table 1.

By comparing the results of Design 1 with those of the North American sheet, we observed three main points:

- ▶ At equal base sheet strength and by using TMP instead of PGW, Company X would be able to decrease the percentage of kraft used in the furnish from 40% to 28%. This is because TMP is stronger than PGW even after recognising differences in fibre quality (i.e. wood species) between the two regions;



- Brighter mechanical pulp had to be used to compensate for the lower kraft usage in the furnish (market kraft typically has a brightness of 88% ISO). In order to increase mechanical pulp brightness from 63% to 66% ISO, bleaching chemicals consumption would have to increase by 8 kg of H₂O₂ per BDt of pulp;
- The biggest drawback with Design 1's base sheet was its low printing opacity, 86.8% as compared to 89.8% for the North American sheet. A three-point opacity deficit is quite significant in LWC markets where print show-through must be minimised. In addition, any significant deviation of specific paper characteristics from a normal range is usually not tolerated by customers. Therefore, based on a market concern, Design 1 was not acceptable.



Table 1
Furnish Composition and Predicted Paper Characteristics of Typical North American & Company X's LWC Base Sheets

	North America	Design 1	Design 2	Design 3
Type of clay used	Regular Clay	Regular Clay	Regular Clay	Calcined Clay
Comments	Reference	Rejected	Rejected	Rejected
Grade	LWC	LWC	LWC	LWC
Total Sheet (gsm)	59.3	59.3	59.3	59.3
Base Sheet (gsm)	44	44	44	44
Furnish Composition				
Chemical pulp (Purchased local kraft)	40%	28.3%	40%	28%
Mechanical pulp (integrated process)	PGW	TMP	TMP	TMP
Mechanical pulp (local swd fibre)	52%	63.7%	45%	64%
Filler	8%	8%	15%	8%
Required Brightness of mech. pulp	63%	66%	61%	66%
Predicted values for base sheet (44 gsm)				
Strength factor (Tear X Tensile) (mN.m ² /g)* (N.m/g)	382	382.7	378	380.5
Brightness (% ISO)	70.6	70.9	70.2	70.8
Printing Opacity (%)	89.8	86.8	89.4	90.1
Furnish costs (US\$/BDt)	404	353	386	370

Clearly, we had to redesign Company X's base sheet furnish. To what extent would the level of regular filler in Company X's sheet have to be increased in order to achieve an opacity acceptable to North American customers, and what would the impact of this increase of filler on base sheet strength properties? The results of Design 2 provided the answers:

- In order to achieve approximately the same opacity as that of the North American reference sheet, the filler level in Company X's sheet had to increase from 8% to 15%. Since filler pigment has a negative impact on sheet strength, our model predicted that the requirement for reinforcing softwood kraft pulp would increase from 28% to 40%;
- With the revised sheet's higher kraft content, only very light bleaching of the integrated pulp was necessary to achieve 61% ISO brightness TMP;



- But the Design 2 furnish was rejected. Due to the high requirement for kraft, the furnish cost would be prohibitive (\$386/BDt vs. \$353\$/BDt). In addition, a high filler content sheet as proposed (i.e. Design 2) would typically be more difficult to manufacture than lower ash content papers such as that of Design 1.

The challenge, therefore, was to select an alternate filler that had higher opacifying power, such as calcined clay or calcium carbonate. The cost of calcined clay is usually twice that of regular clay or calcium carbonate. But to use calcium carbonate, conversion to neutral papermaking would be required. The mill would only consider acid wet-end paper machine chemistry.

Table 2
Optical Characteristics of Clays and Calcium Carbonates

	Brightness (% ISO)	Scattering Coefficient (m ² /kg) ¹
Filler clay	83	150
Calcined clay	93	250
Precipitated calcium carbonate	95	230-260
Fine ground limestone	90	180-200

As shown in Table 2, calcined clay and calcium carbonate have much better optical performance than regular filler clay. Furnish Design 3 in Table 1 shows the characteristics of a Company X, LWC base sheet with calcined clay as the filler:

- Calcined clay has very high scattering coefficient and brightness specifications; and for the Design 3 furnish yields a much more reasonable level of filler content (8%). In fact, by having the same furnish composition as in Design 1 (28% chemical pulp, 64% mechanical pulp and 8% calcined clay), Company X would be able to achieve the desired printing opacity of about 90%.
- Due to calcined clay usage, furnish costs for Design 3 increased by 4.8% (from \$353/BDt for Design 1 to \$370/BDt). However, this was still much less expensive than Design 2 where very high levels of reinforcing pulp escalated furnish costs to \$386/BDt.



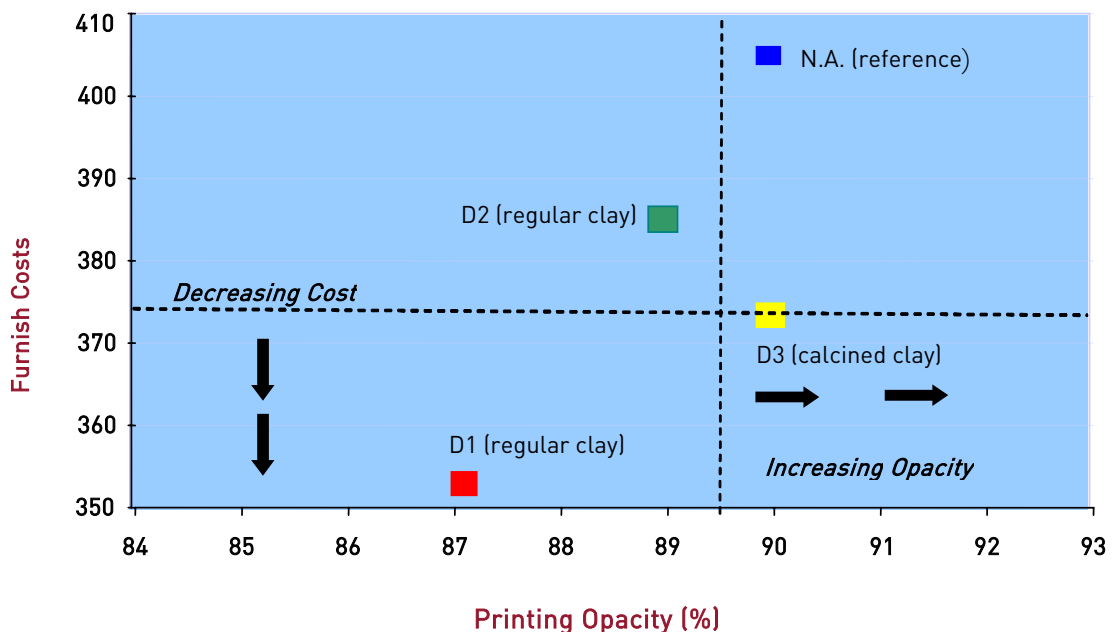
The Design 3 furnish was acceptable because it met the initial paper characteristics targets, could compete in North American markets and offered an acceptable manufacturing cost compromise.

Table 3
Optical Characteristics of Clays and Calcium Carbonates

	Brightness (% ISO)	Scattering Coefficient (m ² /kg) ¹
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Figure 2 illustrate the results of the various sheet design in terms of furnish cost and printing opacity.

Figure 2
D3 was the best design in terms of Printing Opacity and Furnish Cost





The above example showed the power of KSH's paper furnish model. By value-engineering the proportions of chemical and mechanical pulps and fillers, we were able to respect paper market expectations while simultaneously working toward optimised manufacturing costs. Furnish design insights have helped both KSH and its clients understand the relationships between fibre quality, pulping process, furnish costs, market-driven paper properties and project economics.

TEAM

Usually, KSH Consulting's papermaking specialist will lead the project. KSH has built over the years an exhaustive data bank on various pulps characteristics (i.e. beating curves, tensile, tear, burst, scattering coefficients, brightness etc.). The papermaking specialist will perform furnish design and modelling by combining these data with specific furnish characteristics from the mill being studied. If required, he can also get back up from other pulping specialists in the company.

COMPANY PROFILE

General

KSH Solutions Inc. (KSH) is a Canadian consulting, engineering and EPCM services company, founded in 1923 in Montreal, having global reach and extensive experience in the pulp and paper and forest sector. Operating world-wide, KSH has the skills, experience and organisation needed to assist clients improve their asset performance and to develop and execute capital projects of all sizes and complexities, with its consulting, engineering and construction management expertise. In addition, with its European partner and key shareholder, MAN Ferrostaal in Germany, KSH offers its clients the ability to implement their projects under a turnkey / EPC contract customized to the clients' needs.

Built from its long history and strong presence in North America, KSH has expanded its capabilities by providing expertise and services on projects in Europe, Asia, Australia and South America, giving the company a global perspective, as well as the knowledge, track record, and ability to execute projects anywhere in the world.

The entire group provides access to a vast network of resources and offices giving KSH the support to evaluate undertake and execute projects anywhere in the world.

KSH Consulting

KSH Consulting is the consulting arm of KSH Solutions Inc. Our mission is to assist clients make positive, lasting and substantial improvements in their performance.



We have the global insights, consultants and tools to offer objective and sound solutions to various business problems for companies engaged in the pulp and paper and wood processing industries, governments, financial institutions, investors, lenders and sector organisations.

Our integrated services cover the whole supply chain, from raw material to end-use markets, and focus particularly on the following areas:

- ✔ **Resource, Energy and Environmental Management:** studies pertaining to resource supply, demand, cost, and end-use; regional resource comparisons; audits and benchmarking of forest, environmental and energy management practices; development of corporate strategies for sustainable development; development of regional resource management and master plans; and, government policy advice on sustainable developments.
- ✔ **Product Management:** rationalisation and optimisation of existing product-mix; product and manufacturing process design; process and product trial management and product launch assistance.
- ✔ **Marketing:** market analyses, market research, development of marketing plans and market launch strategies, customer satisfaction studies and introduction to key buyers.
- ✔ **Logistics:** distribution logistics planning and optimisation.
- ✔ **Mill Development:** performance audits, benchmarking, optimisation programs and long term development plans for existing assets and mills. Operations, maintenance, and plant management assistance.
- ✔ **Technology Management:** assistance in R&D activity planning, technology assessment and selection, strategic alliance/technology transfer assistance and technological risk management.
- ✔ **Investment Analysis:** opportunity and feasibility assessments, due diligence, asset valuations, business plan development, financial analysis and planning, lender's consultant, owner's consultant, strategic alliance identification, as well as economic and sector studies.

KSH Consulting has acquired strong expertise in consulting and strategic planning in the forest product industry with numerous completed studies. Some relevant furnish design and cost optimisation studies involving KSH Consulting's consultants are described below.



SELECTED EXPERIENCE

Determination of Minimum Kraft Content for Sack Paper (2005). Before proceeding with its own trials for making sack paper, a groundwood paper mill has mandated KSH Consulting to determine the minimum level of kraft, the mill had to add to its furnish, which would allow to meet the sack paper characteristics. By using KSH Consulting's proprietary furnish model, the minimum kraft pulp content was predicted within 5% of accuracy, which was later confirmed by mill trial results. *(Tembec Inc., St. Raymond, 5A1-001)*

Paper Machine Conversion Study from Newsprint to SC Paper (1999). In this study, Hung developed the project design criteria, evaluated the physical and optical properties of the designed sheet based on existing pulps by using our proprietary model and by participating in trials at the Valmet pilot plant in Finland. The trial results gave numerous insights on the furnish limitations and the equipment capabilities. As a result, several recommendations were given to improve the pulp mill area (i.e. screening and refining) and to better define the paper machine configuration. *(Millinocket, 515-001)*

Restart of a Bagasse Printing and Writing Paper Mill (1999). After a long shutdown, the company together with a new Canadian partner, decided to restart the mill. Hung developed new furnish recipes based on bagasse and BCTMP without sacrificing the sheet physical and optical properties. *(Tembec Inc.)*

Mill Conversion Study from Newsprint to LWC Grade. In this study, Hung designed furnish compositions that met the physical and optical properties of coated groundwood papers No. 4 and No.5 based on integrated TMP and also from market BCTMP pulp. He then estimated the manufacturing costs of such grades and a financial analysis was performed to derive the IRR and the NPV of the project.

Market Study for a Greenfield Softwood Kraft Mill in Germany (1998). In order to build a greenfield softwood kraft mill in Germany, the project promoters mandated KSH Consulting to carry out a market study. As part of this mandate, Hung benchmarked the pulp fibre characteristics in different areas of the world and also analysed the price trends of market pulps. *(Klockner INA, Germany, 506-001)*



Strategic Plan for a Market Kraft Pulp Mill (1997). An market kraft pulp producer awarded the mandate to construct an optimisation base-case scenario in which the pulp mill would operate as 100% market pulp, with little or no affiliated sales and would systematically distil the many paper product options for integration down to the most promising scenarios. A market sales and product screening approach was developed to reduce the originally proposed 23 paper products to six grades offering promise for a forward integration study for the mill. As part of this mandate, Hung analysed the fibre furnish, and estimated mill manufacturing costs, manpower requirements and capital costs for the various paper options. The integration options were then measured against the base-case scenario and recommendations were made. Discounted cash flow modelling was included in this analysis of investment options. *(Kimberly Clark, Terrace Bay)*

Substitution Values of a Newly-Developed Pulp and MOW-based Deinked Pulp. At the request of a pulp and paper company, we analysed the substitution values of a newly-developed pulp and MOW-based pulp with a view to determine whether or not the new pulp has more value than MOW-based pulp. By using our furnish design model and applying to different furnish composition and mill configurations, we found the newly-developed pulp has the highest value if it is used to displaced the expensive market pulp (usually BSKP). In addition, we found the newly developed pulp has a premium value of about \$30-\$60 over MOW. The main reason was the new pulp, being stronger than MOW, could displaced more BSKP than MOW.

Forward Integration Study for a Market BCTMP Mill (1996). The mandate given to us was to identify a paper product which could be integrated at this BCTMP mill in order to reduce the mill's exposure to the BCTMP markets and to improve the mill's long term viability. A product screening approach was used to reduce the originally proposed 20 paper products to 4 grades for a more detailed integration study for the mill. Again, Hung analysed the fibre furnish, estimated the pulp and paper manufacturing costs, manpower requirements and capital investments required for the different pulp and paper scenarios. The value of the existing assets was first determined by estimating the NPV (net present value) of future cash flows generated by the mill. A proforma financial analysis for different options was then carried out in order to select the best scenario for the mill. Hung along with his team members gave a final presentation to the board of directors. *(Donohue Inc.)*

Furnish Design for a new LWC Paper Machine (1993). A pulp and paper company planned to install a new LWC paper machine in Eastern Canada. All the furnish compositions for various basis weights have been defined during the planning stage. The company asked us to validate the furnish recipes. By using our furnish model, we were able to show that their recipes were too high in market reinforcing pulp, and a drop of 5-7 per cent in softwood kraft usage would be entirely possible. *(Industry Canada/ CPPA)*



TOOLS AND MODELS

In addition to our global insights, analytical skills and database, the proposed study team has access to various models to support its analytical process. Some of the models that are used are as follows:

- Pulp characteristics database for different processes (i.e. Kraft, TMP, BCTMP, GWD, PGW, sulphite etc.) and for different wood species (i.e. softwood and hardwood in various regions of the world, eucalyptus, mixed tropical hardwood, acacia, bagasse, bamboo, etc.).
- Distribution logistics optimisation.
- Financial model.
- Conceptual cost estimating.
- Cash cost curves.
- Econometric modelling.
- Mass & energy balance.

CONTACT

For more information, please contact:

Hung Ma

Senior Consultant, Papermaking and Economics
KSH Consulting
1 Place Alexis Nihon
3400 de Maisonneuve W.
Suite 1600
Montreal, Quebec
Canada, H3Z 3B8

Tel: 514.932.4611
Fax: 514.939.5266
hma@ksh.ca

www.ksh.ca