Cost impact of integrated supply chain management in the pulping industry of Southern Africa

Robert N Pallett & Willem MJ Hugo
Unisa Graduate School of Business Leadership

The international pulp industry is exposed to fierce competition. A large proportion of Southern African pulp is exported and the industry has to compete in international markets. The competitive success of the Southern African industry is largely dependent on a raw material resource of low cost wood. By improving efficiencies in raw material handling and utilisation, to provide a more uniform mill furnish, the Southern African industry could further reduce the unit cost of wood, increase mill throughput, and enhance pulp quality to improve competitive position. Integrated supply chain management is a key tool to achieving this. Recent research on timber raw materials has quantified the benefits of differentiating eucalypt hardwood species before pulping and varying cooking conditions to suit the material. Results from plant scale tests conducted with two species are reported. Eucalyptus grandis represents a well-established pulp raw material and Eucalyptus smithii a new raw material source. Each was cooked separately but under standard cooking conditions suited to Eucalyptus grandis. The results revealed a considerable loss of fibre and reduced pulp quality for Eucalyptus smithii. Total cost analysis suggests the loss is of considerable economic significance to the pulpmill. A high level of supply chain integration is seen as a key tool to recovering these losses. This relies on sharing information to develop partnerships across functional boundaries and synchronising material flows to link and align raw material supply and cooking processes with customer needs. The Southern African pulping industry currently exhibits a low level of supply chain integration, characterised by independent departments, high levels of inventory, and a narrow cost reduction focus. A model of information and material flows is presented as a means of achieving higher levels of integration. This requires long-term commitment, strong technical support, and an active encouragement of exchange of ideas, skills, and personnel across divisional boundaries between mill and forest. Based on this model an attempt is made to quantify total cost in the supply chain in an effort to verify the soundness of the supply chain concept in the pulping industry.

Introduction

The international pulping industry trading in commodity pulp products has been ranked with steel and petrochemicals as being exposed to some of the fiercest international competition (Swann 1993: 22-31). The industry is presently dominated by northern hemisphere producers in North America and Scandinavia, but southern hemisphere producers are increasingly gaining market share because of access to a large resource of fast growing, low cost wood raw material. Cheap wood is a key advantage to international competitiveness.

In Southern Africa, a large proportion of pulp produced is exported and the industry has to compete with other international producers. The success of the industry is very dependent on a resource of fast growing, low cost wood. By improving efficiencies in raw material handling and utilisation, the industry could reduce the unit cost of wood and improve mill throughput and pulp quality, thereby sustaining and increasing international market share. Improved production efficiencies are possible by differentiating timber according to the pulping properties of different species in order to process a more uniform mill furnish.

From an integrated supply chain viewpoint, the pulp production process in Southern Africa begins with growing a plantation timber resource; continues with the felling and transporting of timber raw material to the mill and processing the material to make pulp; and ends with marketing pulp on international markets. The process from the start of timber production involves a long period of time. Nevertheless, it is important to understand the full process because species, growth rate, and age of timber act as sources of variation which affect pulping characteristics of the timber and hence the production process and market value of the pulp end product.

It is apparent that to meet future demand for low cost timber, the range of species, growth habits, and ages of timber raw material at the mill gate will increase. It is therefore becoming increasingly significant to differentiate timber according to pulping characteristics before processing, in order to improve the uniformity of mill furnish. Integrating the supply chain from forest to mill is seen as important to implementing a system of timber differentiation to achieve productivity improvements. Integrated supply chain principles and the current status of the Southern African pulping industry are discussed as a basis for recommendations made to help further integration.

Cost impact of integrated supply chain management in the pulping industry of Southern Africa
Background

The Southern African pulping industry

South African industrial development as a whole and including the pulping industry, is still in the early phases of the integration of logistics activities. Supply channel integration and integration between functions within individual companies are generally at a low level (Cilliers & Nagel 1994: 4-14). The Southern African industry exhibits many of the characteristics associated with the 'base-line' condition of functional independence established by Stevens (1989: 3-8) in achieving an integrated supply chain. For example, responsibility for different activities in the chain is vested in separate and almost independent business units. This leads to high levels of inventory of both timber raw material and pulp end product. Inventory buffers are widely used as a price hedge in the international commodity pulp industry and are a major cause of rapid swings between oversupply and strong demand which make forecasting demand and price movements very difficult. The result is short-term planning and reactive production strategies. Functional boundaries are entrenched with incompatible control systems between functions and units. Adversarial attitudes between timber suppliers and timber processors are also experienced at an operational level. Production cost reduction efforts are usually focused within organisations and business units and rarely extend beyond their boundaries. Cost reduction and profit improvement at the expense of supply chain partners by transferring costs upstream or downstream is known to occur. For example, decisions to change the specifications for acceptable timber to the mill are made unilaterally by the mill and at increased cost to the supplier.

However, there is some evidence of an improving willingness to promote increased integration between forest and mill and between distribution functions and customers. These initiatives are being driven by cross-functional technical teams within companies in the industry. For example, technical departments within divisions supplying the processors with timber have highlighted processing opportunities which exist in the industry. The opportunities relate to developing an understanding of how raw material influences pulp and paper properties downstream in the value-adding process. To this end, a fibre grading system has been developed at Usutu Pulp Co. in Swaziland which has the potential to provide greater consistency in pulp strength characteristics by scheduling raw material supply from the forest to achieve a desirable blend (Morris, Palmer & Quilter 1993). Similar developments have taken place at Sappi Ltd where strong partnerships have been forged between Sappi Forests Research and the mill research and development divisions (Sappi Forests Research 1993-1995). Much of the research has focused on developing an understanding of the variation in growth and pulping properties of eucalypt species used in commercial forestry to a point where forecasting demand and price movements very difficult. The result is short-term planning and reactive production strategies. Functional boundaries are entrenched with incompatible control systems between functions and units. Adversarial attitudes between timber suppliers and timber processors are also experienced at an operational level. Production cost reduction efforts are usually focused within organisations and business units and rarely extend beyond their boundaries. Cost reduction and profit improvement at the expense of supply chain partners by transferring costs upstream or downstream is known to occur. For example, decisions to change the specifications for acceptable timber to the mill are made unilaterally by the mill and at increased cost to the supplier.

To demonstrate, at a plant scale, the benefits of differentiating timber to mill production efficiencies, over 1 000 tons each of Eucalyptus smithii and Eucalyptus grandis were pulped separately by the acid bisulphite process used in dissolving pulp production. Standard production cooking procedures were used for both species and the viscosity of the pulp was measured from three samples of each of nine cooks. Viscosity is a measure of pulp quality in terms of the length of cellulose fibres. Pulp yield was measured under a standard cooking regime, by four baskets suspended in one of the digesters and under a shortened cooking regime, by six digester pots in a minirig attached to the same digester and using the same cooking liquor.

The tests consistently demonstrated that Eucalyptus smithii and Eucalyptus grandis have very different pulping characteristics. For the nine standard cooks carried out for each species, Eucalyptus smithii consistently cooked to a viscosity below standard pulp quality requirements under standard cooking conditions. The low viscosities measured for this species indicate that chips were overcooked, resulting in loss of fibre and reduced pulp brightness. Under standard cooking conditions, an average pulp yield of 48 per cent was measured for this species, compared with an average pulp yield of 52 per cent under a shortened cooking time in the minirig. The loss of fibre due to overcooking represents a four per cent difference in pulp yield. This makes a significant difference to mill throughput. The results from these tests indicated that if the differences in pulping characteristics of Eucalyptus smithii and Eucalyptus grandis are ignored, and both species are processed under the same cooking regime, there is a loss of fibre, reduced pulp yield, and reduced pulp quality from a rapidly delignifying material like Eucalyptus smithii. In addi-
The supply chain is defined as the connected series of activities when overcooking material (Pallet 1997).

These tests clearly indicated a need for timber differentiation in the pulping industry. Evidently, the differentiation of timber must in turn influence the supply of raw materials and therefore also various other activities in the supply chain. The question which must be answered is: What is the impact of these changes on the total cost in the supply chain and ultimately on the cost of the product to the final customer?

Total cost analysis is a key measure of the benefits of integrating the supply chain (Lambert & Stock 1993: 39). An analysis of total costs serves to target cost trade-offs within the pulp production process and quantify the total cost benefit derived from using differentiated timber. Total cost is derived from cost components associated with plantation management, harvesting, transport, woodyard processing, and pulping.

**Problem formulation**

In view of the above the problem statement of this study can be formulated as follows:

How can the application of the principles of supply chain management contribute to efficiency improvements and ultimately to optimising total cost in the pulping industry of South Africa?

**Objectives**

The objectives of this study are twofold:

Firstly, to develop a model for information and material flows in the supply chain of this industry, by applying fundamental principles of supply chain management to the South African pulping industry.

Secondly, to determine the total cost implications and cost benefits of implementing supply chain principles in the pulping industry, based on the guidelines provided by the model.

**Research method**

The first objective can be attained by analysing and integrating secondary sources of information on the supply chain and on the South African pulp industry. This information is then used to build a theoretical model which can serve as a basis for total cost calculations.

Using the basic technical analysis of the differentiation of timber conducted by Pallet (1997) on the cooking process of pulp as a point of departure and the various links in the supply chain of the pulping industry as identified in the model, a total cost formula which provides for cost trade-offs in the supply chain is derived. This formula is then used to quantify the total cost of the integrated supply chain of the pulping industry.

**Supply chain management in the South African pulping industry**

**Basic principles revisited**

The supply chain is defined as the connected series of activities concerned with planning, coordinating and controlling material, parts, and finished goods from suppliers to customers (Stevens 1989). The concept of the integrated supply chain management extends the principles related to materials management, parts and finished goods flow and control, and information management outside the boundaries of any single organisation to include suppliers and customers, to the mutual benefit of all parties. Integration occurs at the buyer/supplier interface throughout the supply chain and cooperation and teamwork between buyers and sellers is a key element to achieving integration (Larson 1993). This requires a holistic approach to the entire production process which is different from that currently adopted by conventional organisations who still follow a 'traditional approach' to supply chain management. A traditional approach to supply chain management is characterised by formality, clearly defined boundaries between supplier and purchaser, and a focus on price and product in all interfaces between parties involved in the flow of materials. Research (Sabbath 1995; Saunders 1994; Christopher 1992) emphasises that the traditional approach to supply chain management leads to inventory build-up, slow response times, lack of differentiation in the treatment and flow management of all materials, functional boundaries, and no cost transparency.

South African industrial development as a whole and including the pulp and paper industry, is still in the early phases of the integration of logistics activities. Supply channel integration between functions and integration between functions within individual organisations are generally at a low level (Cilliers & Nagel 1994). Relations between buyer and supplier within the supply chain are frequently adversarial rather than cooperative. It would appear that the South African pulp industry in particular still adopts a traditional approach to supply chain management.

As opposed to the traditional approach, the concept of the integrated approach to supply chain management extends management thinking beyond the boundaries of the organisation to develop relationships that benefit both parties (supplier and customer) and add value to the entire transformation (production) process. There are two important principles to achieving supply chain integration. The first is the integration of buyer and supplier through the development of partnerships throughout the supply chain. The second is the development of a process orientation. This means viewing the entire transformation process in a holistic manner, from raw materials to finished product at point of consumption. A closer analysis of these two elements highlights the relevance to the pulp industry.

Supply chain integration is built on a cooperative partnership between buyer and supplier with open communication and transfer of information between organisations. It is also built on the recognition of two perspectives at the buyer/supplier interface. The perspective of the supplier is one of meeting customer requirements within the constraints set by the supplier’s organisation. The perspective of the buyer at the same interface is to seek added value from the supplier for the purchasing organisation. For these perspectives to coincide, the supplier requires an understanding of the purchasing organisation’s strategy to ascertain what is valuable to the purchaser, and the buyer needs to recognise the constraints of the supplier. The development of a successful partnership across functional and organisational boundaries requires recognition of three important factors: information exchange, business and technical expertise, and a team approach (Landeros, Reck & Planck 1995; Reck, Landeros & Lyth 1992; Saunders 1994; Fawcett & Fawcett 1995; Harrington 1995).
The second element mentioned above is the development of a process orientation. In a supply chain, including the supply of timber to the pulpmill, it is the flow and processing of materials that give rise to value-adding opportunity. To achieve a smooth-flowing integrated logistics pipeline requires an approach that facilitates end to end process management. It is through aligning processes and material flows that strategic capability due to value addition is developed within an organisation. The key to transforming poorly integrated business processes into an integrated supply chain with strategic capability is to focus each process across functional and divisional barriers on customer needs at the end of the supply chain.

Implementation model for the Southern African pulping industry

The question that now arises is how can the principles described above be implemented in the supply chain of the Southern African pulping industry? To reiterate, there are two key principles to integrating the supply chain of the pulping industry. The first is the development of partnerships across functional boundaries within the chain and the second is a focus on the entire process from raw material supply to marketing the final product. Information and information exchange are the foundation of partnership development and material flows from the connecting pathways that link the entire process. Figure 1 illustrates the flow of materials and the shared information requirements that are necessary to integrate the supply chain in the pulping industry of Southern Africa.

The model reflects an advanced stage of supply chain integration which extends the scope of integration outside the organisation to focus on the external customer. This embodies a shift in production perception from product orientation to being customer-oriented. The model has two major components. One is the functionalised but clearly interlinked components of supply, production and marketing. The second is the process-oriented production team which serves to coordinate the production functions and provide consistency in decisions relating to raw materials supply, pulp production, and marketing strategy.

In the model the production process spans the gap between the constraints of wood resource on the one hand and the requirements of the customers in terms of their products and markets on the other hand. The wood resource is constrained by the need to maximise fibre production per hectare to sustain a supply of low cost wood.

The wood resource is drawn upon to meet the needs of the supply chain subject to the constraints imposed by the availability of timber of different grades. Timber supply is directed by the felling plan which uses age class, species distribution, standing timber volumes, and compartment information to produce a harvesting schedule. The execution of the felling plan takes place with the flow of wood from the plantation to the mill. This is where control in supply operation is exercised. This requires information regarding inventory, in terms of timber grades and the levels of stocks on roadside, in the depots, and in the woodyard. It also involves measurement of costs reflecting the value of timber supplied according to grade.

Material flow between supply and production components is represented by the flow of the wood. It is important that the
woodflow be monitored from the plantation to the woodyard in order to keep the timber grades separate (refer to Figure 1).

The pulping schedule centres on the production plan. This focuses on mill production considerations like maximising throughput, cost control strategies, and cooking procedures to meet pulp quality requirements. The execution of the production plan takes place with the flow of pulp from production to marketing and to the customer. In this regard it is important to emphasise that the figure clearly indicates the feedback of information from customer to production in order to ensure that customer requirements in terms of quantities, qualities, and timing are being adhered to. This also forms the basis of marketing feedback to update the production plan.

The marketing component in Figure 1 is the direct link with the customer and is the source of insight into the nature of the market and individual customers for the entire chain. The marketing plan requires information regarding product demand and price, the organisation’s competitive position in the market, and the power of the buyer of its product. Marketing information together with supply and production information to the production team allow derivation of the product mix which is fed back into the marketing plan.

The role of the process-oriented production team in Figure 1 is to focus the process of turning wood into pulp onto customers’ requirements. This team should be made up of members working within the supply, production and marketing functions but with a wider interest than pure functional interests, encompassing the entire process and with a focus on optimising the flow in the supply chain. Information accessed by the team should include: the availability of timber of different grades making up the wood resource; production constraints in the pulping process; and marketing opportunities as well as areas that need to be addressed in terms of product quality. In turn, the team should direct planning and flow of materials and products by integrating and coordinating external supply, external and internal flow, and customer requirements. The ultimate yardstick of success of the supply chain is lowest total cost of ownership to the end customer. This primary objective can only be achieved by maintaining an integrated approach to the supply chain and by trading off costs in the entire process of creating customer value.

**Total cost and cost benefits of supply chain management**

In the discussion on the need for timber differentiation reference was made to a technical analysis of the differences in cooking profiles and pulp yields of high and low grade timber. In attaining the second objective of this study, which is to determine the total cost implications and cost benefits of implementing supply chain principles in the pulping industry, the results from these tests are used as one of the inputs to quantify the impact of differentiated timber on the total cost of pulp production as well as the impact on profit opportunity.

The analysis of total cost defines the sequence of operations within the pulp production process and provides complete integration of the supply chain from growing timber to pulp production (refer to Figure 1). It also serves to align the processes within the production chain by relating the costs for each component to the final pulp end product.

A total cost equation is derived and components and costs quantified for a dissolving pulp mill. The analysis serves to quantify the total cost benefit in the production process from using differentiated timber and to target cost trade-offs within the pulp production process in general and within the supply chain in particular.

**Total cost components**

The total cost of pulp production can be divided into two sections. The first is a function of the costs of plantation management for wood production and the second is a function of the costs of pulp production in the mill. Wood production costs can be subdivided further into the costs of plantation establishment (land preparation, fertilising, weed control, nursery, field planting); the cost of plantation maintenance (fertilisation, weed control, fire protection, pest and disease protection); the cost of harvesting trees at the end of the rotation; and the cost of transporting wood to the pulpmill. Pulp production costs can be subdivided into woodyard costs (chipping and storage) and pulping costs (chemicals, energy, and water). Each of these components makes up the total cost equation.

**Total cost equation**

The total cost of pulp production when integrated with timber production is defined as a function of the following components:

\[
C = f(C_{pm}, C_h, C_t, C_w, C_p)
\]

where

- \(C = \) the total cost of pulp production (R/ton pulp)
- \(C_{pm} = \) the cost of plantation management (R/ha)
- \(C_h = \) the cost of harvesting (R/ton wood)
- \(C_t = \) the cost of transport (R/ton wood)
- \(C_w = \) the cost of the woodyard (R/ton wood)
- \(C_p = \) the costs of pulping (R/ton pulp)
- \(f = \) function

The cost benefit associated with grading timber relates to the scale economies achieved in terms of higher pulp yields in the mill for the same fixed cost throughout the supply chain. This is measured by introducing four factors that convert the costs of individual components within the supply chain to standard units for all cost components. For example, the real cost of timber production per hectare is converted from tons of wood per hectare to tons of pulp per hectare using the wood conversion factor. In this study, volume (m^3/ha), wood density (ton wood/m^3 wood), pulp yield (ton pulp/ton wood) and a wood conversion factor (m^3 wood/ton pulp) are used as conversion parameters. The consumption of wood to make pulp is inversely related to the product of wood density and pulp yield as expressed in the following equation (Borralho, Cotterill & Kanowski 1993):

\[
WC = 1/(DEN \times PY)
\]

where

- \(WC = \) the wood conversion factor (m^3 wood/ton pulp)
- \(DEN = \) the density of wood (ton wood/m^3 wood)
- \(PY = \) pulp yield (ton pulp/ton wood)

The conversion factors standardise units and allow measurement of raw material costs in terms of mill value. They convert the cost of plantation management from R/ha and the cost of harvesting, transport, and woodyard from R/ton wood, to a cost of pulp production in Raton pulp produced.
Other factors required in the total cost equation include:

- \( \text{VOL} \) = the average volume growth of the plantation (m\(^3\) of wood under bark per hectare)
- \( \text{PYm} \) = the mill average mass of oven dry pulp produced per ton of bone dry timber which is 0.44 for Saiccor.

The total cost of pulp production can then be expressed as follows:

\[
C = \left[ \frac{\text{WC}}{\text{VOL}}(\text{Cpm}) \right] + \left[ \frac{\text{Ch} + \text{Ct} + \text{Cw}}{\text{PY}} \right] + 0.44/\text{PY}(\text{Cp})
\]

By quantifying the cost of each component, and understanding the pulp yield, density and yield characteristics of the timber, the total cost of production of a ton of pulp can be calculated. The costs of each component are quantified in the following section.

**Component costs**

The total cost components for pulp production are quantified below for typical eucalypt forestry conditions at the Saiccor mill in South Africa. The forestry related costs of wood production and delivery to the mill are taken from the annual report of the Forestry Economic Services for the calendar year January to December 1995 (Rusk, Pennefeather, Cronje & Meyer 1996). These cost reports are published annually and are considered to be the most comprehensive cost reporting available on plantation forestry. The 1995 survey sampled 56 per cent of the 1.3 million hectares of plantation in South Africa. The data is collected from a wide spectrum of timber growers from major corporations to small growers. Detailed costs for eucalypt plantation management, harvesting, and transport are reported. All costs are the average costs for production of dissolving pulp in South Africa. The costs are divided into Woodward costs and pulp production costs.

**The costs of plantation management**

Plantation management includes the direct costs of establishment/re-establishment, maintenance and protection and an overhead cost component. These costs were discounted to a net present value (NPV) assuming a nine year growth rotation (Rusk et al. 1996) and using a 5 per cent real interest rate (inflation free). These assumptions correspond to typical eucalypt growing conditions in South Africa (Uys & Kotze 1992). Costs of land were not considered.

The net present value of plantation management costs is presented in Table 1. From the table, the cost of establishment and re-establishment is the weighted average of both planting and coppicing of eucalypts. The total planting costs include the costs of land preparation, planting, blanking, and fertilising (total R1 595/34. ha). Planting or coppicing are incurred at the beginning of the rotation. The total maintenance cost includes the costs of weed control, brashing, and clearing storm, wind and fire damaged trees. Protection costs include the costs of pest control and the control of noxious weeds, fire protection and insurance, and conservation costs. Forest overheads are indirect costs that cannot be directly allocated to any of the silvicultural, harvesting or transport operations. They include costs incurred by administration, the replacement of hand tools, road and building maintenance, and maintenance of other improvements. The total cost of R583.24/ha is incurred annually for the length of the rotation, in this case for nine years.

### Table 1. The NPV of plantation management for eucalyptus plantations grown on a 9 year rotation in South Africa (Rusk et al. 1996)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Cost component</th>
<th>Cost (R/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>Land preparation</td>
<td>611.19</td>
</tr>
<tr>
<td></td>
<td>Planting</td>
<td>537.26</td>
</tr>
<tr>
<td></td>
<td>Blanking</td>
<td>177.02</td>
</tr>
<tr>
<td></td>
<td>Fertilising</td>
<td>259.87</td>
</tr>
<tr>
<td></td>
<td>Coppicing</td>
<td>331.94</td>
</tr>
<tr>
<td></td>
<td>Total establishment cost</td>
<td>1123.03</td>
</tr>
<tr>
<td>Annual costs</td>
<td>Maintenance</td>
<td>85.56</td>
</tr>
<tr>
<td></td>
<td>Protection</td>
<td>130.30</td>
</tr>
<tr>
<td></td>
<td>Overheads</td>
<td>367.38</td>
</tr>
<tr>
<td></td>
<td>Total annual cost</td>
<td>583.24</td>
</tr>
<tr>
<td>Total plantation management cost over 9 years</td>
<td>6372.19</td>
<td></td>
</tr>
<tr>
<td>NPV at the end of year 9</td>
<td>5268.60</td>
<td></td>
</tr>
</tbody>
</table>

Note: The total establishment cost is a weighted average of costs associated with planting (63%) and coppicing (37%)

The total cost of plantation management of R5 268.60/ha represents a standard cost for all eucalypt species. No distinction is warranted between high grade and low grade species. The cost benefits to differentiating timber in this component of the total cost equation derive from scale economies achieved from growing timber of higher value to the mill (higher pulp yields) for the same plantation management cost as low grade species.

**The costs of harvesting and transport**

The costs of harvesting and transport are reported as direct costs only (see Table 2). Overhead costs are included in the management of the plantation (Cpm). Costs presented in the table are the weighted average costs for these activities. The cost of harvesting (R22.97/ton wood) is the total expenditure on felling timber and delivering it to roadside divided by the total tonnage felled. The cost of transport (R50.13/ton wood) includes the total cost of loading timber at roadside, shorthaul transport to depot and delivery to the mill woodyard divided by the total tonnage delivered to the mill.

### Table 2. The costs of harvesting and transporting timber to the mill (Rusk et al. 1996)

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Cost (R/ton wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>22.97</td>
</tr>
<tr>
<td>Transport</td>
<td>50.13</td>
</tr>
</tbody>
</table>

The cost of harvesting and transport is the same for all grades of timber. The cost benefits of differentiating timber at the n-dil derive from the scale economies achieved by recognising the higher value of certain timber species to mill productivity.
The cost of the woodyard

Woodyard costs are presented in Table 3. The amount of R7.74/ton of wood represents the cost of chipping and storing timber raw material before processing. It is assumed that woodyard production costs are the same for all timber grades. As before, cost benefit is derived from chipping wood of higher value to the mill when timber is differentiated.

Table 3. Woodyard production costs (Industry sources)

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Cost (R/ton wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodyard</td>
<td>7.74</td>
</tr>
</tbody>
</table>

The cost of pulping

Pulp production costs are summarised in Table 4. The pulping input variable costs are the direct costs of cooking wood chips involving chemicals, energy, and water at a cost of R123.84/ton pulp. Indirect overhead fixed costs are R54.46/ton. The cost benefits to differentiating timber relate partly to savings in energy when altering cooking regime for high grade species, but mainly to higher pulp yields for the same production cost achieved with higher grade species.

Table 4. Pulping production costs (Industry sources)

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Cost (R/ton pulp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulping input variable costs</td>
<td>123.84</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>54.46</td>
</tr>
<tr>
<td>Total</td>
<td>178.30</td>
</tr>
</tbody>
</table>

Total cost analysis

The total cost analysis quantifies the difference in the total cost of pulp production when processing differentiated timber and undifferentiated timber. Cost benefits due to timber grading relate to improved economies of scale in all the processes making up the integrated supply chain. Improved scale economies are achieved when fibre yield is maximised in pulping manufacture and the fixed costs incurred throughout the supply chain are minimised when measured per ton of pulp produced. Cost increases due to the timber grading process must also be considered and incorporated into the total cost equation. Total cost benefit is achieved when trade-offs between cost increases and savings favour increased savings.

Cost trade-offs

The integrated supply chain examines the timber and pulp production process in its entirety. Timber grading and pulping separately requires maintaining the identity of timber from plantation to the digester. This is a possible source of cost increases in the process. At present, systems exist to maintain the identity of timber from the plantation to the woodyard gate, thus no cost increase in the harvesting and transport components of the supply chain have been incorporated. In the woodyard, however, roundwood and chips of different grades would have to be stored separately before pulping. The woodyard at Saiccor currently differentiates two types of raw material (wattle and saligna). This is done in order to process wattle through the magnesium section of the plant only. A timber grading precedent therefore already exists in the woodyard at Saiccor. If three grades of timber were introduced, there would need to be some restructuring of the woodyard requiring a small capital investment. The increased costs of depreciation and repairs and maintenance of new assets would increase the costs of the woodyard. For a R10m capital investment, the woodyard cost component (Cw) would increase to R9.00/ton of wood processed. The increased woodyard costs would have to be offset by the savings made in the manufacture of pulp from differentiated raw material.

Altering cooking requirements to suit high timber grades would result in savings in energy and reduction in the pulp production input variable costs for these grades. A 10 per cent reduction in energy use would reduce the variable cost of pulping (Cpv) to R120.00 per ton of pulp. The total cost balance as a result of cost trade-offs can be quantified using the total cost equation with the results from the technical plant scale tests (referred to earlier), as input data.

Input data

The results achieved in the technical tests are summarised in Table 5. The wood densities used for Eucalyptus smithii and Eucalyptus grandis in the table are those previously measured within the KwaZulu-Natal midlands under similar growing conditions to the material used in the plant scale cooks (Clarke 1995). The volume of timber grown per hectare (VOL) was derived from actual measurements of mean annual increment on plantations in KwaZulu-Natal grown on a 9.1 year rotation (Rusk et al. 1996). These records likely included plantations from which material for the tests was derived.

Table 5. Input data for total cost analysis of tests conducted at Saiccor (Clarke 1995; Rusk et al. 1996)

<table>
<thead>
<tr>
<th>Timber grade</th>
<th>Species</th>
<th>Density (ton/m³)</th>
<th>Volume (tons/ha)</th>
<th>Pulp yield (ton pulp/ton wood)</th>
<th>Undifferentiated</th>
<th>Differentiated</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Eucalyptus smithii</td>
<td>0.55</td>
<td>123</td>
<td>48.0</td>
<td>51.8</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Eucalyptus grandis</td>
<td>0.44</td>
<td>123</td>
<td>53.1</td>
<td>54.2</td>
<td></td>
</tr>
</tbody>
</table>

Pulp yield data in Table 5 is divided into that representing undifferentiated timber and differentiated timber.

Cost analysis

The component costs and the total cost for pulping undifferentiated and differentiated Eucalyptus smithii and Eucalyptus grandis timber under different cooking regimes are summarised in Table 6. In the case of differentiated high and low grade timber, cost trade-offs have been incorporated. The woodyard component (Cw) has increased to R9.00/ton of wood and the variable cost of pulping (Cpv) reduced to R120.00/ton of pulp for high grade timber requiring less energy.

From the table, savings in total cost are made when both high grade and low grade timber are differentiated and cooked differently to the standard cooking regime currently practiced. The savings are greatest for high grade species like Eucalyptus smithii, where the total cost of pulp production under standard cooking conditions is R494.11/ton and R457.03/ton under a cooking regime better suited to the mate-
rial. This represents a saving of R37.08 for every ton of pulp produced from the number of this species when differentiated. Savings are also possible for low grade species like Eucalyptus grandis where the total cost of pulp production under undifferentiated cooking conditions is R483.32/ton and R475.83/ton under cooking conditions better suited to the material. This represents a saving of R7.49 for every ton of pulp produced from the timber of this species when differentiated.

Table 6. Cost components and total cost per ton of pulp for undifferentiated timber under standard cooking conditions and differentiated with cook adjusted to timber grade (Section on cost components)

<table>
<thead>
<tr>
<th>Timber grade</th>
<th>Species</th>
<th>Cpm (R/ha)</th>
<th>Ch (R/tor pulp)</th>
<th>Ct (R/ton wood)</th>
<th>Cw (R/ton pulp)</th>
<th>Cpf (R/ton wood)</th>
<th>Cpr (R/ton pulp)</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undifferentiated</td>
<td>E smithii</td>
<td>5268.60</td>
<td>22.97</td>
<td>50.13</td>
<td>7.74</td>
<td>54.46</td>
<td>123.84</td>
<td>494.11</td>
</tr>
<tr>
<td>Undifferentiated</td>
<td>E grandis</td>
<td>5268.60</td>
<td>22.97</td>
<td>50.13</td>
<td>7.74</td>
<td>54.46</td>
<td>123.84</td>
<td>483.32</td>
</tr>
<tr>
<td>High grade</td>
<td>E smithii</td>
<td>5268.60</td>
<td>22.97</td>
<td>50.13</td>
<td>9.00</td>
<td>54.46</td>
<td>120.00</td>
<td>437.03</td>
</tr>
<tr>
<td>Low grade</td>
<td>E grandis</td>
<td>5268.60</td>
<td>22.97</td>
<td>50.13</td>
<td>9.00</td>
<td>54.46</td>
<td>123.84</td>
<td>475.83</td>
</tr>
</tbody>
</table>

The analysis of the total cost equation in Table 6 quantifies the extent of the material wastage that occurs when undifferentiated timber versus differentiated timber is used in the pulping industry. In the case of both high grade and low grade timbers, savings in total cost were made by differentiating the raw material before cooking and adjusting the cooking procedure to suit the material. High grade material represents the upper margin of the savings that can be achieved (R37.08/ton of pulp) and low grade material the lower end (R7.49/ton of pulp). It is reasonable to assume that moderate graded timber would lie between the two. The savings would have a significant impact on production costs in a mill with the capacity to produce 600 000 tons of pulp per annum like Saiccor (Engineering Week 1995).

The savings quantified above refer only to the production of an unbleached pulp. There is considerable potential for further savings downstream from the pulp production plant in the process. For example, the overcooking of Eucalyptus smithii reduces the brightness of the pulp and requires prolonged bleaching to achieve acceptable standards of bleached pulp brightness. Adjustment of cooking regime to suit the timber grade being cooked would prevent prolonged bleaching. Consistent pulp characteristics, like viscosity and brightness, help the downstream processes achieve scale economies with longer runs of material of the same nature. This is also likely to provide a better quality of end product with accompanying increased value. The plant scale tests demonstrated the consistency of viscosity that can be achieved when material is graded and cooked separately. This would also produce savings in the downstream process.

The savings that are possible from differentiating timber before processing would also improve competitiveness in the marketplace. By lowering production costs in the mill, the position of Saiccor as lowest cost dissolving pulp producer in the world would be strengthened. The savings would also lead to increased profitability of the business by increasing the difference between the market price and production costs per ton of pulp. Further increases in profitability could arise, for example, from production of higher graded pulps, like 94 alpha, to increase market share in higher value products like acetate flake. It is likely that by differentiating timber before processing, the product mix could be shifted to include a higher proportion of higher value products. In an advanced phase of integration of the supply chain, it would be possible to accommodate the requirements of niche markets for higher value products by matching and processing the fibre resource from plantation through to mill to meet the needs of the market.

Recommendations

In order to fully understand and utilise the benefits of greater efficiency and cost reduction in the supply chain of the pulp industry the following is recommended:

- Conduct further plant scale and laboratory tests with other eucalypt species to confirm the timber grading system as developed for dissolving pulp production.
- Test the timber grading system and associated cost benefits for the kraft pulping process.
- Extend the cost benefit analysis to include downstream processing of unbleached pulp in the bleaching and paper making processes.
- Carry out an investigation into the layout changes and associated capital expenditure required in the woodyard to cater for differentiated timber chipping and storage requirements.
- Develop a cross-functional production team with strong technical support to coordinate timber differentiation and synchronise material supply with pulp production and market requirements.
- The phased integration of the supply chain concept in the pulping industry and the concomitant development of more advanced costing procedures to quantify the cost trade-offs and cost benefits of each phase.

Conclusion

The benefits of integrating the supply chain in the pulping industry are economically significant. They relate to the improved conversion of raw material to saleable product by differentiating timber according to pulping characteristics thereby improving the uniformity of the mill furnish. This in turn increases mill throughput and enhances pulp quality.

Achieving an integrated supply chain relies on the development of partnerships across functional and divisional boundaries and on orientating the production process towards the needs of the customer. In the Southern African pulping industry, the current level of supply chain integration is low with responsibility for different activities in the chain vested in separate business units and almost independent departments. This leads to high inventory levels, an adversarial relationship between forest and mill, short-term and reactive production planning, and cost reductions at the expense of supply chain partners. The benefits of improved material management and timber differentiation have been highlighted by technical support teams between forest and mill.

The achievement of a higher level of integration between forest and mill at an operational level is required to inherit the
benefits of differentiating timber. A model of information and material flows relating to the pulping industry and incorporating the principles of integrated supply chain management is presented. To be implemented successfully requires long-term commitment, strengthening of technical support, and active encouragement of exchange of ideas, skills, and personnel across divisional boundaries.

References


