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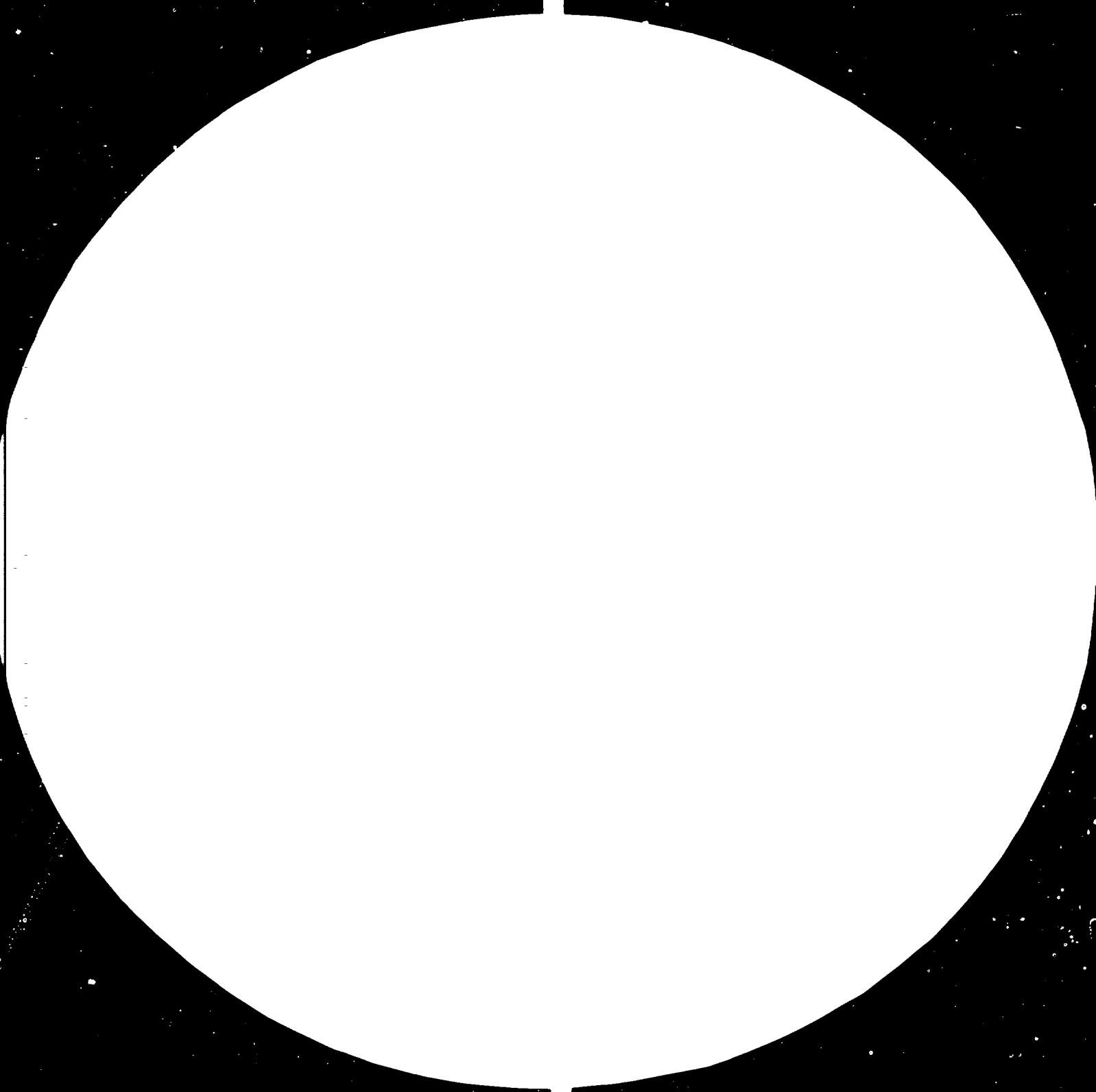

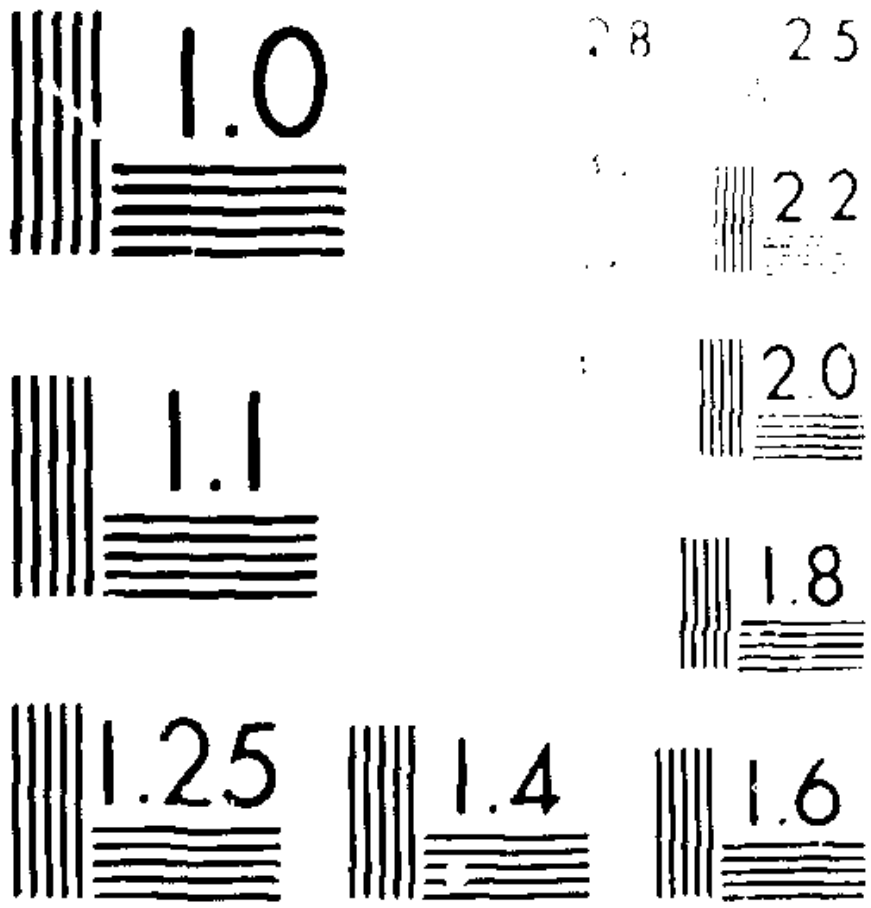
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CRITERIA FOR SELECTION OF SMALL OR LARGE-SCALE PULP AND PAPER MILLS FOR THE DEVELOPING COUNTRIES, SMALL-SCALE MULTI-GRADE PAPER MILLS AND THE USE OF SISAL FIBRES*

by

J. C. Easton**

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** President, Jaakko Poyry Consulting Ltd., P.O.Box 73, Swanley BR8 8HL, Kent, England

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1
INTRODUCTION

The developing countries contain a major share of the world's resources of fibre raw materials in the form of natural and man-made forests; agricultural residues such as straw, bagasse, bamboo, grasses, reeds, flax, cotton linters, etc. However, as a group, the developing countries are net importers of forest products due largely to their imports of pulp and paper. These countries, often in conjunction with the international development agencies and/or private enterprise from the developed countries as well as individual developed country Governments, have been investigating the development of domestic pulp and paper industries. Many of these projects have been aimed at utilising the natural fibre resources of the country to generate an increased inflow of foreign exchange. In terms of the number of projects identified only a relatively small number have been developed to date.

In the industrialised countries the decisive criterion for expansion of the industry is usually financial return on investment. Increasing capital and operating costs in these countries have led to mills becoming steadily larger and more sophisticated in order to benefit from the economies of scale. Figure 1 shows the average capacity of sulphate pulpmills in the major pulping countries since 1960. There are not any major differences between the size of new mills in any of the countries shown. However, due to the influence of older mills the average size is lower in Scandinavia and Canada. This "large is beautiful" concept has been, in many cases, forced upon projects in the developing countries.

Since the shortage of pulp and paper products in 1974-75 considerable attention has been devoted to the demand and supply of paper products in the developing countries. Concerned parties have been asking the question "If for certain developing countries export-orientated large scale mills are not the answer, then how can these countries utilise their human, forest and land resources to develop a paper industry to meet their own needs with possible exports to neighbouring areas?"

Jaakko Pöyry have been actively investigating possible means of reducing the relative costs of small scale mills for developing countries.

In the following paper, we investigate the criteria which influence the decision towards a large scale or small scale mill and the possible advantages and disadvantages of the small scale pulp and paper mill.

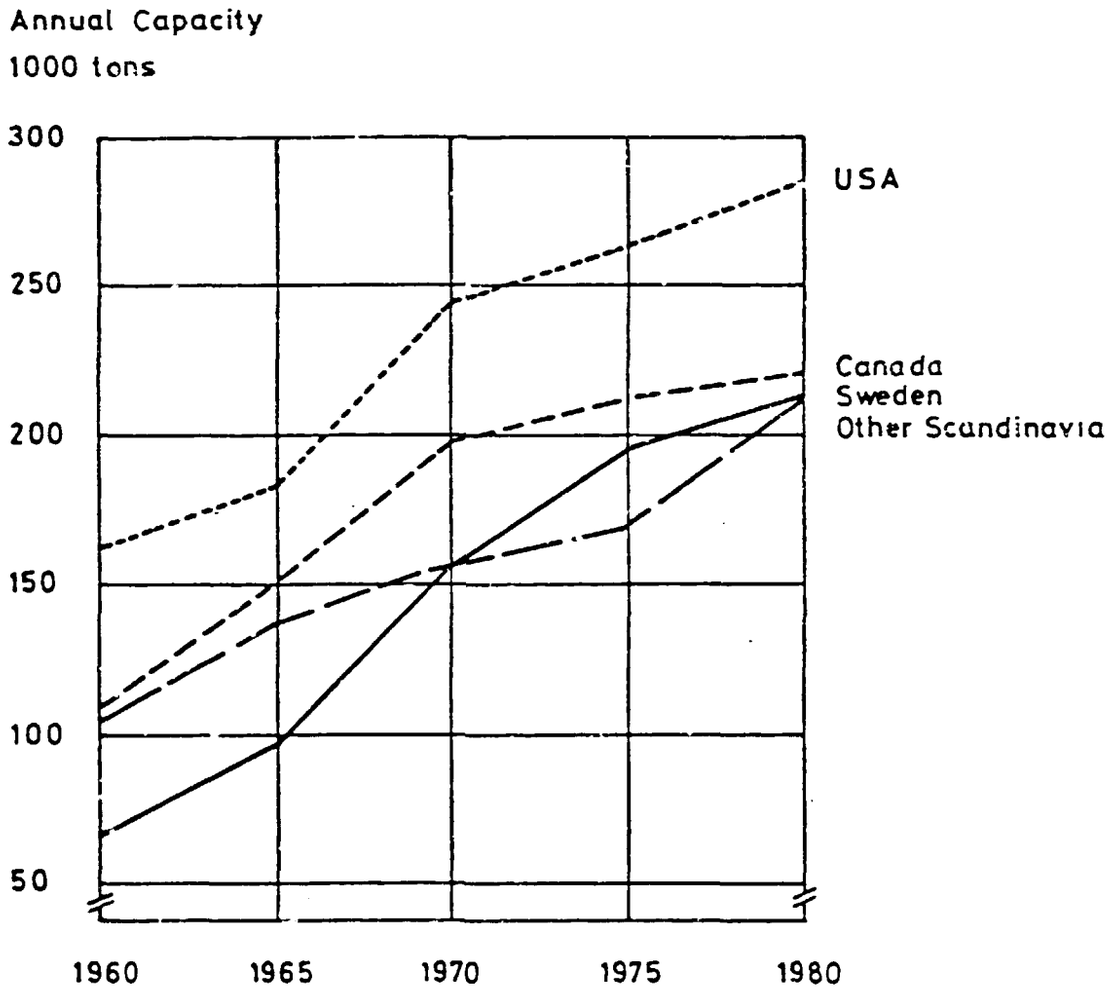
Jaakko Pöyry also maintain a fibre research group in Helsinki and from this group we present a brief resume on the application of sisal fibres.

2 CRITERIA FOR THE SELECTION OF SMALL OR LARGE SCALE PULP AND PAPER MILLS

The criteria which must be examined when considering a pulp and paper project in a developing country with regard to the scale of operation are:

- type of mill
- availability and type of fibrous raw material
- market characteristics
- environmental and social aspects
- physical limitations
- capital availability
- financial and economic aspects.

FIG 1 AVERAGE SIZE OF SULPHATE PULP MILLS



However, it should first be defined what is meant by a small scale mill. As was already demonstrated in Figure 1 there has been a significant increase in average mill capacities over the last twenty years due to economic conditions in the developed countries and this trend has been transferred to the developing countries in numerous cases. What was a large mill in the mid-1960's would now be considered a small scale mill. Based upon wood as a raw material resource, a mill of 200 tons per day capacity would today be considered a small scale operation compared to the large units of 700 tons per day and over. However, for a mill based upon non-wood fibres, a single pulping unit of this size would be considered a large installation. Of the mills in the world based on non-wood fibres, about 70 % are 100 tons per day or less in capacity.

The type of mill has considerable influence on the capacity which may be envisaged. In the case of a chemical pulping operation based upon wood, the physical limitations on essentially single line operation appear to be between 1,000 and 1,400 tons per day depending on the species. For non-wood fibres the upper limit for bagasse and similar fibrous materials cooked in continuous digesters appears to be around 200 tons per day. For other non-wood fibres pulped in batch digesters, the economies of scale are not as pronounced and the size may be smaller.

In mechanical pulping the economies of scale are not as significant as for chemical pulping with limitations on the capacity of each pulping unit. Normally, the capacity of the mechanical pulping unit will be matched to the requirement of the paper machine where the economies may be more pronounced.

Thus, for our discussion, let us think of small scale mills in the order of 100 tons per day of finished product, possibly up to a maximum of 200 tons per day.

Probably the most significant factor influencing the size of an integrated pulp and paper operation is the market towards which the mill is aimed. If the primary object is to operate as an export pulp and paper mill then the unit will need to be competitive on the international markets with the large scale mills in the developed countries. If, however, the mill is aimed towards the domestic market then the market is often not sufficient to support a large producer of bulk products and the market for printing and writing papers can be extremely heterogeneous.

A mill selling to the domestic market in a developing country can benefit from a natural price advantage due to the cost of freight and handling on imported products. The estimated cost for a mill in Scandinavia, based upon 1979 cost levels, delivering woodfree printing and writing papers, is estimated as follows for an East African port:

Item	Cost US/ton
Wood	130
Purchased Fibre	-
Energy	55
Chemicals	50
Packaging	20
Salaries and Wages	70
Other Fixed	48
Total Manufacturing Cost	373
Freight and Handling	79
Capital Charges	233
Cost Delivered Port	685

Similarly, the delivered cost for linerboard from the Southern USA delivered to an East African port is estimated to be:

Item	Cost US$/ton
Wood	80
Energy	26
Chemicals	10
Packaging	3
Salaries and Wages	30
Other Fixed	35
Total Manufacturing Cost	184
Freight and Handling	79
Capital Charges	157
Total Delivered Cost	420

The above freight charges have been based upon charter rates; however, in many cases liner freight would apply which is considerably more costly.

Raw material supply can be a significant factor in many developing countries when determining mill capacity. When basing a mill on a non-wood fibre resource the problem of raw material collection often places a constraint on pulping capacity. Collecting bagasse from several sugar mills may be very costly and overcome any economies of scale which a large mill may have over a smaller mill based upon the bagasse available from a single mill or within a reasonable catchment area.

Environmental and social aspects can place constraints on the size of mill which can be contemplated. Such aspects in developing countries are the forest ownership and land ownership patterns, the dependence and protection of indigenous fruit trees, number of people available for manufacturing and harvesting operations. In some cases developing country areas are not densely populated and the installation of a large forest industry complex would involve bringing in the bulk of the work force and a complete disruption and change in the lifestyle of the indigenous people.

Availability of capital is becoming a sizeable problem, not just in the developing countries, but in the industry. The cost of building large, integrated pulp and paper mills has escalated to where they strain the debt servicing capabilities of even the largest companies. It would appear reasonable to expect that for many developing countries it would be easier to obtain financing for a small scale investment than the hundreds of millions of Dollars required for large scale mills.

Figure 2 shows the investment curves at current 1980 cost levels for integrated and unintegrated woodfree and wood-containing printing and writing paper mills. From these curves, it may be seen that the economies of scale are not as significant for an unintegrated paper mill as for integrated pulping and paper mills.

3 SMALL SCALE MILLS FOR DEVELOPING COUNTRIES

Concerned parties have been asking the question "If for certain developing contries export orientated mills are not the answer, then how can these countries utilise the available resources to develop a paper industry aimed at the domestic market?"

In developing small scale mills for developing countries it is not sufficient to scale down the mills designed for the developed countries. There is a need to develop mills which are less expensive than conventionally designed mills and easier to build and maintain, yet still easy to operate.

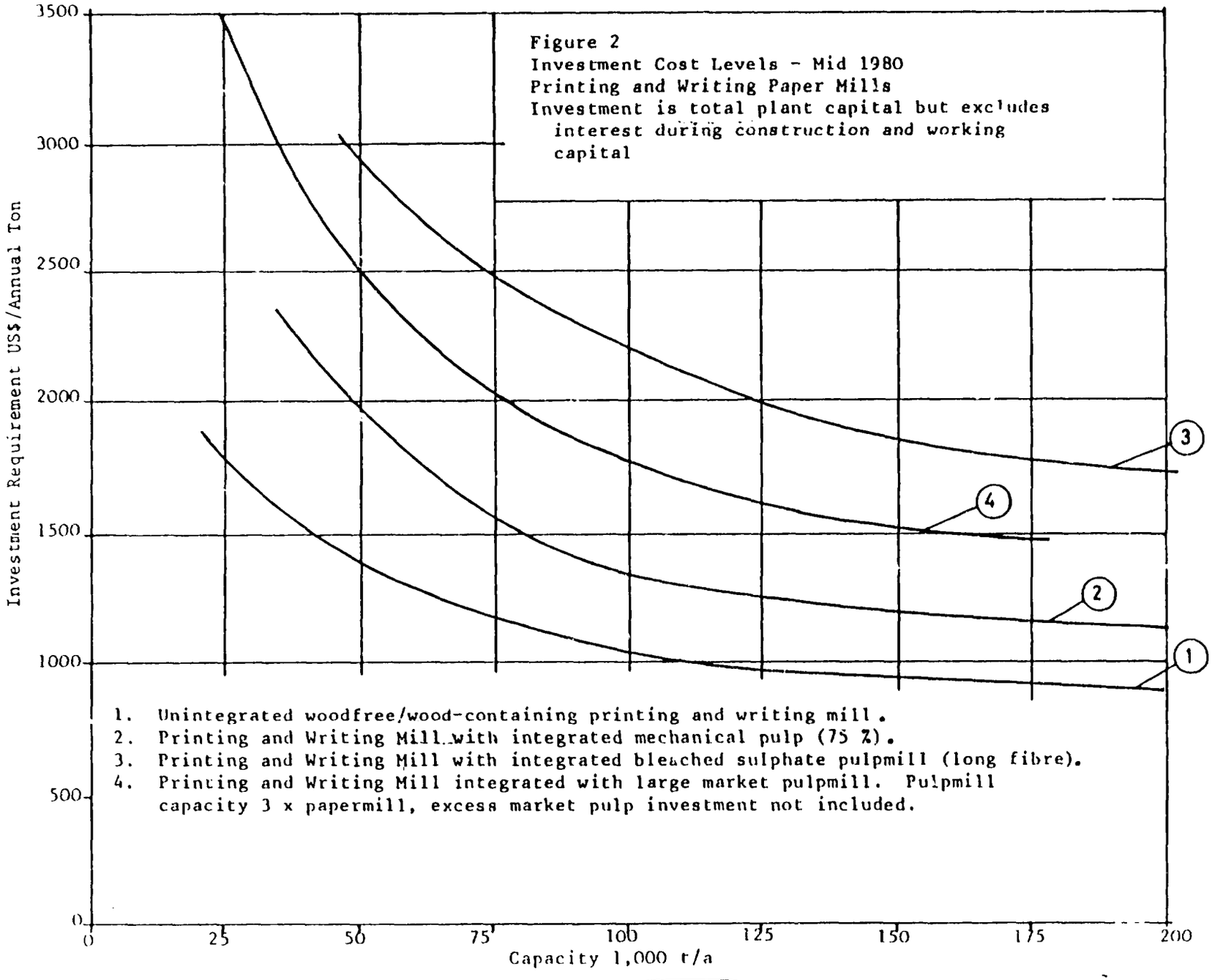


Figure 2
Investment Cost Levels - Mid 1980
Printing and Writing Paper Mills
Investment is total plant capital but excludes interest during construction and working capital
Investment Requirement US$/Annual Ton
3500
3000
2500
2000
1500
1000
500
0
0
25
50
75
100
125
150
175
200
Capacity 1,000 t/a
1. Unintegrated woodfree/wood-containing printing and writing mill.
2. Printing and Writing Mill with integrated mechanical pulp (75 %).
3. Printing and Writing Mill with integrated bleached sulphate pulpmill (long fibre).
4. Printing and Writing Mill integrated with large market pulpmill. Pulpmill capacity 3 x papermill, excess market pulp investment not included.
1
2
3
4

Jaakko Pöyry have investigated small scale pulp and industrial paper mills, woodfree and wood-containing integrated pulp and paper mills, and market bleached kraft pulp mills. The following briefly reviews the work on an integrated sulphate pulp and industrial paper mill producing linerboard.

Based upon Jaakko Pöyry's experience with developing countries, the following guidelines were derived:

- the mill should make acceptable papers from locally available material
- the mill should be simple, straightforward and reliable, based on proven production processes
- the mill operation should be as simple as possible with the need for highly skilled operating and maintenance staff minimised
- the mill should be labour intensive rather than capital intensive
- the capital cost per ton of product should be minimised.

The demand for paper in the developing countries falls largely into two main groups:

- cultural papers which usually account for 20 to 50 % of a country's demand, and
- industrial papers which account for 50 to 80 % of consumption.

In our studies for a suitable integrated unbleached kraft pulping and wrapping and packaging paper mill, Jaakko Pöyry have based the mill on these basic design criteria:

Annual Paper Production	35,000 tons/annum
Operating Period	350 days/annum
Average Daily Production	100 tons/day
Overall Operating Efficiency	77 %
Basis Weight Range	70 - 300 g/m^2
Average Basis Weight	
- Linerboard	160 g/m^2
- Sack Papers	70 g/m^2
Average Wood Density	400 $BDkg/m^3$
Annual Wood Requirement	180,000 m^3rub/a

4
SMALL SCALE VERSUS LARGE SCALE PULP AND PAPER MILLS

4.1
Financing

Large export-orientated pulp and paper mills can cost 300 to 500 million Dollars which might require some 80 to 100 million Dollars equity investment in addition to suppliers' credits and loans. An investment of the above magnitude would have a tremendous impact on the total economy of many developing countries. A small scale mill which could be established for 65 to 85 million Dollars should be able to realise more benefit from grants and soft loans and, when combined with suppliers' credits and other loans, may only require some 15 to 20 million Dollars equity capital.

4.2
Infrastructure

The lower quantities of imported materials for the small mill would not place the same strain on dock and transportation systems.

In designing the small scale mill, consideration needs to be given to minimising the requirement of highly trained specialist services.

4.3
Forestry

The forest operations would be considerably easier to cope with for a small mill than for a large mill. In terms of wood requirement the small mill versus a large 300,000 tons per annum mill would be as follows:

Paper Production	t/a	35,000	300,000
Wood Consumption	m^3ub/t	4.5	4.5
Annual Wood Consumption	m^3	157,500	1,350,000
Annual Increment	m^3/ha	20	20
Plantation Area (net)		7,900	67,500
Wood to Transport Annually			
- green weight with bark	t	143,000	1,350,000
Average Truck Loads	t	10	24 [1)]
Number of Truck Loads	No./a	14,330	56,250
Working Days	d/a	250	300
Truck Loads	load/d	58	188
Average Transport Distance	km	25	65
Round Trip	min	175	280
Ton-km/day		14,400	292,500
Number of Trucks Required			
- one shift/day	No.	23 + 7	-
- two shifts/day	No.	12 + 4	60 + 15 [1)]
- three shifts/day	No.	-	40 + 10 [1)]

1) Truck and Trailer

4.4
Economic Evaluation

Based upon cost levels in 1979, Jaakko Pöyry prepared a preliminary evaluation of the competitive position for a low cost mill in a developing country versus a large mill in the USA exporting linerboard to the same country.

Through simplification of the mill design and instrumentation as well as the application of labour intensive technology, and on the assumption that burned lime could be purchased, so eliminating the lime kiln, Jaakko Pöyry estimated that the capital cost could be reduced by about 20 %.

Figure 3 compares the total cost of producing a ton of linerboard for the small scale mill in a hypothetical developing country with a large 200,000 ton per annum mill model based in the Southern USA delivering to the same developing country. The small mill costs are based upon conditions which could be considered representative for many developing countries.

The comparison has been evaluated initially in the first case based upon capital charges amounting to 15 % per annum of the plant capital investment plus 10 % of the investment in working capital, as illustrated in columns A and C. However, developing countries have access to development loans at low interest rates which could, if applied, substantially lower the overall interest rate. This is illustrated by the second column for each mill model, i.e. columns B and D, where capital charges have been taken at 12 % per annum on 80 % of the plant capital for the large mill and 6 % per annum average rate on 70 % of the plant capital for the small mill.

From the analysis illustrated in Figure 3, the following observations can be drawn:

- wood costs have been taken to be the same

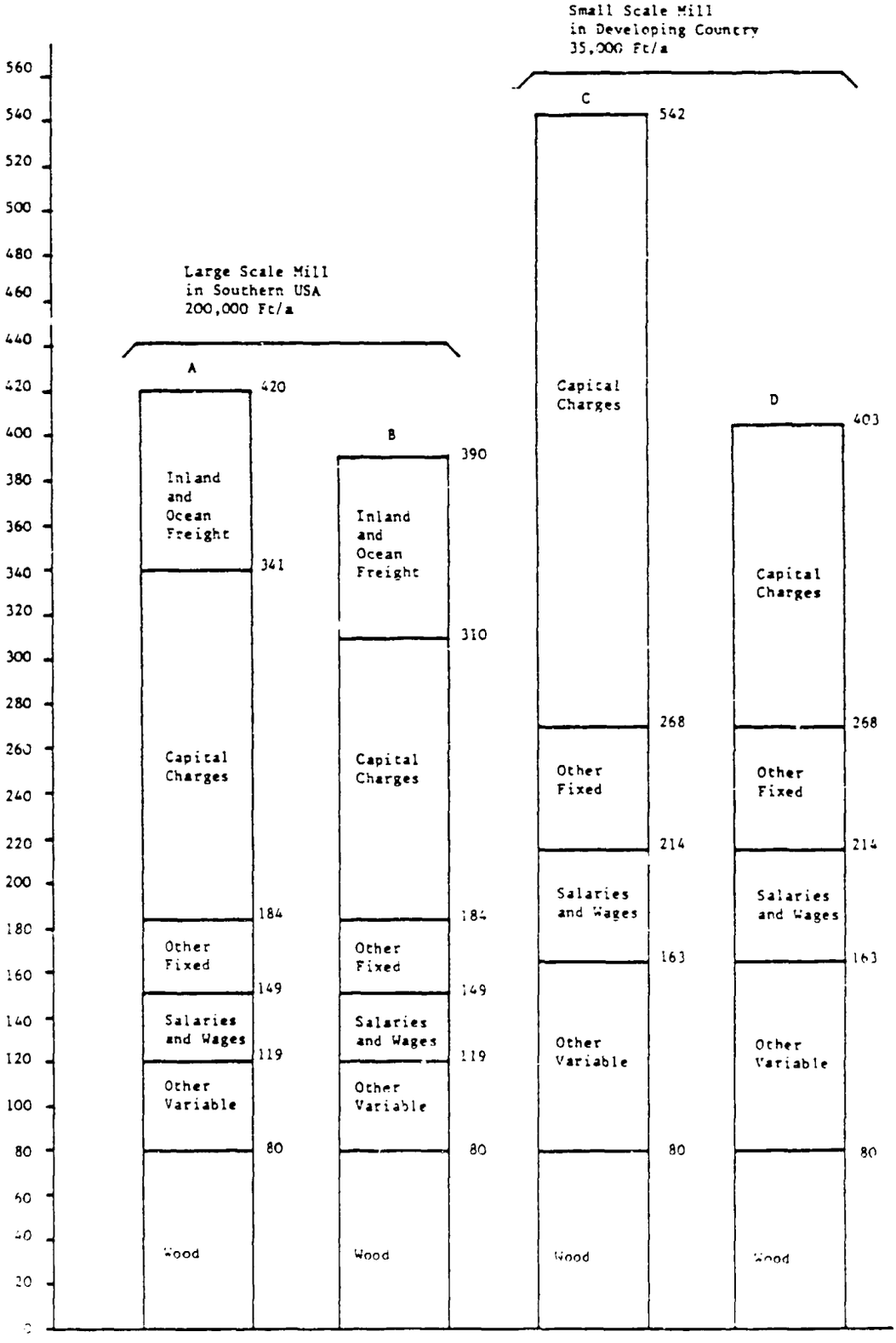
- variable costs would be higher for the small mill due to the simplified design and higher chemical costs due to no kiln

- fixed costs, despite lower personnel costs in developing countries, are higher for the small scale mill due to the labour intensive design of the small mill and the economies of scale for the large mill

- under similar financing arrangements, the small scale mill would be expected to be at a cost disadvantage to new large export linerboard mills shipping into the country without some form of financial assistance or import protection

FIGURE 3

COST OF PRODUCTION AND TRANSPORT FOR LARGE EXPORT MILL (USA)
AND SMALL SCALE DEVELOPING COUNTRY MILL - LINERBOARD



- if the small scale mill were able to benefit from low cost loans then it would appear to be able to approach a competitive cost level against imports from new export mills.

Thus, despite the anticipated reduction in capital investment and savings in transport costs resulting from the mill being in the market area, the financial viability and competitive position of the small mill in a developing country would, in general, still depend upon favourable financing or protection of some sort. This analysis has been based upon general conditions and specific conditions could alter the position significantly.

5
SMALL SCALE MULTI-PRODUCT PAPER MILLS

The small scale unintegrated paper mill producing woodfree printing and writing grades, speciality paper grades and other grades from purchased pulps and waste papers are common in much of the developing and developed world.

There are factors which can be expected to influence the future of such mills and these are briefly discussed in this section of the paper.

Jaakko Pöyry's studies in developing countries have indicated that the demand for paper and paperboard falls largely into two main groups. In the smaller countries with lower populations the industrial paper grades tend to account for the largest proportion of total demand whereas in countries with large populations the demand tends to be more evenly divided between cultural and industrial papers.

In developing countries the per capita consumption of paper is usually very low and the relative total requirement for paper subsequently fairly small. The market tends to comprise many different paper grades. It is not unusual to find mills in developing countries producing 10 to 15,000 tons per annum of paper comprising as many as 30 different paper qualities. Often in developing countries the market is for the final converted paper product and therefore it is necessary for the mill to include converting facilities such as cut-to-size, note book assembly, etc. This means that 70 to 100 converted finished products from one mill may be quite possible. The production of a large number of grades in short runs results in low machine efficiency and capacity utilisation.

Jaakko Pöyry have recently prepared studies for woodfree paper mills evaluating the return on investment as a function of mill size and the average size of orders. The results of these studies are summarised in Figure 4. The studies reflect conditions applicable to Scandinavia and therefore it must be urged that the ROI should not be taken at face value but regarded as a comparative order.

From these studies, Jaakko Pöyry made the following observations:

1. In the importing area of Western Europe the sizes of machines producing woodfree papers vary considerably. Almost 50 % of the total machine capacity is accounted for by small machines with a capacity less than 20,000 tons/annum.

2. The Nordic exporting areas have a number of small machines but the large machines account for a larger proportion of the total capacity. The proportion of large machines is expected to increase.

3. In Europe, woodfree papers were specialty grades 30 years ago. With technical advances more standardised grades have emerged and many fine paper grades which used to be specialties have become bulk grades and can be produced on large machines.

4. The profitability level for a large paper machine is critical on having reasonably large runs between grade changes. In the case of relatively small runs between grade changes the economy of scale is negligible or even negative for large machines compared with smaller machines.

The results of these studies can clearly be seen to favour the installation of relatively small scale machines in these developing countries where the markets, particularly for cultural papers, tend to be small and and comprise many grades which result in small runs between grade changes.

The small multi-product paper mill can provide a logical first step in establishing a pulp and paper industry in a developing country:

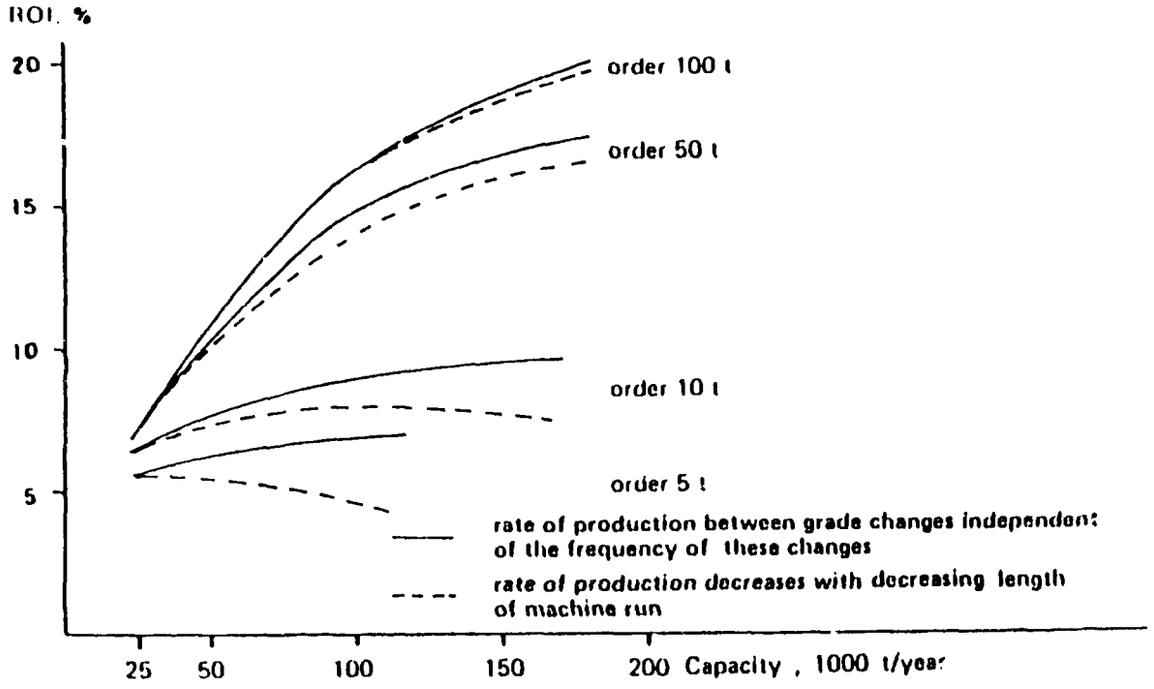
- able to supply the small multi-product market without adversely affecting profitability levels

- relatively low investment cost

- when combined with mechanical pulping, can be established on relatively small wood resource or with pulping of other fibre resource

Fig. 4

RETURN ON INVESTMENT OF UNINTEGRATED FINE PAPER MILLS
AS A FUNCTION OF MILL SIZE



- number of jobs created not significantly different to large mill especially when combined with converting facilities

- level of protection required to ensure profitability not significantly different to large mill when selling to domestic market.

There are additional factors which should, however, be evaluated when considering a small scale multi-purpose paper mill in a developing country. These are:

(a) The traditional fibre producing regions of Western Europe and North America, especially Western Europe, can foresee constraints developing on their available resources. This is leading to the emergence of bulk woodfree paper grades produced in large mills. In Western Europe increasing amounts of these papers will be produced in large 100,000 ton per annum paper mills of two types, i.e.

Type 1 will be a large unintegrated mill located close to the market on purchased pulp and waste paper.

Type 2 will be a large paper mill integrated with a pulpmill.

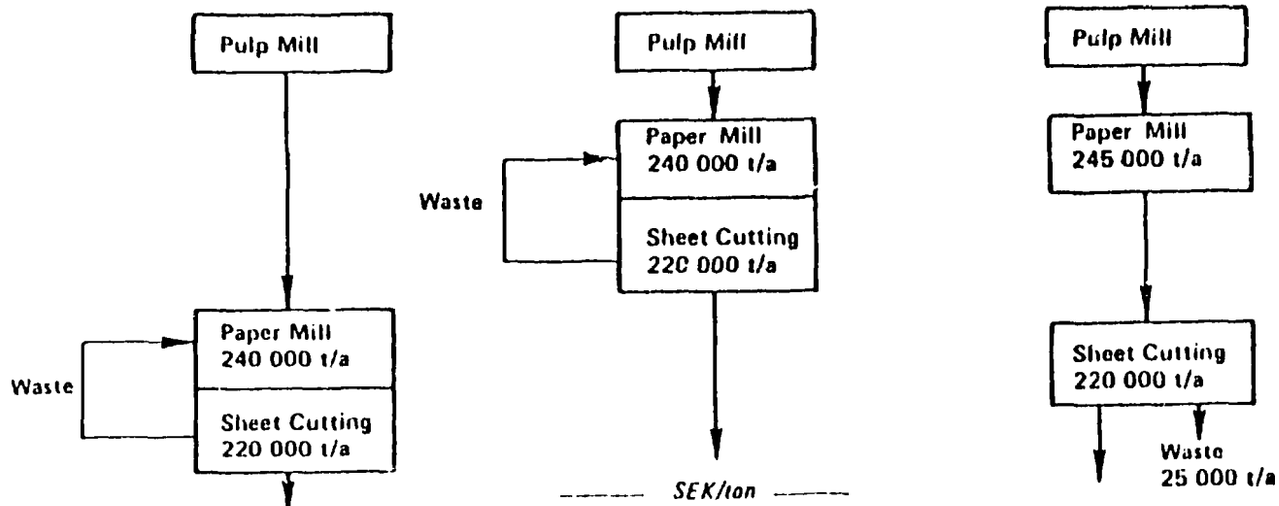
Jaakko Pöyry have studied the relative cost of such large mills for the paper mill located either with a pulpmill in Scandinavia or in the market place in Western Europe. The results of these studies are illustrated in Figure 5.

On the left we have an unintegrated paper mill with sheet cutting close to the market getting its pul[illegible] a pulpmill in Scandinavia. In the middle we have similar paper mill on the same site as the pulpmill with the paper shipped cut-to-size directly to customers in Western Europe. On the right is the same integrated pulp and paper mill but with sheet cutting in the market area. The broke from this converting plant would be sold as waste paper.

The total manufacturing and delivery costs have been calculated in all three cases based on one profit centre. As we see, the integrated pulp and paper mill with remote sheet cutting model indicated a slight cost advantage over the fully integrated complex , both of which showed a cost advantage over the unintegrated paper mill case model. It is therefore likely that we will see more large, fully integrated chemical pulp and woodfree printing and writing paper mills in the future. Undoubtedly, these mills will probably look towards the developing countries for some of their markets.

Fig. 5

WOODFREE PRINTING PAPER
PAPER MILL AND SHEET CUTTING
MANUFACTURING COSTS



	SEK/ton		
Variable costs	2240	1970	2000
Fixed costs	460	400	420
Freight	160	350	255
ROI 20%	1140	1060	1080
Total CIF Rotterdam	4000	3780	3755
Relative costs	106	101	100

COST LEVEL SECOND QUARTER 1980

(b) Some grades which would normally be considered bulk grades in the developed countries may be equivalent to specialty grades in the developing countries. Specialty grades are essentially those grades of papers which are not of such general use that they may be run in large quantities on a paper machine. Due to the limited requirement in some markets, even grades such as newsprint, banks, bonds, etc. may become equivalent to specialty grades and, due to small shipments and subsequent high freight and handling costs, very expensive to supply from abroad. These then may present attractive products for the small scale multi-product paper mill.

(c) In Western Europe the traditional unintegrated paper mills with small machines are going to find it more difficult to compete with large modern units in the bulk grades and will be forced to concentrate on the specialty grades. It is likely that there will be further rationalisation of the industries in countries such as the UK, France, Holland, Belgium, Germany, Italy, etc. which may result in the availability of used paper machines suitable for application in developing countries. The financial benefits of used equipment must not be over-rated as cost savings are not as great as they may initially appear and you may be buying someone else's problems.

(d) Shortages of paper grade pulps have been experienced, especially by developing countries, during the last decade. Pulp supplies to the small scale multi-product mill could be expensive and difficult to obtain during periods of tight supply when considering the number of different pulp grades and relatively small quantities which may be required.

6
PULPING AND USE OF SISAL

Sisal (Agave) is a native of Mexico. Brazil is currently the largest producer followed by Tanzania and Kenya. Sisal is a member of the hemp family having longer fibres than either true hemp or Manila hemp. It is quite a unique fibre with a long fibre length, very high tear strength, a high porosity but only a moderate tensile strength.

The sisal plant flowers between 6 and 8 years and dies after flowering. Harvesting begins two to two and one-half years after planting and produces approximately 200 leaves during its useful life. The leaves are harvested manually throughout the year.

The leaves are cut into short lengths and hammermilled to remove juice and pith. The fibres are then dried. This process has been developed by Companhia de Celulose da Bahia (CCB) who have recently started up their 300 ton per day market bleached sisal pulp mill. CCB obtain 60 kg of dried fibres per ton of green leaves which corresponds to about three tons of bleached pulp per hectare of 5,000 sisal plants.

Pulping of sisal is by normal alkaline soda which is an uncomplicated, easily controlled process. Bleaching is easy and consumption of bleaching chemicals moderate.

In addition to high tear strength, sisal pulp yields a high porosity, bulk, absorbency and folding endurance.

Sisal pulp has been used advantageously as follows:

- as reinforcing pulp in newsprint; a lower proportion of sisal pulp is required when compared with semi-bleached pine sulphate pulp

- the desirable strength properties of sisal pulp make it desirable for bag papers, thin wrapping papers, telephone cable papers, cigarette papers, bank note papers, tea bag papers, filter papers and carbon papers. The high ash content of sisal pulp is detrimental to the insulating properties of the paper and thus its use is limited to the less demanding insulating cable papers. Wrapping papers from sisal pulp can be lower caliper than those made from pine sulphate pulp with equal essential strength properties

- the bulky nature of sisal pulp makes it desirable for thin woodfree printing and writing papers and bible paper

- the high absorbency property of sisal pulp allows its use in tissues

- the high strength properties of sisal pulp allow the production of competitive quality of sack-kraft when combined with bagasse or hardwood pulps.

7 CONCLUSION

In conclusion, we should like to make the following points:

1. The principal factors influencing the decision whether to plan for a small or large scale pulp and paper mill are:

   - domestic or export market
   - raw material supply, type and quantity
   - mechanical or chemical based pulping
   - financial and economic.

2. Despite the reduction in capital investment resulting from the investigations to date by Jaakko Pöyry and savings in product transport resulting from being located in the market area, the financial viability and competitive position of the small scale integrated pulp and paper mill in a developing country would still, in general, depend upon favourable financing arrangements or protection of some form. The analysis has, however, been based upon generalised conditions applicable to developing countries as a whole. Specific situations can vary considerably and can effect the financial position significantly. Thus the technical and financial aspects of each project should be specifically evaluated.

3. There is a place in the developing countries for the small scale multi-product paper mill. This mill often needs to be integrated with converting facilities to meet the market needs. Consideration should be given to possible competition in so-called bulk grades and possible constraints on pulp supplies.

4. With regard to sisal pulping, it appears that there are no problems with known technology producing a desirable grade of bleached soda pulp yielding highly desirable tear, porosity, bulk, fold and absorbency properties.