Waste paper recycling: A community technology approach

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Waste Paper Recycling
A Community Technology Approach

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PART II

A FEASIBILITY STUDY OF
'COMMUNITY'-SCALE PAPER RECYCLING
Part I of this thesis highlights both some potential benefits from the development of community-based recycling enterprises and the need for further research to investigate their feasibility more fully. It also provides evidence, although far from complete, to support the assumption that some recycling technology can be appropriate to the development of 'community'-scale industries/enterprises.

The issues explored in these chapters led to and supported the hypothesis that "paper-recycling can be a technology appropriate to the development of 'community'-scale enterprises". Part II of the thesis is concerned with exploring this hypothesis in more detail. In particular, the approach chosen was to investigate the appropriateness of one particular paper recycling option to the development of 'community'-scale enterprise. To this end, a recycling option based on the 'Melbourne 5' plant was selected as the recycling technology concluded in Chapter 5 to be appropriate to this type and scale of enterprise. A feasibility study was carried out of a 'community'-scale paper recycling enterprise, using the Melbourne 5 plant, and which aimed to:

(i) examine the technical, financial and economic feasibility of manufacturing and marketing a recycled paper product in a Community Technology context.
(ii) relate the findings of the evaluation above to the broader concerns and principles of Community Technology. Focusing mainly on the notions of community involvement and scale of community.

Of the recycling activities/technologies considered in Chapter 5, only waste paper recycling appeared to offer any potential for developing 'community'-scale recycling activities. The Melbourne paper recycling plants were the only available equipment investigated that seemed suitable as a neighbourhood scale recycling activity; and the Pulp Packaging Unit and a '1 tpd' paper recycling plant the only 'community'-scale recycling activities encountered. Chapter 5 highlights the need for further research to evaluate the technical and economic feasibility of establishing recycling enterprises based on all these processes. Of these three 'community'-scale paper recycling processes the Melbourne 5 plant, the only neighbourhood-scale paper recycling technology, was chosen for the feasibility study. The scale of operation and cost of this equipment meant that it was accessible to such a project, involving practical demonstration and operation of the equipment to facilitate both technical and economic assessments. With this scale of operation, involvement with community groups was also possible, to gain valuable operating experience. The latter aspect was particularly important as no data was available at the beginning of this study relating to operating experience with the Melbourne 5 plants anywhere, although a number of plants are known to be in use in Third World countries.

The feasibility study is subdivided into three major sections - Chapters 8, 9 and 10 - taking the form of a pilot study, a subsequent
evaluation report, and an assessment of the Community Technology context of the project. The aims of the feasibility study are to use a pilot study to design and develop an appropriate recycled product in a Community Technology framework and to use the original data generated in this study to evaluate the broader technical, financial and economic feasibility of manufacturing and marketing such a product in a Community Technology context. The assessment of the Community Technology context of the project also involves a wider discussion and interpretation of these research findings, in relation to its appropriateness to Community Technology ideas. It explores further the community involvement in the project, and the appropriate scale of community concerned, and an assessment of the role it could play in promoting community self-reliance.

7.1 RESEARCH METHOD

The process leading to the preparation of a technical, financial and economic evaluation, of the proposed paper making and recycling enterprise, was recognised to be essentially a design and evaluation study. The pilot study and subsequent evaluation report therefore used a format drawn from the approaches commonly adopted in Engineering Design Evaluation, the System Analysis approach, and in the New Product Development Process.

Engineering design frequently incorporates the use of Value Analysis (VA) in its design and evaluation procedures. Turner (1984) describes a typical VA approach as follows:
"1 gather information: identify primary function and assemble
essential cost and other data

2 speculate on different methods of achieving the primary
function, other means of manufacture, alternative materials,
etc by using creativity techniques

3 evaluate: review each idea suggested by the speculation,
rank and estimate cost

4 select the best idea or ideas from a function and cost
point of view listing good and bad features."

The evaluation stage would involve a variety of assessment criteria
from a broad spectrum of disciplines involved in the process, such
as production marketing and financial measures.

Similar approaches and concepts are also used in systems analysis.
Defining systems analysis as "a coordinated set of procedures which
addresses the fundamental issue of design and management: that of
specifying how men, money and materials should be combined to
achieve a larger purpose", De Neufville and Stafford (1971) suggested
that a systems analysis of a design problem should take the form:

"1 definition of objectives

2 formulation of measures of effectiveness

3 generation of alternatives

4 evaluation of alternatives

5 selection "
Clearly both the Value Analysis and Systems Analysis approaches see the design of appropriate products as an iterative process of synthesis and evaluation using techniques from a variety of disciplines. This system's approach to design is echoed by Hein et al. (1984) who suggests that an integrated product development strategy should be adopted when developing new products. In particular they recommend that the design, marketing and manufacturing aspects of a potential new product are developed in concept and that inputs from these disciplines should be considered in a number of discrete stages.

The process of New Product Development in practice draws heavily upon the conceptual approaches briefly described. A particular feature of the New Product Development process is the emphasis placed on the early screening and evaluation of projects before the costly and time consuming product development and test marketing stages are undertaken. A typical new product development process is described by Turner (1985) as including the following five stages where the output from each stage is a decision to proceed to the next:

1 search
   - the analysis of all new ideas to decide whether an idea has the germ of success

2 screen
   - an objective analysis of a chosen idea against the framework of company experience
   - does the product meet a minimum standard?
   - to decide whether to evaluate in depth
The research method followed in carrying out the technical, financial and economic evaluation of the proposed paper recycling enterprise drew on a synthesis of the design and evaluation methods described above. It concentrates on these aspects described in the first 3 stages of Turner's process described above (Turner, 1985), that is to the point of actual product development and testing; and incorporates the 5 stages of the Systems Analysis approach as described by De Neufville and Stafford (1971). The research method adopted can be summarised as follows:
1 Generation of ideas: involving gathering information and defining objectives

2 Preliminary screening: involving the consideration of measures of effectiveness, the generation of alternatives, and preliminary selection

3 Evaluation: involving detailed marketing, financial, economic and technical assessment.

The process followed in these 3 stages then enables preliminary conclusions to be drawn about the viability of the enterprise being evaluated.

The research procedure followed in the preparation of the technical, financial and economic aspects of the feasibility study conformed to this research method, with stages 1 and 2 corresponding to the pilot study and stage 3, the evaluation report. The process was both iterative and dynamic, allowing feedback between stages, and incorporated technical and manufacturing, marketing and financial inputs. The procedure followed in this part of the feasibility study is described more fully in sections 7.2.1. and 7.2.2, and summarised in Figure 7.1. Section 7.2.3 describes the procedure followed in assessing the Community Technology context of the project.

7.2 RESEARCH PROCEDURE

7.2.1 The Pilot Study

The pilot study was designed to identify and quantify various technical,
financial and commercial parameters related to the development of a recycling enterprise. This included attempting to provide full data on operating experience and product acceptability (both to potential consumers and in terms of consistency of output and quality control) and to collect realistic financial data by running the paper recycling plant in conditions approximating those likely in the proposed 'community' paper recycling enterprise. The pilot study was carried out in cooperation with the Milton Keynes Neighbourhood Care Youth Opportunities Programme (YOP). The YOP scheme was identified as a possible collaborator in this project by the Milton Keynes Play Association in an exploratory investigation of potential sponsors amongst community groups in Milton Keynes.

In particular the pilot study was used to:

(i) carry out a technical evaluation of a Melbourne 5 machine, including modification where considered necessary; and determine the technical and organisational aspects of making a marketable product using existing technology. (Section 8.1)

(ii) make an assessment of the product range this paper recycling plant was capable of producing, and provide a range of samples to conduct a preliminary market research study to determine likely competition market price and sales volume. (Sections 8.1 and 8.3)

(iii) carry out a financial appraisal of the costs associated with paper recycling using the existing or modified 'Melbourne 5' plant. (Section 8.2)
(iv) select an appropriate product for further assessment.

7.2.2 Evaluation Report

The results and analysis of the pilot study were then used in preparing a wider evaluation of the proposed paper recycling enterprise in a Community Technology context. This evaluation report both describes the iterative design and evaluation process carried out in assessing the results of the pilot study, and appraises the viability of establishing the proposed paper recycling enterprise on a Community Technology basis, using technical, financial and economic criteria. The evaluation was carried out in part using the economic framework outlined in Section 2.2.2, providing both an assessment of the financial viability and a wider social appraisal.

In particular the evaluation report focussed on the following areas:

(i) technical investigation into increasing the production output
   (Section 9.1)

(ii) financial evaluation including carrying out a sensitivity analysis to explore the cost-volume-profit relationship; the use of market research to identify the most promising product and determine potential sales volume and price; and a financial analysis showing the projected first years trading performance and evaluation using the Internal Rate of Return technique
   (Section 9.2)
(iii) economic assessment of the proposed enterprise including an
evaluation of the social and environmental impacts and the
consequent assessment of economic viability, using unit cost
determination, sensitivity analysis and Internal Rate of Return
techniques (Section 9.3)

7.2.3 Assessment of Community Technology Context

Chapter 10 then draws on the conclusions of the Evaluation Report to
consider what role this paper recycling technology and process might
play in a community context. This also includes a discussion of
community involvement both as potential sponsors of the proposed
'community' enterprise and users of the paper produced; exploring
potential uses and users within a chosen community, and developing
contacts with community groups. The size of community that the
proposed enterprise is most appropriate to, was also investigated,
as was the role that it could play in promoting community self-
reliance.
FIGURE 7.1 Research Procedure - the technical, financial and economic evaluation

Generation of Ideas

- Selection of recycling technology and process
- Product ideas and options

Preliminary Screening

- Technical assessment of production technology and product development
- Determining and analysing costs of production
- Screening alternative products - marketing, financial and technical
- Selection of an appropriate product for further development

Evaluation

- Technical - assess methods for increasing production
- Financial - use sensitivity analysis to optimise level of production and market research to investigate product, sales volume and price
- Financial analysis including forecasts of 1st years trading and the use of IRR technique
- Economic - the social and environmental impacts of the project and its economic viability using unit cost, sensitivity analysis and IRR techniques
CHAPTER 8

RESULTS AND ANALYSIS OF THE PILOT STUDY

The generation of ideas and preliminary screening stages, (as described in the last chapter) are carried out using the pilot study to generate original technical and financial data. The pilot study provided data and information for:

1 Selection of recycling option.

2 Selection and technical assessment of available manufacturing technology.

3 Determining and analysising the costs of production.

4 Design of a range of alternative recycled paper products.

5 Initial screening of alternative products according to technical, marketing and production criteria.

6 Selection of appropriate product for further evaluation.

The results and analysis of the pilot study are best grouped and described in four sections - technical and product development aspects; financial analysis aspects; preliminary market research; and preliminary product selection.
8.1 TECHNICAL EVALUATION AND PRODUCT DEVELOPMENT

This section describes the technical work carried out on developing different products, focusing on producing sugar paper and art paper, and in assessing the performance of the Melbourne 5 plant, including any modifications considered necessary.

8.1.1 'Melbourne 5'

The Melbourne range of plants are designed and marketed by Anthony Hopkinson of Third Scale Technology Ltd, Melbourne Bury, Royston, Hertfordshire. He developed a number of variations of basically the same equipment and in 1980 was producing and marketing two of these plants: the Melbourne 5 and the Super Melbourne. The Super Melbourne produces a larger sheet of paper, 850 mm by 650 mm; but of a quality only suitable for use as packaging materials. The greater flexibility in the product capabilities of the Melbourne 5 made it more appropriate to the needs of this project in exploring the possibilities of producing a range of writing, printing, and drawing papers.

Melbourne 5 is a sheet forming paper making plant incorporating a pulper, a former unit which produces a sheet of paper 420 mm by 600 mm, and a press. The machine was also supplied with about 20 felts and meshes. Additional equipment required was a drying facility for the sheets of paper, and minor items such as containers for pulp and water. The original 'Melbourne 5' equipment is shown in Fig. 8.1, and the equipment layout in Fig. 8.2.
Fig 8.1 'MELBOURNE 5' PAPER RECYCLING PLANT
Fig 8.1 Continued
Fig 8.2  MELBOURNE 5 EQUIPMENT LAYOUT

Drying and storage of finished paper

STACKING TABLE FOR SEPARATING SHEETS AFTER PRESSING

PRESS

STACKING TABLE WHERE POST OF PAPER IS BUILT

FORMER UNIT

PULPER

STORAGE OF (SHREDDED) WASTE PAPER
The three major items of equipment which comprise the Melbourne 5 are described below in greater detail; together with a brief description of their operation.

(a) **The pulper**

The Melbourne 5 pulper is a kitchen sink waste-disposal unit, fitted below a stainless steel sink, such that it recirculates the contents of the sink (see Fig. 8.3).

The sink has an approximate capacity for pulping of 15 litres, and pulps at consistencies between 1% and 4% fibre in water consistency. Newsprint, due to its bulkier nature, pulps better at lower consistencies of between 1 and 2.5% compared to office waste paper which can be pulped at consistencies up to 4%. The pulper requires the paper to be torn or shredded prior to pulping, otherwise the mechanism becomes jammed. The reduction of dry, shredded paper to a usable pulp takes between 15 and 20 minutes depending on the type of waste paper used; newsprint requires a shorter pulping time than stronger 'office' waste paper.

(b) **The former**

It is in the former that sheets of paper are made. It consists of a large fibreglass tank and a stainless steel former unit. The former is suspended in the tank, and by means of a system of pulleys can be lowered into and raised out of the water in the tank. The tank is filled with water. The water level in the tank is kept constant by means of an overflow pipe.
Fig 8.3 'MELBOURNE 5' PULPER
(Figure 8.4 shows details of the former unit's construction.)

A sheet of paper is made in the following way:

(i) The former is raised and 'deckle' lifted to place a sheet of mesh onto the wire grid. The mesh used is nylon sheet with a gauge of 12 holes/cm. The 'deckle' is then replaced to hold the sheet in place. (Fig. 8.5a)

(ii) The former is lowered into the water so that the mesh is under the surface; the depth can vary from 2.5 mm to 15 mm, and experience will determine the best level for the paper being made. There must be sufficient dilution of pulp to allow a free distribution of the paper fibres; balanced against this, faster drainage is achieved with a smaller depth of water. (Fig. 8.5b)

(iii) A measured quantity of pulp is poured into the deckle and swirled around until an even consistency is achieved. (Fig. 8.5c)

(iv) The former is then raised again, allowing water to drain through (Fig. 8.5d). Once the deckle is raised, the mesh carrying the wet sheet of paper is lifted off the wire onto the stacking table, where it is covered with a felt. Alternate sheets of mesh and paper and felts are piled up to form a post (see Fig. 8.6). Wooden boards are placed top and bottom of the post, ready for pressing. The felts used are a synthetic material, with high absorbency of water.
Fig 8.4 'MELBOURNE 5' FORMER UNIT
Fig 8.5 FORMING A SHEET OF PAPER
Fig 8.5 Continued
Fig 8.6 BUILDING A POST
(c) **The press**

Once a post has been built up, it is pressed to remove some of the water and to consolidate the sheets of paper.

The Melbourne 5 press is incorporated in the same frame as the stacking and separating tables. It is manufactured from 25 mm x 25 mm hollow steel tubing, bolted and welded together. The post is placed in this frame and pressed by the force exerted by a three ton 'car jack' working between the top board of the post and the frame (Fig. 8.7). The frame had been designed to be unable to withstand the full force of the 'jack'.

After pressing the felts from the mesh and paper are separated on the separating table, and the paper left to dry, either on or off the mesh.

8.1.2 **Modifications to the equipment**

'Melbourne 5' was designed for use in Third World countries and primarily for the purpose of producing packaging papers. It was expected that a number of modifications would have to be made to the equipment before it would be suitable for the purposes of this case study. In particular it was obvious from outset a drying unit or system had to be devised. The need for further modifications became apparent as a number of paper-making trials tested a variety of parameters including different raw materials, weight of each sheet made, pressing and pulping times.
Fig 8.7 THE 'MELBOURNE 5' PRESS
The modifications made are described below, under the headings pulper, former, and drying unit, and in section 8.1.3. The latter sets out the inadequacies of Melbourne 5's press, and the process of designing a replacement press for the plant. The modified equipment became known as the ATG paper recycling plant, to distinguish it from the original Melbourne 5. Further design modifications would have been desirable had sufficient time and facilities been available; such as improvements in the forming process to improve product output rates.

(a) The pulper

Two problems arise with the pulper; one, its small capacity, and the other, the requirements that waste paper be shredded or torn into small pieces before pulping.

Fifteen litres of pulp at 3% consistency will make about ten sheets of paper. To produce a batch or post of twenty-five to thirty sheets for each pressing therefore requires three batches of pulp. This represents an inconvenience and potential block in production as forming has to cease while a new batch is produced. This problem could be alleviated either by replacing the sink with a larger vessel or by adding a storage vessel between pulping and forming. The waste disposal unit is capable of handling a larger load, as demonstrated by Bruce Glasser's use of a similar waste disposal unit pulper with a thirty to forty litre container (Glasser, 1979). However the simpler of the two solutions was chosen and a storage vessel added between pulping and forming, allowing several batches of pulp to be stored, and decoupling the pulping and forming operations (see Fig. 8.8).
Fig 8.8 'MODIFIED' MELBOURNE 5 PULPER
Access to a small shredding machine, used at the Open University to shred confidential documents was a valuable addition to Melbourne 5 in its early operation, allowing easy preparation of waste paper for pulping. However, this would not be the situation if the machine were used elsewhere. Addition of a small shredder to the machine or a pre-pulping stage which could break down sheets of paper were both ways to overcome this problem.

The major process involved in the preparation of a waste paper pulp is pulping or defibering. This separates the bonded fibres in water, and is commonly carried out by a pulper or hyrapulper; although other defibering machines such as deflakers, dispersers, disintegrators, defiberers or kneeders are used. Essentially the action of a pulper or hyrapulper is to break up the paper in water to produce a fibre/water slurry as a result of violent agitation and repeated exposure to rotating elements, but impart little or no fibre treatment. Clapperton (1952) describes this action as "imparting vigorous mechanical action upon the stock (paper fibre and water)". A typical hyrapulper design is shown in Fig. 8.9.

It may be necessary to follow this pulping stage with further defibering to break up fibre clumps. This is usually carried out by defibering equipment which is described by Grant et al. (1978) as "compelling the feed-stock to pass between a moving and a static metal element, the gap being from virtually zero to 15 mm". This action applies shear forces to the fibre clumps, hence defibering them.
Fig 8.9 TYPICAL DESIGN OF A HYDRAPULPER
The action of the waste disposal unit, used as Melbourne 5's pulper, is described by the manufacturers as a cutting, grating and shredding action, in which a rotary grinder throws the waste material (in this case waste paper) against a stationary cutter. This action, which is forcing the feedstock between a moving and static element, more approximates to that of defibering equipment than to a pulper or hydrapulper. Therefore it would appear that the addition of a pulper to Melbourne 5 should improve its pulping capabilities and would be a great benefit if it could also process whole sheets of paper.

A piece of equipment suitable for use as a waste paper pulper or hydrapulper is a top loading washing machine with an agitator or rotor, which imparts a vigorous mechanical action in a similar way to a hydrapulper. This choice was heavily influenced by experience of other hand-made paper-makers. Anthony Hopkinson has experimented with a Hoover single tub washing machine, both unmodified and converted to pedal-power and now includes such a unit in the Super Melbourne plant; Bruce Glasser uses a Servis single-tub washing machine to both heat and pulp, and then subsequently refines his pulp further using a waste disposal unit pulper. Other paper-makers have made use of washing machine parts, such as John Babcock's washing machine/hydrapulper, described in Heller (1978).

Heller (1978) also lists a large variety of possible equipment that could be used or adapted for pulping - from mincing machines, clay mixers, food mixers, to laboratory models of the Hollander beater. The latter by far is the superior piece of pulping equipment, but also the most expensive, as well as being fairly difficult to obtain.
It is also true that for recycling waste papers, the beating action of the Hollander, is not necessary, as the fibres have previously been prepared for paper making. The gentler action of a hydropulper is often sufficient to break down waste paper into an adequate pulp.

A second-hand Hoover single-tub washing machine was purchased as the first stage pulper (see Fig. 8.10). This provided improved flexibility in pulping which is achieved by virtue of the different actions of the two pulpers, the Hoover washing machine and the waste disposal unit allowing combinations of heating, hydropulping and defibering to be varied according to raw materials used and finished product desired. The Hoover washing machine has a heating element which allows the pulp to be heated before or during pulping. This can improve the pulping process, assisting breaking down of paper into its constituent fibres.

Additional advantages of this choice of first stage pulper, over the use of a shredder were the low cost (only in the region of £10 second hand) and availability of Hoover washing machines.

The Hoover washing machine or pulper has a capacity of 40 litres, and operates most efficiently at between 3 and 6% consistency of fibre in water. It was found to break down sheets of office or computer paper in 1-2 hours, and newspaper in 30 minutes-1 hour. A longer pulping time was necessary at higher consistencies. The pulp produced was not completely defibered but sufficiently so to only require 5-10 minutes further processing by the waste disposal unit defiberer.
Fig 8.10  'HOOVER WASHING MACHINE' PULPER
(b) The former

Three minor modifications have been made to the former to improve its operation. First, a splash guard was fixed into the side of the tank adjacent to the hinged side of the former unit. This was simply to prevent water dripping onto the floor every time the deckle is raised.

The seal made by the deckle when a sheet of mesh is in place needed improvement as problems arose both with pulp leaking through into the tank and with the mesh not being held firmly in place as the former is lowered into the water. The second modification involved fixing draught-proofing foam strip around the edge of the deckle.

The third modification was the provision of a drainage tap at the base of the tank to assist cleaning and emptying which is necessary when the water becomes too contaminated with fibres, ink and dye from the pulp.

(c) The drying unit

The addition of a drying unit was an obvious modification, as the Melbourne 5 had no provision for drying. The available literature on drying hand-made papers gave a predominantly historical perspective, and some basis to assess a variety of possible methods. Experience of individual hand-made papermakers, such as Bruce Glasser, Anthony Hopkinson, and others, was also valued. This main factors to consider are whether to leave the paper to air dry or provide a source of heat and/or a forced draught, whether to dry vertically or horizontally, on or off the mesh, or on another surface.
Air drying is probably the most common method used historically to dry hand-made papers. A variety of air-drying techniques are described by Hunter (1978) and some of these are shown in Fig. 8.11. In European hand-made paper mills, paper was often hung on ropes (of cow or horse hair to prevent staining) in well ventilated lofts. In hotter climates, it is common for paper to dry outside. Studley (1978) quotes that:

"Sheets must dry slowly, usually in the open air, or a moderately warm room, to prevent ripples."

It is commonly stated that an advantage of air drying is that it gives a more even drying, leading to less cockling and curling of the paper. Also, as no source of heat is required, it is a cheap method, although it does require more space.

If heat is to be used, it can be applied in a variety of ways. Opinion seems to favour low temperature heat, as expressed in the quote above, and by Heller (1979) stating:

"Place (the paper) on open slatted racks near a low temperature source of heat."

This is borne out by experience at the hand-made paper mill at Wookey Hole, where paper is dried on racks in a moderately warm room. A stronger source of heat can be used, but unless applied evenly, can cause considerable curling and cockling of the surface as the paper shrinks. One way to avoid this problem is by drying the paper on a heated roller or drum. Farnsworth (1980) uses a photographic
Fig 8.11 TRADITIONAL METHODS OF DRYING HAND-MADE PAPERS
print dryer at the Farnsworth Paper Mill in California to dry their hand-made papers. This can be effective, but is a more expensive process than air drying, and slow to operate, even though the drying time is shorter. Another factor to consider is that the paper may need to be heated to a certain temperature before the size becomes effective. Heat could, however, be applied at some time other than during drying. Both heating and air movement help speed up the drying process and hence reduce the space needed for drying; however, this is offset by the cost of providing heat.

There appears from the literature to be little advantage or disadvantage to either vertical or horizontal drying, except for convenience in use. Paper has been hung over rope, laid on racks made of slats, wire mesh, hessian or hardboard, pasted onto boards, and even the sides of houses to dry.

With the Melbourne 5 machine, there is the additional choice of whether the paper is to be dried on the mesh, removed to be dried alone, or couched onto another surface, for example, to provide a smooth surface or a special texture. The choice is, to some extent, dependent on how effectively the paper has been pressed and thus how easily it can be handled without the mesh. Using the Melbourne 5 press, it is difficult to remove a sheet of paper from its mesh after pressing, without damaging it, as the water content is still too high. Hence, one of the choices of drying options was initially confined to drying on the mesh. Once the 24 tonne press was in use, the wet sheets of paper could be adequately handled after pressing off the mesh and could be dried alone.
Both vertical and horizontal drying were experimented with. The first drying unit built was simply a rectangular box, open at the top with grooves along two sides, allowing sheets of mesh carrying wet paper to be hung, pegged with clothes pegs to dowelling rods across the gap (see Fig. 8.12). Air drying without heat took at least 18 hours, and caused some curling in the paper. The drying time was found to be reduced by passing heated air through the box. This, however, resulted in uneven drying and considerable curling in the sheet, which was difficult to correct when the paper was fully dry.

To prevent these curling problems, horizontal drying was tried, laying the mesh, plus wet sheets of paper, on drying racks. This way, a number of sheets can be piled on top of one another, keeping the sheets flatter as they dry. Another advantage to horizontal drying is that the wet sheets of paper can be removed from the mesh for drying, freeing the mesh for use in making further sheets of paper. This was not possible with the vertical drying method used where the strength of the mesh was necessary to carry the weight of the paper.

A number of rectangular wooden frames with aluminium slats running across them (see Fig. 8.13) were constructed, on which the paper can be laid, one or more sheets at a time. To economise on space, these racks are assembled one above the other, such that they can be raised towards the ceiling once loaded for drying; rope and pulleys are used for this purpose.
Fig 8.12  ATG DRYING UNIT - NO 1
Fig 8.13  HORIZONTAL DRYING RACKS AND ASSEMBLY SYSTEM - ATG DRYING UNIT NO 2
The paper dries flatter and more evenly on these horizontal racks, but is still subject to cockling and some curling at the edges. This can be corrected by repeated pressing of the paper when almost dry and when fully dry. Drying time is similar to that needed for vertical drying, and was found to be dependant on weather conditions, and/or the internal environment of the drying room. It varies from around 12-18 hours in a warm, dry environment to in excess of 7 days in a cold, damp environment.

Increased air circulation shortened drying time without adversely affecting the paper, and that this effect was increased when the air was heated moderately. High temperature heat again produced excessive curling and cockling in the paper. These experiments with drying led to the conclusion that the drying room or area must be very well ventilated, and preferably also warm and dry. Suitable conditions could be provided by the use of solar heating, either passive or active, with a good air flow.

8.1.3 The Press

One of the most obvious deficiencies in Melbourne 5 for its use in this case study was the press. Two problems soon became apparent; firstly that the force being supplied by the car jack was not being evenly distributed over the post, and secondly, that even if this were to be corrected, the maximum pressure that this press could exert on the post would be inadequate. Because the Melbourne 5 was designed to produce low quality packaging papers, it was not considered necessary to generate high pressures in the press. In addition, the design of the press had to take into account the constraints of low cost, and simplicity of fabrication, balancing these against the maximum pressure obtainable simplicity of design and fabrication were considered
essential, by the designer, if the Melbourne were to prove an appropriate machine for Third World countries.

Pressing the wet sheets of paper after forming performs two functions: water removal and consolidation of the sheet. Before pressing the average sheet will have a consistency of about 90% water, and will need very careful handling as it has very little strength or stability as a sheet of paper. Pressing removes some of this water which both assists the drying process and enables easier handling of the sheet.

The average consistency after pressing in the Melbourne 5 press was found by weighing samples wet and dry before and after pressing, to be 85% water. This consistency is still too high to enable the sheet to be handled easily, without damage, without the support of the mesh. At consistencies below about 75% water, the wet sheet of paper can be reasonably freely handled without damage. 'Handling' refers to, for example, picking up the sheet and placing it on drying racks.

Grant et al (1978) state

"Water extraction is not the sole function of the press... indeed it is the press (part) that provides some of the quality characteristics of the final sheet by consolidation".

Pressing a sheet of wet paper assists fibre to fibre bonding, and consolidates the sheet such that it is less bulky and often stronger.

This indicated that if as initial experiments showed that the Melbourne 5 press was inadequate at water removal, that this inadequacy also affected the quality of the paper produced. In order to test this assumption, and assess an adequate force for pressing the paper,
the available literature on pressing paper (in particular pressing sheets of hand-made paper) was consulted, and a series of tests at a range of pressures carried out.

Heller (1978) quotes two pressures for pressing paper:
(i) \(150 \text{ lb/in}^2 = 1018 \text{ kN/m}^2\) (or \(34 \text{ tonne/0.33m}^2\))
(ii) \(500 \text{ lb/in}^2 = 3400 \text{ kN/m}^2\) (or \(114 \text{ tonne/0.33m}^2\))

No theoretical or practical justification is given for the first, and the second is quoted "to give a dryness of 65-75% dry content". Figures for pressure are usually quoted as lb/in\(^2\) or kN/m\(^2\), or in terms of the total force applied over the sheet, or sheets of paper. The sheets of paper produced by Melbourne 5 are 0.33m\(^2\) in area, hence it is useful to consider also the comparative pressure as a force over 0.33m\(^2\).

Hunter (1978) quotes a figure of 3000-45000kN/m\(^2\) (or 100-150 tonnes/0.33m\(^2\)) as a suitable pressure, but again with no theoretical justification. Grant et al (1978) suggests a pressure of 4700 kN/m\(^2\) (or 160 tonnes/0.33m\(^2\)) and Sweetman (1977) states, from experience at Wookey Hole Mill, that a pressure of 7000 kN/m\(^2\) (or 235 tonnes/0.33m\(^2\)) is required to press paper.

Experience gathered from individual hand-made paper-makers demonstrate that smaller pressures can work adequately. Bruce Glasser uses a press with a maximum force of 180 kN/m\(^2\) (or 6 tonnes/0.33m\(^2\)). Both the Farnsborough and Imago mills in California use forces up to 595 kN/m\(^2\) (or 20 tonne/0.33m\(^2\)) in their presses. All three paper-makers successfully market their finished papers.
Lack of theoretical explanation made it difficult to assess what might be an adequate pressure to aim for in designing a new press for the Melbourne 5 plant. Much of the information relies on historically accepted knowledge developed in the craft of paper-making, without indicating whether these pressures are in fact necessary and that smaller pressures would be sufficient, or not.

Comparing the figures quoted above, with the pressure realised in the Melbourne 5 press shows the latter to be significantly weaker. The Melbourne 5 press applies a force of about 1 tonne over 0.33m², whereas other hand-made paper makers use, or have used between 6 and 235 tonnes/0.33m².

Therefore the assumption was made that at least 6 tonnes force was required and preferably more. An important factor which limited the maximum pressure aimed at in designing a new press though, was balancing cost and ease of fabrication and operation with this maximum pressure. However two questions were still unanswered at this stage.

(i) Is there an optimum pressure at which the paper would best be pressed with respect to the quality of the finished paper and water removed?

(ii) Is it necessary to use a flat-plate press? or would a roller press produce better results?

A number of experiments were then designed to try and answer these questions, and the results used to develop design criteria for a new press. Additional criteria were low cost, and ease of fabrication and use. A 24 tonne flat plate press, was the result of these criteria.
(a) Roller press

The theoretical advantage of using rollers to press the wet sheets of paper is that to apply a linear pressure with a roller does not require as high force as a flat plate press delivering the same pressure. A flat plate press in this case would deliver a pressure equal to the force exerted over the area of the paper being pressed (ie pressure = force/0.33m$^2$). A roller press would deliver a linear pressure, which it was assumed for comparison not to be point contact but over a line of width 10mm. Therefore the area over which the force is delivered in a roller press will be the width of the paper and felts, (or post) multiplied by 10mm (ie 500 x 10 x 10$^{-6}$ m$^2$) which is 0.005m$^2$. The pressure delivered by a roller press in this case will equal force/0.005m$^2$. (This means that for the pressure in the roller press to equal that delivered in a flat plate press will only require 1/66 of the force (ie force roller = 0.015 force flat plate).

To test the idea of a roller press in practice, a cast-iron frame wooden roller mangle was purchased. The rollers needed some attention, and were filled and skimmed to bring their surfaces parallel to each other. The pressures exerted by these rollers were not expected to be sufficiently high to produce good results but adequate to demonstrate the practicability of using a roller press before building a stronger "mangle". Unfortunately, the mangle was found to be difficult to use, time-consuming and to cause deformation of the sheet. (Due to the high degree of wetness of the sheet, the mangle set up a ripple wave through the sheet, hence deforming it.) Pressing a sheet between two aluminium plates to avoid this effect, was not successful.

It appeared therefore that a number of problems needed overcoming in the design of a suitable roller press, and that it might only be
suitable as a second press, to be used after initial pressing in a flat press. Time constraints unfortunately meant a choice at this stage between pursuing experimentation with roller press designs and flat-plate presses. The use of flat-plate presses was the more proven method of pressing hand-made paper, and hence this approach was pursued.

(b) **Tests to determine optimum pressure**

No clear indication of the optimum desirable pressure came from the available literature on pressing hand-made paper, with recommended pressures from around 180-7000 kN/m² (6-235 tonnes/0.33m²) quoted.

In order to determine an optimum desirable pressure for a flat-plate press for the Melbourne plant a series of tests on small samples of paper, to find out more clearly the relationship between pressure, time and water removal, were carried out.

These tests were carried out using a stress/strain measuring machine, which had load cells delivering forces ranging from 0-100kN. The tests were carried out on sample sheets 100mm x 100mm, made by hand using a small mould and deckle. This resulted in pressures in the range 0-6000 kN/m² (equivalent to 0-200 tonnes/0.33m²). The length of time pressed was also varied from 1-120 minutes.

In each test the water content of the sheet before pressing, and after pressing was determined by weighing sample sheets immediately and when air-dry. These results of those tests are shown below in table 8.1, and plotted out in figs 8.14 and 8.15. They show that the water content decreases as both time and pressure increase. The relationship is not linear; the slope of the curves decrease as either pressure or time increase. There appears to be no obvious break points in the
## Table 8.1 PRESSURE TESTING RESULTS

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Moisture Content of Paper (%) after pressing for</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 min</td>
</tr>
<tr>
<td>39kN/m² (1.3 tonnes/0.33m²)</td>
<td>85.6</td>
</tr>
<tr>
<td>98kN/m² (3.3t/0.33m²)</td>
<td>84.3</td>
</tr>
<tr>
<td>196kN/m² (6.6t/0.33m²)</td>
<td>84.1</td>
</tr>
<tr>
<td>294kN/m² (9.9t/0.33m²)</td>
<td>83.8</td>
</tr>
<tr>
<td>392kN/m² (13.2t/0.33m²)</td>
<td>80.0</td>
</tr>
<tr>
<td>490kN/m² (16.5t/0.33m²)</td>
<td>79.7</td>
</tr>
<tr>
<td>1000kN/m² (33.6t/0.33m²)</td>
<td>77.6</td>
</tr>
<tr>
<td>2000kN/m² (67.3t/0.33m²)</td>
<td>75.6</td>
</tr>
<tr>
<td>4000kN/m² (134t/0.33m²)</td>
<td>75.1</td>
</tr>
<tr>
<td>6000kN/m² (202t/0.33m²)</td>
<td>71.7</td>
</tr>
</tbody>
</table>

**Note**

Average Moisture content of the control group (ie (before pressing) was 88.2%
Fig 8.15
GRAPH OF MOISTURE VS TIME (Constant pressure 29.4 kN/m²)

Moisture (%) vs Time (Minutes)

Optimum time range
curve, neither is there a point at which increasing pressure or time cease to improve water removal within the range tested. However, there appear to be diminishing returns, as both time and pressure are increased. The graphs show the slopes decreasing significantly at around 10-20 minutes and 750-1250\,kN/m^2 (25-40 tonnes/0.33m^2).

These results give an indication of the relationship between water removal, pressure and time, and indicate suitable times and pressures to aim at in the design of a press for the Melbourne plant. Water removal to a moisture content of about 75\% would appear, from the literature and practical experience in handling sheets of paper with different moisture contents, to be adequate. This can be achieved by a pressure or about 300kN/m^2 (10 tonnes/0.33^2) for 30 minutes, or greater pressure for less time. Concluding that increasing pressure and time will improve the water removal, but that at above pressures of 750-1200\,kN/m^2 (25-40 tonnes/0.33m^2) for more than 10-20 minutes diminishing improvements result. It was considered that these pressure and time ranges therefore were the optimum ones to aim at in designing a new press.

This optimum refers only to water removal though, and the effects of varying pressures on the quality of the sheet were not included in this analysis. Quality of the sheet of paper was difficult to assess quantitatively without specialist equipment which was not readily available. In relation to this project such specialist analysis of the paper was not thought to be relevant, particularly when considering that subsequent assessment of the quality of the paper and potential product range that could be produced would be carried out on the basis
of subjective qualitative assessment, not quantitative analysis. However qualitative assessment of the small test sheets made in these experiments did not reveal much, and it was concluded that the effect of pressure and time variations on quality could not be assessed until more extensive experiments could be carried out on full-sized sheets of paper.

Hence an additional criterion was included in the design specification of the new press: that rather than look for the minimum pressure necessary to achieve the desired water removal, that the maximum practical pressure within the cost restraints should be arrived at, in order that further tests could be carried out on the relationship between pressure, time and quality. This consideration supported the conclusion above to aim at a maximum pressure in the range of 750-1200kN/m$^2$ (25-40 tonnes/0.33m$^2$) as the optimum for the new press, rather than the lower pressure of 300kN/m$^2$ (10 tonnes/0.33m$^2$) which achieves adequate water removal.

(c) The design of the 'ATG' press

In considering the design criteria for a replacement press, desired maximum pressure was the major but not sole factor. Cost and ease of manufacture, and replicability had also to be considered.

This meant readily available parts and materials, and workshop manufacture. Cost constraints were more difficult to define. It will depend on the use that the machine is to be put to, on what the pay back time, and hence the cost brackets, will need to be. The criteria was to minimise cost as much as practicable, whilst aiming to produce a pressure of up to 750-1200kN/m$^2$ (25-40 tonnes/0.33m$^2$).
A designer was commissioned, and taking the above constraints into account, arrived at a suitable design for a 24 tonne press, at an expected cost of £500 for materials. This design was built, and is shown in fig 8.16. Some of the features of the design are described below. The operation of the ATG press with the Melbourne 5 plant was found to be very successful.

- The paper press was designed to exert a continuous force of up to 24 tonnes over an extended period upon a stack of damp paper from the Melbourne 5 paper-making machine. The force is exerted by a hydraulic cylinder and the hydraulic pressure is developed by hand with a pump which means that the press is not dependent on an electrical or compressed air supply. Up to one minute of pumping is required in order to close the plates on the stack of paper and apply the maximum force, but thereafter the force is maintained without further effort.

- A water tray is fitted on top of the bottom plate which catches the water which is squeezed out of the damp paper and channels it to a single outlet where it is piped down into a bucket. The tray is made of aluminium to prevent rusting, and is designed so that a stack of paper may be slid directly onto the flat pressing face.

- The plates between which the paper is pressed were sized slightly larger than the sheets of mesh used in the Melbourne 5 so as to ensure that a stack of damp paper positioned without perfect accuracy would still be pressed over its entire area. The gap between the plates is sufficient to take at least 30 minutes of production.
Fig 8.16  THE ATG PRESS
Fig 8.16 continued
- All the hydraulic components are located below the bottom plate so as to eliminate the possibility of hydraulic fluid leaking onto the paper and ruining it. Also, having the hydraulic cylinder underneath the moving bottom plate means that gravity may be utilised to return the plate to its rest position, eliminating the need for return springs. In practice an additional force was found necessary to overcome the friction of the seals in the cylinder, and return the bottom assembly. This force was first achieved by adding weights to the bottom plate; but a more satisfactory solution was arrived at which involved the addition of a small foot-pump to the hydraulic system to enable the cylinder to be pumped down (see fig 8.17).

- A pressure gauge is provided close to the hand pump which indicates the pressure at the cylinder. 3000 PSI is the maximum working pressure and corresponds to 24 tonnes. Lower pressures correspond to proportionately lower forces.

- The frame and plates were designed using rolled steel sections so as to minimise the deflections of the plates. Theoretical calculations indicate that the maximum deflection of each plate under the maximum load would be 0.4mm. This degree of stiffness in the plates ensures that the pressure is effectively constant over the entire area of the paper.

- The press was designed to be of simple construction, and may be built in a well-equipped workshop.
Fig 8.17 THE ATG PRESS - MODIFIED
(d) Tests to determine the relationship between pressure, time and the quality of the paper produced

To determine the relationship of the quality of paper produced with the pressure used, a range of papers were made varying both the amount of pressure and the time under pressure for each batch. The way in which these parameters were varied is shown in table 8.2 and comparison of the resulting papers gave the following results:

- The papers pressed at 50 kN/m² (1.6 tonnes/0.33 m²) did not handle well after pressing, probably because too little water had been removed during pressing.

- The papers pressed at 50 kN/m² (1.6 tonnes/0.33 m²) were noticeably softer to the feel than other papers pressed at 250 kN/m² (8 tonnes/0.33 m²) and above. They tore more easily, and their softer surface scratched and rubbed away more easily, and gave less definition when written or drawn on.

- No other significant differences were found between the papers, and no differences in quality were apparent between papers pressed at 250, 500, 750 kN/m² (8, 16 and 24 tonnes/0.33 m²) for any length of time.

The main conclusion to be drawn from this is that there is a noticeable improvement in the quality of the paper when the pressure is increased from 50 to 250 kN/m² (1.6 to 8 tonnes/0.33 m²), but that above 250 kN/m² (8 tonnes/0.33 m²) no further improvement occurs. This does not however indicate what the minimum pressure, above which no noticeable improvement in quality occurs, is. Additional tests at pressures between 50 and 250 kN/m² (1.6 and 8 tonnes/0.33 m²) would be necessary to determine this.

Combining the results of these tests with those described for earlier water-removal, however, shows that it is not actually necessary to determine the minimum pressure required to produce adequate
quality paper. The minimum pressure required to achieve adequate water removal from the paper (ie to reduce moisture content to 75%) in reasonable working time (ie 30 minutes) was 300 kN/m² (10 tonnes/0.33 m²).

Table 8.2 PAPERS MADE TO TEST THE RELATIONSHIP BETWEEN PRESSURE, TIME AND QUALITY

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Time 1 min</th>
<th>5 mins</th>
<th>15 mins</th>
<th>30 mins</th>
<th>60 mins</th>
<th>150 mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 kN/m² (1.6 tonnes/0.33 m²)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>250 kN/m² (8 tonnes/0.33 m²)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>250 kN/m² (16 tonnes/0.33 m²)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>750 kN/m² (25 tonnes/0.33 m²)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔ ✔</td>
</tr>
</tbody>
</table>

- indicates papers made under these conditions

Having already determined that 10 tonnes/0.33 m² is sufficient pressure to produce adequate quality paper, then it can be concluded that this is the minimum adequate pressure for the paper press. Higher pressures will achieve better water removal and hence reduce drying time. However, this benefit must be balanced against the cost of the press, and a press designed to achieve a maximum pressure of 300 kN/m² (10 tonnes/0.33 m²) will be significantly cheaper than a press with a maximum pressure of 750 kN/m² (24 tonnes/0.33 m²). If cost is an important factor, then a press with a maximum pressure of 300 kN/m² will probably be the optimum choice.
8.1.4 Production Output

In order to acquire some realistic, practical data on the projected production output of the ATG paper recycling plant it was necessary to use the experience of operating the equipment outside of laboratory test conditions. This was achieved in the pilot study, working in collaboration with the Milton Keynes Neighbourhood Care Youth Opportunities Programme (YOP) scheme. This involved working with a team of a supervisor and three YOP trainees; the trainees were operating the ATG paper recycling plant one day per week over a period of five months. A detailed record of hours worked, output, reject rate, inputs, and other running costs and overheads, was kept throughout the project. A summary of this record is included as Appendix 1. Fig. 8.18 shows the YOP trainees operating the ATG paper recycling plant, and Fig. 8.19 the equipment layout and workshop.

In analysing this data, a number of factors need to be taken into consideration, which had a significant effect on the performance of the YOP trainees as workers in this production exercise. The YOP supervisor showed a certain lack of involvement and interest in the project which contributed much towards the lack of motivation seen in the YOP trainees. This was compounded by working only one shortened day (due to the supervisor's staff meeting) per week, which was very disruptive of any continuity in the experiment and hampered the trainees' development of skills. Under these conditions it became difficult to establish an atmosphere of serious work in the project. In this respect then the results should be interpreted in the following ways:
Fig 8.18 YOP TRAINEES OPERATING ATG PAPER RECYCLING PLANT
Fig 8.19 PAPER RECYCLING WORKSHOP
discount weeks 4, 5 and 11 which were unusually disruptive periods, shown by the high reject rates (greater than 30%) for those weeks;

consider the average output to be a low estimate of what could be achieved by a more involved, motivated group of two or three workers.

The latter interpretation was confirmed by carrying out another short production experiment with two other members of the AT Group (results summarised in Appendix 1) giving output data for four and a half hours' production, which was then analysed to facilitate comparison with the YOP project data. The papers produced by both groups were graded into 3 categories: grade I (the best quality sheets produced with even fibre distribution and no imperfections such as spotting or tears in the sheets); grade II (medium quality sheets with small imperfections such as spotting, and less even fibre distribution, being acceptable); and reject sheets which had imperfections such as tears, holes or significantly uneven fibre distribution. Grade I sheets were judged to be of suitable quality for use as art paper, and grades I and II were of suitable quality for use as sugar paper. The average number of sheets of (sugar paper quality) paper produced by YOP trainees per hour was seven, whereas AT Group members produced twelve. This was achieved by a combination of a higher production rate and lower reject rate.

Analysis of the record of these two production trials showed that the time taken to perform the individual functions in the process varied little between the two groups. The AT Group members however were able to organise the series of functions more efficiently, and hence achieve
a higher production rate. It is possible that with greater experience, the workers could become more efficient and achieve a higher production rate than the AT Group members achieved, but probably not significantly more.

Based on these results an optimised production chart for the paper plant operated by two workers, was compiled based on the average times achieved for each individual function. This chart is included in Appendix 1 and gives an optimal production output of 12.5 sheets of sugar paper quality and 11.5 sheets of art paper quality per hour of production. Two competent and motivated workers should be able to achieve this figure after a period of training.

In running a paper-recycling business, other functions other than paper-making would be involved, such as ordering raw materials, sales, delivery and collections, and business administration and accounts. These aspects were not included in the YOP project, but allowance must be made for them for an accurate picture of the production output of such a community enterprise to be obtained, and hence an accurate financial evaluation undertaken. A very conservative estimate of one half a day per week, or a one-person day per week, was assumed would be necessary to perform these functions in a two-person paper recycling business. Hence the weekly optimum production output would be four and a half days' production at 12.5 sheets of sugar paper quality and 11.5 sheets of art paper quality per hour, which is 393 of sugar paper quality and 365 sheets of art paper quality per week (see Appendix 1). This is equivalent to 35 reams of sugar paper quality or 33 reams of art paper quality per annum.
8.1.5 **Product Development**

Initial investigations of the potential product range of the ATG paper recycling plant included discussions with Anthony Hopkinson (the designer of the Melbourne plant), hand-made paper-makers Bruce Glasser, Peter Bower and Chris Gander, the manager and paper-makers at the Wookey Hole hand-made papermill in Somerset and the Paper Science Department at the University of Manchester Institute of Science and Technology (UMIST). These discussions, together with ideas stimulated by the literature on hand-made papers, and other paper products, and some initial experiments with the Melbourne 5 plant, suggested the following range of possible products which could be made:

(i) sheets of paper and card for writing, drawing and printing uses;

(ii) packaging papers such as wrapping papers, or lining papers;

(iii) moulded products such as masks, display goods and decorative ware and moulded packaging for fruit, eggs, etc;

(iv) laminated paper products, using a resin binder, including the possibility of developing a lightweight roofing tile, and other building materials.
Within each of the above groups of products lies considerable scope for experimentation, and hence it was not possible to explore fully all the potential products. The equipment was capable, without further modification, of producing sheets of paper and card for the range of uses described in product categories (i) and (ii) above. The production of moulded paper, paper/resin and laminated goods all require further development of the ATG paper recycling plant to incorporate additional equipment and processes. Also some work is being done in this area by Anthony Hopkinson of Third Scale Technology Ltd. For these reasons investigations were concentrated on the production of sheets of paper or card. Also for the additional reasons outlined below, packaging papers were disregarded. The range of products was narrowed further to paper and card for writing, drawing and printing uses.

Packaging products have the advantage of a very widespread demand with almost all industrial, retail and agricultural processes using some packaging materials. However neighbourhood scale packaging production would have to compete with widely available, cheap, bulk-produced packaging materials, already produced from recycled waste paper.

There may be potential markets for a neighbourhood-based recycling mill in supplying a specific or specialised local demand. For example a moulded packaging product designed for a specific component or item, or a product which serves a local need such as the mill in Ambert, France (described in Chapter 5) which produces paper for packing apples in this apple growing district. Such a local demand or need
in the Milton Keynes area was not obvious on preliminary investigation.

Writing, printing and drawing papers (excluding newsprint) account for just under 20% of the paper and board consumed in the UK; about 1.5 million tonnes per annum. The demand for these papers exists in any 'community', in particular in respect of papers for schools and individual use. Papers for offices and for printing will have a more varying demand from area to area, but nonetheless widespread. The range of product uses and specifications in this category are considerable, including cartridge paper, sugar paper, coated book paper, duplicating paper and many more, and although some could be satisfied by the recycled paper made on the ATG paper plant, others could not.

This stage of the feasibility study therefore was seen as identifying the range of papers, suitable for writing, drawing and printing uses, which could be produced on the ATG recycling plant. Further consideration of the potential markets for these papers, and the economics of their production will be explained in Chapters 9 and 10. To determine the range of characteristics that could be produced, a series of experiments was carried out on varying factors such as weight, additives and raw material. The papers made were then compared in a number of ways initially including a subjective assessment and the use of some simple tests. Further product evaluation, using assessment of consumer reactions, was carried out in the evaluation report and is described in Chapter 9.

(a) Paper-making tests

A range of different papers were made by varying the following:
o **raw material:** Three different types of waste paper were used; newspaper, mixed office waste and computer paper;

- **weight of each sheet:** paper is often categorised by its weight, the measurement used is gsm, or grammes per square metre. For example, a typical typing paper would be 70 gsm, a sugar (or drawing) paper 150 gsm, and a thin card around 300 gsm. Preliminary experiments on the ATG paper plant showed that paper and card could be made successfully from about 100 gsm to 400 gsm. Below 100 gsm there was insufficient fibre to form a full sheet, and above 400 gsm the sheet became too thick to allow sufficient drainage for the fibres to hold together. Heavier papers could be made, though, by pressing together once-pressed sheets of paper whilst still wet (i.e. laminating).

- **addition of size:** unsized paper will generally be absorbant and cause water-based inks or paints to 'feather' or spread. A variety of chemicals can be used as sizing agents (see Chapter 5) and a commercial synthetic size, Aquapel, an alkyl ketone dimer compound, was chosen. There are a number of grades of Aquapel, and the manufacturers recommended using numbers 3 or 5 for hand-made papers. Hopkinson (1978) recommended using Aquapel at concentrations of 15 ml per 50 gms dry weight of fibre. This corresponds to about 75 ml per 15 L of pulp/one refiner batch, containing on average 250 gms dry weight of fibre. To compare different degrees of sizing a range of 25-150 ml of size per refiner load, was experimented with.

- **addition of starch:** Starch is often added to papers to improve its handling, or rattle, its strength, to give a better surface, and
reduce surface fluffing. Quantities recommended by hand-made paper-makers, Studley (1878) and Hopkinson (1978), are in the range of 1 tablespoon of starch powder for between 50 and 150 grammes dry weight of fibre in the pulp. This corresponds to between 2 and 5 tablespoons of starch powder per refiner load of pulp containing on average 250 gms dry weight of fibre. A household starch was used.

- **addition of china clay**: China clay is added as a filler to produce a smoother surface, and improve the printability of the sheet. It is not often used with hand-made papers. Hopkinson (1978) recommends that china clay should not be used at concentrations above 10% of the dry weight of pulp, as its presence interferes with fibre bonding thus weakening the sheet. Quantities corresponding to 5% and 10% of dry weight of fibre, that is approx 12 and 25 gms per pulper load, were experimented with.

- **addition of dyes**: Although not affecting the other physical properties of the sheet addition of dye-stuffs change the appearance of the paper, and a range of basic dyes for paper-making were experimented with.

Of the above six parameters, the last factor, the addition of dyes, was considered independently of the other five, as this did not affect the physical properties of the sheet. In order to assess the effects of changes in the other five parameters, one parameter was varied at a time, whilst the other four were kept constant, and at least six sheets of each type was made. Not every possible variation was explored, just the range of papers listed in Table 8.3, which were considered sufficient
to assess the effects of each parameter. Examples of some of these different papers can be found in Appendix 2: Paper Sample File.

Table 8.3 RANGE OF PAPERS MADE

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Weight/gsm</th>
<th>Size</th>
<th>Starch</th>
<th>China Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>newspaper</td>
<td>100, 100, 150, 200, 250, 300, 350, 400, 400</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>25ml, 50ml, 100ml, 150ml</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50ml</td>
<td>2 tbsp</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td></td>
<td>none</td>
<td>2 tbsp</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td></td>
<td>none</td>
<td>12gm</td>
<td>25gm</td>
</tr>
<tr>
<td>Computer paper</td>
<td>same range as above</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office waste paper</td>
<td>same range as above</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first group of experiments showed that the range of weights of papers that could be made adequately was between 100 gsm and 400 gsm (see sample group A in the paper sample file). Between 100 and 150 gsm the sheets of paper were thin, and not very strong, and it was difficult
to achieve an even consistency and distribution of fibres throughout the sheet. This was shown up by the higher proportion of reject sheets for papers under 150gsm than above. The best consistent results in terms of even distribution of fibres and finish were achieved in the range of 150gsm - 250 gsm. These papers were of suitable weights for printing and drawing, and possibly writing, papers. Above 250gsm, the papers produced more resembled thin card, and were quite successful although suffered more than the lighter weight papers from problems of uneven drying and associated cockling and curling in the sheet. As a result of this, 200gsm was chosen as a suitable weight for subsequent tests to compare the effects of size, starch and china clay on the papers produced.

The use of dyes was experimented with independently of all the other variables and a wide range of different coloured papers were made, ranging from off-white, through pastel shades to deep colours. The colour of the finished sheet is affected by the colour of the waste paper used and hence the colour the paper being made can be controlled by the addition of a suitable coloured waste paper. This has the advantage of not colouring the water, and is cheaper than using dyes.

(b) Product Assessment

Having produced a wide range of papers, the next step was to compare their properties, and to assess the product capabilities of these papers. This was initially done in two ways:

(i) subjective assessment - visual, comparison of papers, plus comparison of their 'feel' (eg crackle, smoothness etc).

(ii) simple comparative tests.
Subjective Assessment

The comparisons drawn in this assessment are supported by reference to a file of paper samples submitted, together with this thesis. The 150-200 gsm ATG papers have a similar feel, weight and thickness to sugar and brushwork papers, used for drawing and painting, particularly by schools sample (compare A2 and A3 with H1, 2 and 3) surface hardness is also similar, although the newspaper-based ATG papers were softer. Also all these ATG papers felt stronger and heavier than the paper typically used for children's sketch pads.

Some cartridge papers and pastels paper have similar feel, weight and thickness to the medium weight ATG papers, in general they had much harder surfaces than all but the office or computer waste-based ATG papers with starch (compare C6 - 9 with H4 and 5). Watercolour papers such as sample H6 felt harder and stronger than the ATG papers.

The lighter weight (100-150gsm) office and computer waste-based ATG papers (see samples A1 and A2) felt suitable for use as writing paper, whereas the newspaper-based ATG papers were too soft and 'spongey' in their texture. In general the office and computer-based ATG papers were slightly stronger, didn't tear as easily, and had harder surfaces than those made from newspaper (compare papers in sample group B). The newspaper-based papers in general though seemed bulkier, and appeared more opaque, so as to give the appearance of a more even fibre distribution.

Addition of china clay to the paper seems to improve the smoothness and opacity of some of the sheets, in particular with the office and computer-waste-based papers, as seen in sample group E. Starch imparts a stiffness and 'crackle' to the sheet, and seems to produce a harder
surface in the papers to which it is added, as demonstrated by samples C6 -9 and sample group D. Two tablespoons however seemed adequate, as with higher concentrations there was a tendency for the paper to stick to the mesh, and spoil the surface. In particular the addition of starch to the newspaper-based ATG papers produced a less soft, or spongey, surface to the sheet, a very useful improvement.

Surface texture is an important factor in what a paper is used for, and by varying the texture, the range of uses can be widened. The variety of textures experimented with, including smooth, mesh, felt or rough, and others such as plywood imprint, produced a useful range of papers (see sample group F). A smooth surface considerably improved the quality of the paper for some writing and drawing work, particularly for pen and ink, and pencil work.

It is possible to produce a wide range of coloured papers. However the newspaper-based ATG papers tend to have rather duller, more muted shades than the other papers. The office-and-computer-waste based ATG papers were better for pastel shades or bright colours, although the computer-waste-based papers all had a bluish tinge to them due to the blue dye in the waste paper.

(ii) **Simple Comparative Tests**

Samples of each type of paper were tested by writing, drawing and printing on them, and to facilitate comparison, the same word or number was written or drawn for each medium used. The media used were:

1. biro; 2. felt-tip pen; 3. fountain pen and ink; 4. pencil;
5. coloured pencil; 6. oil pastel; 7. pastel; 8. water colour;
9. crayon. Each sample was also tested for its suitability for letterpress printing, and a selection of papers for screen printing.
In addition these papers compared with some tests done on commercially available papers including papers from the GLC supplies department and used by schools in Milton Keynes (samples of some of the papers tested are included in sample group H). The GLC papers tested were heavy (150gsm) and medium (100gsm) sugar paper, brushwork paper (140gsm) heavy cartridge (160gsm), medium cartridge (118gsm), three other 160gsm cartridge papers with smooth, not (ie matt) and rough surface finishes, and exercise-book paper. Another sugar paper (180gsm) was tested, as well as 150gsm watercolour paper; 90gsm pastels paper; cheap, 'good' quality, 'hand-made' and recycled writing papers; a children's drawing sketch pad; and a scribble pad.

In making comparisons, four main characteristics were examined: absorbancy, and suitability as writing paper, as drawing/painting paper, and as printing paper.

- Absorbancy

Two tests were used to compare the absorbancy of the papers made:
- the rate at which an ink blot soaked in to the paper, and how it spread.
- the response to watercolour paints, and a watercolour wash.

Both were judged subjectively on a scale of 1-5, with '1' referring to papers with very little absorbancy (ie those which were repellant to watercolour paints, and absorbed very little ink) and '5' to those which were very absorbant (ie ink and watercolour paints soaked into the paper straight away, and it was difficult to apply a watercolour wash). Table 8.4 shows the results of these tests on the whole range of ATG papers made, and table 8.5 gives the results of the same tests carried out on a range of commercially available papers.

It is obvious from table 8.4 that sizing was effective, and that the
sized papers were less absorbant than the unsized papers. Also that both starch and Aquapel are effective sizing agents.

Tests on the commercially available papers indicated that those intended for use with watercolour or water-based paints and inks (ie cartridge and watercolour papers) had an average rating of '2' for both tests. Some of the ATG papers were rated at '1' for both tests, and these papers seemed to be too highly sized. A rating of '1' for the watercolour paint test in particular indicated that the paper was too highly sized, and it was difficult in these cases to apply watercolour paints to the paper as they appeared to be repelled by the paper. These were typically papers with more than 100ml of Aquapel size, or with both starch and Aquapel size added. This conclusion is supported by table 8.6 showing the average ratings for different groups of papers, and by reference to sample groups C and D which demonstrate the results of both absorbency tests on a range of unsized and sized papers.

Table 8.4 COMPARATIVE ABSORBENCY OF ATG PAPERS TO WATER-BASED INKS AND PAINTS

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>gsm</th>
<th>Aquapel</th>
<th>Starch</th>
<th>Kaolin</th>
<th>Ink-blot Test</th>
<th>Watercolour paints Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unsized Papers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td>100</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>150</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>250</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>300</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>350</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>400</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>&quot;</td>
<td>5%</td>
<td>&quot;</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>10%</td>
<td>&quot;</td>
<td>&quot;</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Computer paper</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&quot;</td>
<td>300</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>&quot;</td>
<td>5%</td>
<td>&quot;</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>&quot;</td>
<td>200</td>
<td>&quot;</td>
<td>10%</td>
<td>&quot;</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

cont/...
### Table 8.4 cont

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Ink-blot* Test</th>
<th>Watercolour* paints Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unsized Papers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 gsm</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>150 gsm</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>200 gsm</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>300 gsm</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>200 gsm</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>200 gsm</td>
<td>10%</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>Sized Papers (Aquapel size only)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>200 25ml</td>
<td>none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>News</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>50ml</td>
<td>none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>100ml</td>
<td>none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Aquapel size and starch)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>200 50ml</td>
<td>2 tbspoon none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>5 tbspoon</td>
<td>none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Starch only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>200 none</td>
<td>2 tbspoon none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>5 tbspoon</td>
<td>none</td>
</tr>
<tr>
<td>Computer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* measured on a scale 1-5; with 1 = low absorbency and 5 = high absorbency.

**papers in these tests did not behave as expected.
Table 8.5  **ABSORBENCY OF COMMERCIAL PAPERS**

<table>
<thead>
<tr>
<th>Paper</th>
<th>Inkblot* test</th>
<th>Watercolour* paints test</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLC supplies dept papers:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar paper - heavy (150gsm)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&quot; &quot; - medium (100gsm)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Brushwork (140gsm)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Cartridge paper - medium (118gsm)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>&quot; &quot; - heavy (160gsm)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exercise book paper</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Art papers:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar paper (180gsm)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>'Kids' sketch pad</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Watercolour paper (150 gsm)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pastels paper (90gsm)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Writing paper:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>'Good' (Basildon Bond)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>'Cheap'</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Recycled paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scribble pad</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Hand-made writing paper (Wookey Hole)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* measured on a scale 1-5; with 1 = low absorbency and 5 = high absorbency.

The papers most suitable for work with watercolour or water-based paints or inks appear to be those with 25-50ml of Aquapel size, or 2 tablespoons of starch. A combination not tried in these tests of 25ml of Aquapel + 1 tablespoon of starch may well also provide adequate sizing in view of these results.

o **Suitability as writing paper**

Most writing papers are in the 60-85gsm range, and it proved to be more difficult to make paper of below 100gsm consistently. Some heavier
weight papers are produced as writing papers, particularly the 'expensive' hand-made papers. The newspaper-based ATG papers were mostly too soft to be a good writing paper, although those with starch were adequate. The other papers all performed well with biro, pencil and felt-tip pens, with better definition being achieved on those papers with harder surfaces. Surface texture also played an important part with smoother surfaces performing better. Few of the papers worked well with fountain pen and ink, because even with the harder surface papers (ie those with starch) the surface scratched and tore.

Table 8.6 SUMMARY OF THE COMPARATIVE ABSORBENCY OF DIFFERENT TYPES OF ATG PAPER

<table>
<thead>
<tr>
<th>ATG Paper Type</th>
<th>Ink blot test*</th>
<th>Watercolour paint test*</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsized</td>
<td>3.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Aquapel size - 25ml</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>- 50ml</td>
<td>1.5</td>
<td>2.2</td>
</tr>
<tr>
<td>-100ml</td>
<td>1.0</td>
<td>1.66</td>
</tr>
<tr>
<td>-150ml</td>
<td>1.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Aquapel size + starch/ (50ml)</td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Starch 2 tblsp</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Starch 5 tblsp</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*measured on a scale 1-5; with 1=low absorbency and 5=high absorbency.

- Suitability as drawing/painting paper

A wide range of drawing/painting papers are made and sold, many with specialist uses and others suitable for a variety of uses.
The ATG papers were compared with a range of commercial papers looking at their suitability for use with pastels, oil pastels, pencils, crayons and watercolour paints. It was difficult to gain a significant comparison from such a small application, but the following points emerged:

- for pencil, crayon, pastels and oil pastels variations in surface texture were probably more significant than other factors, both with the ATG papers and those commercially available (see sample group F);
- once again the softness of newspaper-based ATG papers was a disadvantage with pencils because of definition, but these papers were suitable for using with the other media (see samples B1 and group D);
- some of the ATG papers seemed too repellant of water for them to be suitable for watercolour painting (i.e. those rated '1' in table 8.4; refer to sample group C). All the ATG papers cockle and stretch when wet and don't shrink back to shape as they dry. Cartridge papers behave in the same way; however the watercolour paper tested did not stretch on wetting;
- all the ATG papers took pastels, oil pastels and crayons well. Commercial pastels paper did seem to have a harder surface than the ATG papers, producing a slightly clearer image (compare sample groups B and C with H5).

o Suitability as printing paper

Only letterpress and screen printing were experimented with, as other printing processes such as offset litho and duplicating require papers of a more consistent and even thickness to facilitate trouble-free feeding. The letterpress printing tests were carried out with an
Adana hand operated 5' x 3' machine, with consistently good results (see samples G6 and 7). The softness of the ATG papers produced a good imprint, and here the softness of the newspaper-based papers was an advantage.

A selection of papers were tried out for suitability for screen printing, first using a ready prepared screen of a fine-lined Indian drawing and water-based inks (see sample G4). The ATG papers tested included papers made from newspaper and office wastes, unsized papers and papers with 25, 50, 100 and 150 ml of Aquapel size added. The results showed that all the papers took the water-based screen inks used equally well, generally producing good results. The second screen print tried was a collage of trees, using a photographically prepared screen, with oil-based inks (see sample G5). Again definition was very good.

(c) Conclusions

Variations in raw materials used, and additives to the pulp such as starch, Aquapel size and china clay did not result in markedly different performances between the papers produced, with the exception of absorption qualities. The distinction between sized and unsized paper was an important one, but other variations in paper type due to content or type of pulp were in general not easily distinguished from random variations, inherent in a manufacturing process which does not produce a consistent quality product anyway.

Some small differences which did become apparent were:
(i) newspaper-based papers were bulkier, softer and more opaque than those recycled from office or computer-waste (compare papers in sample group B);

(ii) unsized newspaper based papers had a particularly 'soft' surface which had a tendency to rub away under firm pressure - this was not so apparent with sized newspaper based papers (compare sample B with sample group D);

(iii) the addition of starch gave some additional surface strength to papers (as samples C6-9, and D3 show);

(iv) the addition of kaolin improved the surface smoothness of some papers (see sample group E) but not consistently so.

Sizing was an important quality in the finished papers. If water-based paints or inks are to be used with the paper it is important that it is adequately sized; and 25-50 ml of Aquapel size or about 2 tablespoons of 'household' starch per refiner batch were found to give the best results (see sample group C).

Unsized paper can be used with pastels, oil pastels, acrylic paints, pencils, crayons and printing work.

The best consistent quality was produced with papers around 200 gsm weight, and these papers were most suitable for drawing, painting and printing work.
Papers, of this weight, could be used in schools as a substitute for and supplement to sugar paper. It would probably be necessary to supply all sized paper for this use, particularly for pre-school, first and middle schools, where powder paints are used extensively. Both sized and unsized paper could be available to older students who are more discriminating.

For use as an art paper in a wider market, the paper has some potential. In particular it is most suitable for pastels, oil pastels, chalk, and charcoal drawing, and for screen and letterpress printing, and possibly etching work.

Producing both smooth and rough surface finishes would widen the uses of the paper. And a wide range of colours can be achieved. It would be possible to produce a 100-150 gsm writing paper from office or computer waste paper with Aquapel size and/or starch added.

8.2 FINANCIAL ANALYSIS OF PRODUCTION CAPACITY AND COST BEHAVIOUR

The data acquired during the operation of the pilot project is used to assess the annual projected production costs of an enterprise using the ATG paper recycling plant, employing 2 people, and producing either 'art' or sugar paper.

8.2.1 Calculation of Production Costs

The capital investment requirement of this paper recycling enterprise is the sum of the fixed capital (or capital cost of equipment required) and sufficient start-up or working capital. In this initial financial
analysis working capital is ignored; however in the more detailed financial evaluation in Chapter 9 the cost of working capital is calculated and included in the analysis.

Fixed capital requirements are as follows: the 1980 price for a Melbourne machine, including a pulper, refiner and former unit was £1,300. The cost of the ATG press was £1,000; (although it was concluded in section 8.1.3 that a smaller capacity, and hence cheaper, press would be adequate, this figure has been used in the analysis). Drying facilities and other necessary equipment such as storage containers, and additional felts and mesh and office equipment, are estimated to cost another £300. All these, and subsequent costs, are taken at 1980 values. It is assumed that this paper recycling enterprise would obtain a bank loan (a term loan) repayable over 5 years at 18% interest (rate in 1980) in order to raise the capital required to purchase this equipment.

The operating expenses are calculated from the experience and running costs of the pilot project and have been calculated on an annual basis. However, some costs were clearly not incurred during the pilot study e.g. telephone, postage, professional fees and insurance. These costs have been estimated in order to reflect the true cost of operating the ATG plant.

The pilot project was set up in a rented workshop in New Bradwell Workspace, a cooperatively managed group of workshops housed in a renovated school building. Aimed at providing accommodation suitable for new and small businesses, this matched the circumstances that this
production exercise was attempting to simulate, and hence provided valuable data on space requirements and costs (rent, rates and overheads).

Workshop space of around 250 sq. ft. would be required to house this enterprise, and this was found in New Bradwell Workspace at a cost of £1.60 per annum per sq. ft. for rent and rates plus an overheads premium of £33. This is relatively cheap accommodation of the type that would be sought by a new business.

Other overheads include heating, management costs and the cost of loan finance. Heating costs were calculated to amount to about £240 in an average year. This included using calor gas heaters, approximately £120 to heat the office, and a 46 working year was assumed, and £120 to provide a low temperature, hot air heat source to dry the paper produced.

Management costs include the following:

- stationery, printing, telephone and postage
- accounts, audit and legal fees
- insurance

Material costs include the following: waste paper, size and dyes. The production of 405 sheets per week, each weighing on average 50 gms (assuming the paper produced has an average weight of 200 gsm), implies a maximum consumption of 25 kg of waste paper per week, or 1.15 tonnes p.a. This could most probably be obtained free of charge for the
cost of collection; but assuming it is bought from a charitable or voluntary collecting group at a reasonably generous price of £20/tonne, the annual cost would be £23.

Other raw materials used include size and dyes. If all the paper produced used both size and dye, the cost would be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Quantity/Week</th>
<th>Cost/Week</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>25 ml/refiner batch</td>
<td>81</td>
<td>£50/100</td>
<td>£47 p.a.</td>
</tr>
<tr>
<td>DYE</td>
<td>1 ml/refiner batch</td>
<td>81</td>
<td>£2/1</td>
<td>£7.50 p.a.</td>
</tr>
</tbody>
</table>

This represents a maximum cost of around £80 for materials.

Some form of vehicle for transport of raw materials and possibly finished product would be necessary in the operation of such a paper recycling enterprise. However the anticipated distances involved are small, and a variety of vehicles could be considered, including bicycle and trailer, car or small van, or an electric vehicle. In addition it would not be required for full-time use, this vehicle could be shared with other business or private users, or a vehicle hired when required.

Probably the most realistic estimate of the cost of this transport will be provided by the cost of hiring a van for half a day every 6 months in order to collect raw materials supplies and make some local deliveries. Other deliveries of paper are assumed to be postal. Alternative methods of transport, such as using a shared car scheme vehicle, or a bicycle and trailer would either be less than this or negligible.
Labour is by far the largest single item of production costs. The average gross weekly earnings for manual work in 1980, as quoted in the Employment Gazette (DOE, monthly), was £113.06 for men and £68.73 for women. This gives an overall average of almost £91 per week. For two full-time employees this amounts to £182 per week, plus 20% overheads to cover the employer's contribution for National Insurance, sickness pay, maternity leave etc. (see Director of Social Change, 1980). This brings the total labour cost to £11,357 per annum.

A summary of the Pilot Study production costs are as follows:

<table>
<thead>
<tr>
<th>Capital equipment</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne 5 unit</td>
<td>1,300</td>
</tr>
<tr>
<td>Press</td>
<td>1,000</td>
</tr>
<tr>
<td>Drying unit</td>
<td>200</td>
</tr>
<tr>
<td>Office equipment</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,600</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating expenses (annual)</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank charges (repay £2,600 over 5 yrs.)</td>
<td>520</td>
</tr>
<tr>
<td>Interest (£2,600 at 18%)</td>
<td>468</td>
</tr>
<tr>
<td>Rent (250 ft² x £1.60 ft² + Premium)</td>
<td>433</td>
</tr>
<tr>
<td>Stationery/Printing/Telephone/Postage</td>
<td>450</td>
</tr>
<tr>
<td>Accounts/audit/legal</td>
<td>150</td>
</tr>
<tr>
<td>Insurance</td>
<td>100</td>
</tr>
<tr>
<td>Heating (office and workshop)</td>
<td>240</td>
</tr>
<tr>
<td>Labour (2 employees at £91/wk + 20% x 52)</td>
<td>11,357</td>
</tr>
<tr>
<td>Materials (size, dye, paper)</td>
<td>80</td>
</tr>
<tr>
<td>Transport</td>
<td>20</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>£13,818</strong></td>
</tr>
</tbody>
</table>
8.2.2 **Calculation of Unit Production Costs**

The principle concern in this section is the comparison of production costs for art and sugar paper to contribute to the selection of a product for further evaluation. For the purpose of this analysis and the more detailed evaluation in Chapter 9, a variable costing approach has been adopted as described by Arnold and Hope (1983) and Harper (1974).

The use of cost-volume-profit techniques rather than absorption costing methods was considered appropriate in this case in order to adequately reflect the strong relationship between unit cost and production output. The costs and production outputs were derived from the actual and estimated figures itemised in the previous section. In this comparative analysis, no account is taken of working capital (which in this case is taken to be the difference between the current assets and current liabilities of an enterprise operating the plant on the pilot study basis) but this is considered in more detail in the financial evaluation in Chapter 9.

The unit production costs were calculated as follows:

**Step (1) Analysis of cost behaviour into fixed and variable costs at outputs determined from pilot study;**

**Step (2) Use standard formula to determine unit cost at break-even point.**
STEP I - Analysis of Cost Behaviour

(i) FIXED COSTS

Capital equipment
Melbourne 5 unit 1,300
press 1,000
drying unit 200
office equipment 100
TOTAL £2,600

Annual depreciation charge (over 5 yrs.) = £520

Production and office costs p.a.
rent and premium 433
stationery etc. (fixed part) 225
accounts and professional fees 150
insurance 100
heating (fixed part) 120
interest on loan 468
labour 11,357

TOTAL fixed cost per annum £13,373

(ii) VARIABLE COSTS p.a.
stationery etc. (variable) 225
transport 20
materials 80
heating (variable) 120

TOTAL £445
VARIABLE COST PER REAM PRODUCED

Production output:

Output of paper of sugar paper quality = 393 sheets/wk
or 36 reams p.a.

(this production capacity is for paper grades I and II,
allowing for a 4% reject rate)

Output of paper of art paper quality = 365 sheets/wk
or 33 reams p.a.

(this production capacity is for paper grade I, allowing
for a 10% reject rate)

\[ \text{variable cost/ream} = \frac{445}{36} = 12.36 \]

\[ \text{variable cost/ream} = \frac{445}{33} = 13.48 \]

STEP II - Determine Unit Cost at Breakeven Point

The analysis of cost behaviour is summarised in Step I and using
these analysed costs and outputs, the unit cost at breakeven point
is calculated by applying to following formula:

\[ \text{unit cost} = \frac{\text{fixed cost} + (\text{variable cost/unit} \times \text{output})}{\text{output}} \]
Therefore for sugar paper quality, the unit cost at breakeven point is:

\[
\text{unit cost/ream} = \frac{\mathbf{\text{\£13,373}} + (12.36 \times 36)}{36} \\
= \mathbf{\£384} \text{ (or 77p/sheet)}
\]

And for art paper quality, the unit cost at breakeven point is:

\[
\text{unit cost/ream} = \frac{\mathbf{\text{\£13,373}} + (13.48 \times 33)}{33} \\
= \mathbf{\£419} \text{ (or 84p/sheet)}
\]

It can be seen that the process of producing sugar paper is similar to art paper. The costs of each process are also similar but the higher quality required for art paper leads to a higher reject rate compared to sugar paper. The consequently lower output of finished art paper means that the unit cost/ream of producing art paper is greater than for sugar paper at the breakeven point.

8.3 PRELIMINARY MARKETING RESEARCH

From the product development section it is clear that the ATG paper recycling plant can produce a range of papers and card which could potentially be sold. The aim of this section is to examine the various products from the point of view of market acceptance, potential sales levels, and potential profitability to aid the product selection process.
It was shown in section 8.1.5 that a range of usable printing and
drawing papers could be successfully manufactured, and that the
extremes of the range could be typified by sugar paper and art paper.
The sugar paper at the lower quality end of the range was less
consistent in its appearance and finish and had a low rejection
rate. In comparison, paper to be used as art paper placed more
stringent demands on the paper and therefore required more consistency
of finish, hence a higher reject rate.

This section will examine these 2 types of paper product - sugar paper
quality and art paper quality - with the aim of determining their
market acceptance and assessing their potential to generate sales
revenue. This information is required to assist in product selection.
In order to do this, this preliminary market research will focus on:

- identification of the range of uses
- identification of the range of users and outlets
- identification of the range of prices in the market and
calculation of market size and competition

8.3.1 Range of Product Uses and Users

Section 8.1.5 described the results of the subjective assessment and
the simple comparative tests that indicated that the ATG papers were
probably most suited as art/craft paper predominantly for use in
schools (as a substitute for sugar, brushwork and maybe cartridge
papers) and as a medium quality art paper. To assess the suitability of the ATG papers for these markets, a small sample of potential or typical consumers were asked to use and assess suitability themselves. The range of uses, and the range of users and outlets for the two types of paper are here explored further in parallel, as these two aspects of market research are significantly interdependent.

Table 8.7 SAMPLE GROUP OF ATG PAPER USERS

<table>
<thead>
<tr>
<th>Users</th>
<th>Age of users</th>
<th>Paper used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>creche</td>
<td>18 months - 5 years</td>
<td>powder paints for painting and printing</td>
</tr>
<tr>
<td>playgroup</td>
<td>3 - 5 years</td>
<td>crayon, felt-tip pens, powder paint, pencils</td>
</tr>
<tr>
<td>first school</td>
<td>5 - 8 years</td>
<td>crayon, powder paint</td>
</tr>
<tr>
<td>first school</td>
<td>7 - 8 years</td>
<td>powder paint, chalks, pastels, press printing, as backing paper</td>
</tr>
<tr>
<td>youth club</td>
<td>7 - 9 years</td>
<td>powder paint</td>
</tr>
<tr>
<td>middle school</td>
<td>9 - 10 years</td>
<td>powder paint, pastels as backing paper</td>
</tr>
<tr>
<td>secondary/</td>
<td>13 - 17 years</td>
<td>pastels, waterpaints, sakura, mounting paper</td>
</tr>
<tr>
<td>comprehensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>school</td>
<td></td>
<td></td>
</tr>
<tr>
<td>secondary/</td>
<td>16 - 18 years</td>
<td>oil-based silk screen printing</td>
</tr>
<tr>
<td>comprehensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>school</td>
<td></td>
<td></td>
</tr>
<tr>
<td>life drawing</td>
<td>adult</td>
<td>pencil, biro and crayon</td>
</tr>
<tr>
<td>classes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 individual</td>
<td>adult</td>
<td>pastels, oil pastels, watercolours, water-inks, charcoal, water-based silk-screen printing, acrylic paints</td>
</tr>
<tr>
<td>artists</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The potential users chosen spanned a wide age range, and covers both use in schools and as art papers. The groups chosen, and what they used the paper for, are shown in table 8.7.

The feedback received was examined from two different angles: by age or type of user, and by type of use. This produced two sets of categories of comments. The first group by user included pre-school, first and middle school, secondary/comprehensive school and adult/individual artist. The second group of categories by use included drawing (1) (pencil, biro, felt-tip), drawing (2) (crayon, pastels and charcoal), painting (waterbased and acrylic), screen printing (oil and waterbased inks), and others.

a) Pre-school children

The reaction from the staff and parents of children at the creche and the playgroup was favourable. The range of colours offered was particularly liked, although it was commented that with some of the deeper or brighter colours, the powder paints did not show up sufficiently against the background.

They commented on problems with the absorbency of the unsized papers for powder paints, and the staff at the creche who were using mostly unsized paper concluded:

"we found it too absorbent ...(we would be interested in buying the paper) if it could be improved."
The paper was felt to be good for use with crayons and felt-tip pens, and the size of the sheet was particularly liked by some of the children:

"Often friends would be involved on the same sheet."

Stiffness and thickness of the sheet was commented on by one parent of pre-school children who used the paper at home, who found that the paper:

"can be used without backing on a carpeted floor."

Both the creche and the playgroup have limited resources to buy paper and hence buy predominantly cheap newsprint paper, supplemented by smaller quantities of sugar paper. Although they liked the ATG paper, they didn't feel they could pay anymore for it particularly as, as one parent commented:

"the children are not ready to discriminate."

b) First and middle schools (5-10 years old)

Three teachers and a youth club leader of children in this age group were consulted for their, and their classes reactions to the ATG paper.

Two of the teachers commented that they felt that colours were too strong and bright, and that they distracted from the drawing or painting on them. They felt that pastel shades were more aesthetically
pleasing, and give a better background to work with. However, they both commented that the children liked the brighter colours.

The sized papers were found much more useful, with a lot of powder paint being used by these children which was not suitable on unsized papers. The texture of the paper was commented on favourably by all three teachers and the youth leader:

"Nice texture, interested children and encouraged them to take more care."

"Children liked the texture and commented on how it could be seen through their crayon drawings."

Other comments included "really nice for pastels and chalks" and favourable reactions to using the paper for crayons, press printing and as a backing paper for other pictures. However one teacher who used sugar paper for printing and making into bookcovers felt that the ATG paper was too weak for that type of use. (Here the starched and sized papers may have performed better than the unsized paper tried out for this purpose.)

Another teacher felt that the paper would be better trimmed and that the deckle-edge which wasn't appreciated by the children led to a lot of wastage.

All agreed that they would be interested in buying some of the ATG paper for their classes, either at the same price as GLC sugar paper or more if necessary for "special occasions". The general reaction
seemed to be that small quantities of the ATG paper could substitute or supplement the use of sugar paper; one teacher in particular commented that it could not replace all the uses of sugar paper.

c) Secondary/comprehensive schools (13-18 years old)

The teachers and the students consulted in this group were generally more appreciative of the hand-made quality of the ATG paper. As one teacher commented:

"not a passive medium like the plain white printing papers we usually use for screen printing - this paper adds a character of its own to be taken into account in the work."

Both the teachers said that they would be interested in buying small quantities at higher prices than GLC sugar paper - even substantially higher - since as one teacher put it:

"(I am) very pleased indeed with the paper."

In this group the paper was being used, and judged in the context of both categories of product, i.e. both as sugar paper and to a less extent as art paper. Comparing the ATG paper with the GLC sugar paper used in these schools, one teacher commented that it "behaved like heavy duty sugar paper" and the other "preferred it to the cheaper grades of sugar paper."

Again the texture was favourably commented on: "splendid texture for pastels", and another student using the paper for silk-screen
printing also commented that he preferred the papers with the most marked texture.

Also the range of colours was liked, although a preference for the pastel shades and off-whites was expressed.

On its absorption qualities, one class used the ATG paper with water-based paints and teacher commented that it performed "better than the GLC sugar type equivalent". In fact the reaction from both the teachers and students in the art departments of both these comprehensive schools was favourable to all the uses tried, and this may have been partially biased by the attitude of one of the teachers, in particular, who added that she "liked the concept of re-use".

d) Adult artists

The last group of users span a more diverse set of people, adult artists ranging from inexperienced amateurs to professional artists. On the whole this was the most critical group, which was expected. Comments though related more specifically to what the paper was used for, and thus leads on to a discussion of papers by uses.

e) Drawing (1) (pencil, biro, etc.)

In general the ATG paper was not considered suitable for fine pencil work: "didn't give a free feel", "can't get subtle effects, too course", "difficult to get definition", "wrong type of paper for subtle shading". However, some artists liked the texture and the "graining effect" that could be achieved. Some problems were caused
by the surface texture in rubbing out work; similar criticism was
levelled by another artist for charcoal work.

f) Drawing (2) (pastels, charcoal, etc.)

Surface texture featured as a predominant factor in most of the reactions
to the paper for pastels and charcoal use. However reactions differed
widely:

"good hard surface, doesn't rub away, even when using a lot
of pressure with oil pastels."

"weak surface, rubs away when pressing hard with pastels."

Subsequent correlation of the type of paper used in each of the cases
quoted showed the former was using sized office waste based paper and
newsprint based paper with starch and size; the latter a newsprint
based paper with no starch or size. This demonstrates the importance
of control of raw material and additives; both size and starch increase
the strength of the surface and office waste will generally make a
stronger paper than newspaper waste.

g) Painting

Sizing was an important factor for both water colour and water-inks.
Also one artist commented that unsized paper absorbed the moisture
in pastels making it difficult to achieve the desired effect and to
manoeuvre the pastels.

Papers with 50-100 ml of Aquapel size were well received, as was the
50 ml size plus 2 tablespoons of starch combination. These were
considered by one artist to take water-inks and water colour paints well, producing only temporary stretch and sagging when wet (which shrunk back to shape when dry). However, another artist felt the paper was not "dense enough" to take watercolour washes adequately.

Papers made with 150 ml Aquapel size were considered to be too well sized, and too water repellent for water colour work.

The paler colours were favoured for water colour work because of problems of colour show through. Similar comments were expressed for pastel work.

One artist used acrylic paints on the ATG paper with good results and she thought the paper may also be suitable for use with oil paints.

h) Printing

Sizing didn’t appear important with screen printing even with water-based inks, with good results being achieved with a range of papers. These included unsized newspaper and office waste based paper, and sized papers containing 25-150 ml Aquapel, and showing no noticeable difference between them.

(i) Conclusions

A wide range of users were identified as potential consumers of the ATG paper. Likewise a wide range of uses were identified, both as sugar paper and as an art paper, although in general interest focussed
on its unusual qualities, its uniqueness. It seems unlikely that ATG paper could directly substitute in either the sugar paper or medium quality art paper markets, but that it might fulfil a role as a supplementary or experimental paper offering different and exciting characteristics.

The paper found fairly general acceptance in the schools that used it, again, though, the emphasis was placed on its unusual qualities. Regarding its acceptance as an art paper, as might be expected, the users were more discriminating. Although it did not find all round acceptability, it was regarded as suitable for pastels, oil pastels, chalk, and charcoal drawing, and for screen and letterpress printing, and possibly etching work.

8.3.2 Market Price and Contribution

The market price or unit product value was assessed in these three ways:

(i) Samples of the paper made in the YOP project were sent to the buyers of an art paper supplier, Wagons Art Supplies, Milton Keynes, and a specialist paper product shop, Paperchase, London.

(ii) Comparison with prices received by some individual hand-made paper-makers for their papers.
(iii) By comparison with the prices paid for other papers currently used by potential consumers.

Mr. Pearce, of Waggons Art Supplies, Central Milton Keynes, expressed interest in the paper as a pastels paper, to sell as pads or single sheets. They would offer a price of around 5p/A2 sheet, to be resold at about 10p/sheet. Ms Cash, of Paperchase Products, London, was interested in selling A2 sheets of the paper, in a variety of colours and finishes (e.g. including foil, long fibres, etc. in the finish), and would offer a price of 4p/sheet.

These prices were much lower than those being received by other individual hand-made paper-makers consulted. Bruce Glasser and Peter Bower were receiving 40p per A2 sheet in 1979 from an agent, who distributed their papers to art shops; and R.W. Partridge, of the 3 Rivers Mills was selling his paper at 44-60p per sheet, also in 1979. The 3 Rivers paper does not use recycled pulp, and is of considerably higher quality than the ATG papers. Bruce Glasser and Peter Bower also produced a high quality paper, using equipment very similar to ATG paper recycling plant, with high quality recycled pulp; and therefore one which could be made using ATG paper recycling plant.

The other major area of potential demand for the ATG paper is from schools, playgroups, youth clubs etc. for use as painting and drawing paper. Schools in the Milton Keynes area buy their paper through the Greater London Council Supplies Department. Paper similar to the ATG paper is supplied as Brushwork and Sugar paper in A1, A2 and A4 packs, and costs between 1.2p-1.5p per sheet of A2 size.
Playgroups, creches, etc. not buying through the GLC pay much higher prices for sugar paper. The Open University creche pays the equivalent of 2.1p per A2 sheet; and prices as high as 11p for a single A2 sheet can be found in art paper shops.

The following range of prices were therefore identified:

**sugar paper quality**: between 1.5p and 2p/sheet
or £7.50 and £10.00/ream.
This gives an average market price of £8.75/ream (or 1.75/sheet)

**art paper quality**: between 5p and 40p/sheet
or £25.00 and £200.00/ream.
This gives an average market price of £112.00 (for 22.50p/sheet)

(a) **Contribution to fixed costs**

Having determined the average market price for each product, their contributions to fixed costs can be calculated and compared using the standard technique as described in Simpson (1979).

**sugar paper quality**: average market price/ream = £8.75
marginal cost/ream = £12.36

(this is equal to the variable cost/ream as calculated in Table 8.7)

::: contribution (to fixed costs) = -£3.61
art paper quality : average market price/ream = £112.50
marginal cost/ream = £ 13.48
.: contribution (to fixed costs) = £ 99.02

Clearly, for sugar paper, the average market price is not sufficient to cover even the marginal unit cost of production and at higher levels of production the process would obviously never break even. For art paper, however, although the unit production cost is still greater than the average unit market price, it would seem that with a contribution of £99 per ream expected it would be worth investigating whether or not a break even point could be achieved at higher levels of output. Equally, art paper products with a greater contribution could usefully be identified.

8.3.3 Market Size and Competition

One potential product market and group of potential users identified was sugar paper used by schools. Milton Keynes is a district with a population of 100,000. There are 70 First and Middle schools, and 8 Secondary/Comprehensive schools in Milton Keynes. Initial investigation carried out by letter and telephone calls to a sample of these schools indicated that each school uses between 10 reams and 20 reams (500 sheets) of sugar paper each year (mostly A2 sheets), giving an annual consumption of 800-1,600 reams in Milton Keynes schools.

The ATG paper recycling plant can produce about 36 reams of sugar paper quality per annum. It is unlikely though that ATG paper could
substitute for all the uses sugar paper is used for, but it might be reasonable to expect that 10% of the demand could be satisfied by ATG paper, based on the interest shown by the schools approached. (This does assume that schools would be allowed to buy paper from sources other than GLC Supplies Department). 10% of the demand for sugar paper for schools in Milton Keynes, is between 80 and 160 reams per annum. This market then would provide a more than adequate demand for the total production output of such an enterprise.

The size of the other product market being considered, that for medium quality art paper is more difficult to assess. To find sufficient demand to sell the output of 33 reams per annum of ATG 'art' paper, the enterprise would have to sell further afield than the Milton Keynes area, and ignore the constraints of serving the needs of the local community. The potential regional or national markets for art paper including art shops and art departments in higher education establishments are estimated to be very large in comparison to the very small output of the ATG paper recycling plant and indicated that a more than adequate demand for the total production output of such an enterprise could be found. This point is discussed more fully in the evaluation report.

8.4 SUMMARY AND PRODUCT SELECTION

Sections 8.1, 8.2 and 8.3, based on the pilot study research, have shown that:
A range of technically acceptable recycled paper products can be produced on the Melbourne 5 system.

From technical studies and user trials the two most promising products would appear to be a sugar paper type and a medium quality art paper type.

The output from the Melbourne 5 system was found to be considerably less than rated. The poor output and high manual input in the system contributed to the high unit costs.

At an average output of 36 reams/year for sugar paper the unit cost was found to be £384/ream. For art paper the unit cost was found to be £419/ream at 33 reams/year.

From consideration of likely market prices for both products it was found that while neither product could expect a unit selling price approaching the unit cost, sales of art paper would make a contribution to fixed costs of approximately £99/ream but income from the sugar paper would not even cover the marginal cost per ream.

8.4.1 Product Selection

It is the aim of this section to briefly compare the technical and commercial merits of the two products in order to select a product for further screening and evaluation in part 2 of the feasibility study.
From the technical and production aspects, sugar paper and art paper are very similar; the main differences being the additional skill and competence required in production of the art paper and the associated higher level of quality control. This is reflected in the marginally higher production cost for art paper.

Preliminary market research indicates that the potential volume of sales expected for sugar paper is vast compared to art paper but with outputs of only 36 and 33 reams/year, market size is not a consideration. The major difference between the products is the expected selling price which could be commanded. Clearly the art paper should be selected for further screening on the basis of an expected positive contribution to fixed costs from sales.
CHAPTER 9

EVALUATION REPORT

The pilot study, as described in Chapter 8, was used to generate original technical and financial data which was used in a screening process to identify a type of recycled paper product potentially capable of supporting a community enterprise. In this Chapter the information and findings from the analysis of the pilot study will be used as a basis for a much broader evaluation. This evaluation will take the form of exploring the technical, financial and economic viability of producing and marketing the recycled paper product on a Community Technology basis. In particular the study will focus on:

**Technical viability**

- technical aspects of increasing and optimising output

**Financial viability**

(a) Sensitivity analysis

(i) unit cost related to output

(ii) selling price related to output

(b) Marketing research

(i) identification of appropriate art paper product

(ii) identification of appropriate market segment

(iii) estimation of potential selling price, sales volume.
The aims of the Evaluation Report, are therefore twofold. Firstly to detail the iterative, design and evaluation process which was adopted in the development of a specific paper product which satisfied a variety of technical and commercial criteria, as discussed in Chapter 7. Secondly to appraise, using technical and financial and economic criteria, the viability of producing the product on a Community Technology basis.
9.1 TECHNICAL AND PRODUCTION EVALUATION

The main results and conclusions drawn from the pilot project relating to the technical assessment of the 'community' scale paper recycling plant are summarised below:

- A number of modifications were considered necessary to the Melbourne 5 plant, to improve both the quantity and quality of paper produced. Major modifications were made in the pulping, pressing and drying stages of the process, resulting in what is referred to as the ATG paper recycling plant.

- The ATG paper recycling plant was considered technically adequate for its purpose; further design improvements would have been desirable, had sufficient time and facilities been available.

- The minimum pressure which produced an adequate water removal, and adequate quality results in the paper produced was concluded to be 300 KN/m$^2$ (10 tonnes over 0.33 m$^2$) applied for 30 minutes.

- The ATG paper recycling plant operated by two people is capable of producing 12.5 sheets of sugar paper quality and 11.5 sheets of art paper per hour, possibly more, but not significantly so.

- An enterprise using the ATG paper recycling plant, employing two people should therefore make 393 sheets of sugar paper quality and 365 sheets of art paper quality per week.
The range of products that could be produced by the ATG paper recycling plant, without further modifications, were papers and lightweight card for printing, writing and drawing/art uses, and packaging papers.

The best, consistent results were achieved with papers of around 200 gsm in weight, which were considered most suitable as drawing/art or printing paper.

Varying the type of waste paper used, whether newspaper, office waste or computer paper results in some differences in the paper produced. Most noted was that unsized newsprint-based papers were softer and weaker. However the quality differences were not very marked.

Effective sizing was achieved using 25-50 ml of aquapel size, or about two tablespoons of household starch per refiner batch.

The ATG paper was considered suitable for use as a pastels, chalk or charcoal drawing paper, for screen and letter press printing and possibly for etching, and other art/craft work; and for use in schools, playgroups etc. as a substitute for sugar paper.

It should also be possible to produce a lighter weight (around 100 gsm) paper suitable as writing paper.

The major technical limitation of the Melbourne 5 and the ATG paper recycling plant is the low production output achieved. Modifications were made to the original Melbourne 5 plant, but increased its
production output only marginally. The experience of the pilot project suggested 2 ways in which the production output might be improved. One, which is outside the scope of this study, would involve radically and substantially redesigning the plant to meet a design specification, drawn up with the aim of reaching a sufficiently high production output to achieve financial or economic viability. For art paper quality, selling at £112.50 per ream, the plant would need to produce 123 reams per annum to break-even, more to produce a profit. These figures are related to financial viability and assume the enterprise is operating in a private business or commercial framework. The requirements for an enterprise operating in a situation where economic viability or social desirability is the determining factor would most likely be different and will be explored later in Section 9.3.

The other way in which production output could be increased is by more efficient use of the equipment involved. Observation and timing of the different operations involved in production showed that 'forming the sheets of paper' was the critical operation responsible for determining the production output. This conclusion was reached because it was found to be possible to increase the output of the pulping stage by using extra pulpers or large containers with a minimal increase in the labour required, and similarly for the pressing and drying operations by providing additional space for drying, again with minimal increase in the labour requirement. However it is not feasible for one person to 'form' more than one sheet of paper at a time without substantially redesigning the forming process. However two different configurations of equipment were considered which could increase production output without increasing the production costs in equal proportion, that is by increasing the production efficiency of the process, and these are:
(i) using the equivalent of two ATG paper recycling plant units to produce double the output of paper at 66 reams per annum. This would involve doubling the pulping and drying capacity and using two former units; and would require three operators, two primarily employed in forming and the third in pulping, pressing and drying operations;

(ii) using the equivalent of three ATG paper recycling plant units to produce treble the output of paper at 99 reams per annum. This would involve trebling the pulping and drying capacity and using three former units; and would require five operators, three primarily employed in forming and the other two required to carry out the pulping, pressing and drying operations.

The financial implications of these configurations, designed to double and treble output, are explored in the sensitivity analysis described in Section 9.2.1.

9.2 FINANCIAL EVALUATION

A financial analysis of the proposed project is described in Section 9.2.3. The method of appraisal used is the Internal Rate of Return method as applied to financial data displayed mainly in the form of financial statements for the first year's operation. The projected financial statements were based on the estimated performance of the proposed enterprise using cost data from the pilot study, a sensitivity analysis as described in Section 9.2.1 and the findings from a marketing research programme as detailed in Section 9.2.2.
9.2.1 Sensitivity Analysis

In Section 8.2 of the Pilot Study report the cost behaviour for the ATG paper recycling plant was explored, and the unit production cost for recycled art paper was computed based on the average pilot study output. It is the concern of the financial appraisal section to examine the wider viability of the project in terms of its ability to produce and market a selected product. Hence it is important to consider the effect on the financial performance of various production and sales levels as well as on sales levels. The sensitivity analysis is designed to further explore the cost - volume - profit relationship (see Arnold and Hope, 1983; Bates and Parkinson, 1978; Dewhurst, 1972; and Sizer, 1979) for the proposed enterprise in order to:

- determine the level of output which would minimise unit production cost, i.e. optimise output in relation to unit cost;

- calculate the effect on profitability by varying the unit selling price i.e. optimise selling price in relation to pilot production output;

- calculate the effect on profitability by varying the unit selling price for different levels of output i.e. optimise selling price for various outputs. The analysis is based on the relationship:

\[
\text{Profit} = \text{unit sales price} \times \text{output} = (\text{fixed costs} + \text{variable costs}) \times \text{output}
\]

And at break even point unit sales price = unit cost.
(a) Determination of optimum output

The first two calculations show the effect on the unit cost of slightly varying the output from that achieved in the pilot study. However it was demonstrated in the Technical Evaluation Section 9.1 that higher output levels for the enterprise could be achieved by increasing the labour and capital equipment inputs. These increased inputs have been costed and the unit cost of production calculated for an additional two levels of output.

(i) Unit production cost at average production output - 20%

This output is based on using one paper recycling plant unit operated by two workers. Average production per annum is 33 reams. Therefore average production output - 20% = 26.4 reams p.a.

Fixed and variable costs for this level of production are taken from the analyses in Chapter 8:

Fixed costs = £13,373 p.a.

Variable costs = £13.48 per ream

Therefore the unit cost at average production output - 20%

\[
= 0 + \frac{13,373 + (13.48 \times 26.4)}{26.4}
\]

= £520/ream
(ii) **Unit production cost at average production output + 20%**

As with the last case, this output is based on using one paper recycling plant unit operated by two workers. Average production output + 20% = 39.6 reams p.a.

Fixed and variable costs are the same as in the last case, therefore the unit cost at average production + 20% is calculated as follows:

\[
\text{Unit cost} = \frac{0 + 13,373 + (13.48 \times 39.6)}{39.6}
\]

\[= \£351/\text{ream}\]

(iii) **Unit production cost at double average output**

To double the average output to 66 reams p.a. would require, as described in Section 9.1, using two ATG paper recycling plant units operated by three workers.

New fixed costs required to double output are as follows:

<table>
<thead>
<tr>
<th>Capital equipment:</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATG paper recycling plant (+ 1 additional forming unit)</td>
<td>1,950</td>
</tr>
<tr>
<td>Press</td>
<td>1,000</td>
</tr>
<tr>
<td>Drying unit</td>
<td>400</td>
</tr>
<tr>
<td>Office equipment</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£3,450</strong></td>
</tr>
</tbody>
</table>

.: depreciation over 5 years

\[690\]
Overheads: £
Rent (increase 50%) 650
Stationery etc. (increase 50%) 337
Accounts 150
Insurance 100
Interest charges (@ 18%) 621
Heating (increase 50%) 180
Labour (IM + IF additional F) 15,632

£ 17,670

TOTAL FIXED COSTS: 18,360

Variable costs are assumed to remain the same as for average production output, at £13.48/ream. Therefore the unit cost at double production output

\[
\text{Unit cost} = \frac{0 + 18,360 + (13.48 \times 66)}{66}
\]

= £292/ream

(iv) Unit production costs at treble average output

To treble the average output to 99 reams p.a. would require as described in Section 9.1, using three paper recycling plant units operated by five workers.

Calculation of new fixed costs required to treble output are as follows:
Capital equipment: £

2 x ATG paper recycling plant systems 2,600
2 x Press 2,000
Drying unit 600
Office equipment 100

£5,300 £

.: depreciation over 5 years 1,060

Overheads:

Rent (increase by 100%) 866
Stationery (+ 100%) 450
Accounts 150
Insurance 100
Interest Charges (@ 18%) 954
Heating (+ 100%) 240
Labour (2M + 3F) 27,044

29,804

TOTAL FIXED COSTS: £30,864

Variable costs are assumed to remain at £13.48/ream. Therefore the unit cost at treble average production output

\[
\frac{0 + 30,864 + (13.48 \times 99)}{99} = 325/\text{ream}
\]

These unit costs compare with the unit cost at the average production output (33 reams) of £418/ream.
(b) Selling price sensitivity

It has been previously demonstrated that for an enterprise producing an average of 33 reams per year the unit cost of selling price/ream would have to be approximately £418 to allow the business to break even. The effect on profit and loss of a range of selling prices are examined here, using the expression:

\[
\text{Profit} = \text{selling price} \times \text{output} - [\text{fixed costs} + (\text{variable cost} \times \text{output})]
\]

(i) Selling price = £100/ream
\[
\text{Profit} = 100 \times 33 - [13,352 + (13.48 \times 33)] \\
= 3,300 - 13,770 \\
= (10,470)
\]

(ii) Selling price = £200/ream
\[
\text{Profit} = (7,170)
\]

(iii) Selling price = £300/ream
\[
\text{Profit} = (3,870)
\]

(iv) Selling price = £400/ream
\[
\text{Profit} = (570)
\]

(v) Selling price = £500/ream
\[
\text{Profit} = 2,730
\]

Note that no account of working capital requirement is included in these calculations.
(c) Selling price sensitivity related to output

Combining the results of the previous two sensitivity analyses gives the following data, which is summarised in Table 9.1.

(i) For an output 33 reams/yr
see previous section (b)

(ii) For an output 66 reams/yr

Selling price at £500/ream
Profit = 500 x 66 - [18,366 + 13.48 x 66]
= £33,000 - 19,256
= £13,744

Selling price at £400/ream
Profit = £7,144

Selling price at £300/ream
Profit = £544

Selling price at £200/ream
Profit = (£6,056)

Selling price at £100/ream
Profit = (£12,656)
(iii) For an output 99 reams/yr

Selling price at £500/ream

Profit = £500 \times 99 \ [30,864 + 13.48 \times 99] = 49,500 - 32,199 = £17,301

Selling price at £400/ream

Profit = £7,401

Selling price at £300/ream

Profit = (£2,499)

Selling price at £200/ream

Profit = (£12,399)

Selling price at £100/ream

Profit = (£22,299)

Table 9.1 SUMMARY OF SELLING PRICE SENSITIVITY

<table>
<thead>
<tr>
<th>Selling Price</th>
<th>33 reams</th>
<th>66 reams</th>
<th>99 reams</th>
</tr>
</thead>
<tbody>
<tr>
<td>£100/ream</td>
<td>(10,470)</td>
<td>(12,656)</td>
<td>(22,299)</td>
</tr>
<tr>
<td>£200</td>
<td>(7,170)</td>
<td>(6,056)</td>
<td>(12,399)</td>
</tr>
<tr>
<td>£300</td>
<td>(3,870)</td>
<td>544</td>
<td>(2,499)</td>
</tr>
<tr>
<td>£400</td>
<td>(570)</td>
<td>7,144</td>
<td>7,401</td>
</tr>
<tr>
<td>£500</td>
<td>2,730</td>
<td>13,744</td>
<td>17,301</td>
</tr>
</tbody>
</table>
The main conclusion that can be drawn therefore from the sensitivity analysis is that from the criteria of minimising unit costs it can be seen that an enterprise producing the recycled product selected could minimise unit cost by doubling the output compared with the pilot project. Trebling the output served only to increase unit costs due to large increases in fixed costs.

The selling price calculations suggested that the best means of achieving maximum profit if a high selling price could be commanded (£500) would be to aim to produce treble the output. However if only a low price could be obtained, losses would be minimised by selecting the pilot study output. However by doubling the output the profitability in the mid-range of prices (£200-400) looks more promising.

It would appear from the analysis that producing and selling in the order of 66 reams/year would be appropriate to any proposed enterprise. However if predicted initial sales and prices are low, it would be sensible to commence at the 33 ream output and build on additional capacity when increased sales volume could be commanded. The additional volume, for example, if selling at £300/ream, would transform a loss of £3,870 at the smaller capacity into a profit of £544 at the 66 ream capacity. It would not seem sensible to expand production to 99 ream level unless a high selling price could definitely be commanded.

9.2.2 **Marketing Research**

This section describes the market research carried out for the art paper quality paper produced in the pilot project, and used a
standard market research approach as described in Baker (1979), Dewhurst and Burns (1983) and Littler (1984).

The aims of this market research are as follows:

- to identify the most appropriate use for the product with regard to technical and market requirements;

- to identify the most appropriate market segment for the product with regard to maximising sales revenue;

- to estimate the size of the market segment and sales volume;

- to estimate the market price which the product may command.

The methodology followed involved primarily interviews and some user assessment. In particular the following were carried out:

- preliminary user trials and interviews conducted during the pilot study;

- interview and user assessment of recycled paper for screen printing conducted with Mr. P. Rhodes, Printmaking Dept., Ruskin School of Drawing and Fine Art, Oxford;

- interviews with technical staff at the Printmaking Dept., Ruskin School of Drawing and Fine Art;

- literature review of art and design courses and colleges in the UK.
(a) Product use

Preliminary market research conducted as part of the pilot study suggested that the recycled art paper could be used by artists for a variety of uses. The main uses included:

- painting and pastels
- drawing
- printing (water and oil based screen printing)

When the recycled paper was sampled by potential users and retailers during the pilot study, the overall impression conveyed was that although the paper had interesting qualities such as texture and colour, it could not be compared to the finer quality hand made, wood free papers readily available on the market, albeit at a premium price. Clearly the paper could be sold through retail outlets and direct to local schools, but at a very low price. Retailers indicated that a price of only £25/ream could be commanded for pastel paper while from the previous section it is clear that pastels paper would cost at least £292/ream to produce depending on turnover.

If the paper is to be sold for a price reflecting the high cost of production, it is necessary to identify and enhance its unique qualities and to present the paper as a specialist medium for an identified purpose and group of users. In the user trials the paper performed best when used for silk screen printing as the texture and colour added an extra dimension to the print and allowed the artists to experiment and explore new techniques. Moreover these characteristics were seen as features unique to the recycled product but obviously
experimentation would only be a minor element of normal screen printing. The role of experimentation and use of experimental papers in screen printing was considered to be of major importance in the education or training of printers rather than in commercial activities.

(b) Market segmentation

It was decided to further explore the potential for selling the recycled product to art colleges and large schools as a unique medium for print making including silk-screen printing. Selling direct to art colleges rather than through wholesalers or retailers would also have the benefit of maximising price.

Interviews with members of staff from the Print Making Department, Ruskin School of Drawing and Fine Art, a professional assessment, and trials of the papers for printmaking, confirmed that the recycled paper could have a role to play in the training of art students. The recycled paper was not seen as replacing the more uniform, traditional print papers or the quality hand-made wood-free papers within Art Departments but as a supplement to them providing an unusual medium for experimentation. Art departments within colleges stock a broad range of papers for use by students.

The market for the recycled paper as a printing medium was therefore defined as all colleges, polytechnics and universities offering art and design related courses. Degree postgraduate foundation courses and professional courses (Bohm and Wellings, 1985; CNAA, 1983; Heap, 1983; and Which Degrees, 1984) are offered in art and design but not all of the courses offer silk screen printing as a course component
or option. Degree courses normally offer students the choice of specialising in one of four major fields: fine art, graphic design, textiles and fashion or three-dimensional design. Fine art courses include a printmaking component while printmaking is often an option on graphic design courses. In addition to art and design courses, a number of colleges offer courses specifically on print making.

(c) Estimation of market size and sales volume

Of the 115 universities, polytechnics and colleges offering art and design qualifications, 52 offer Fine Art options while a further 41 offer a Graphic Design option including silk screen work. Additionally there are 35 courses on printmaking. Clearly, many colleges, especially polytechniques, offer all three courses within art and design departments. The qualifications awarded by the colleges for the courses above tend to be B.A. degrees while the remaining colleges offering art and design qualifications focus more on pre-degree foundational courses and vocational courses of a general nature. Consequently these colleges would not appear to have as large a potential for the use for print quality recycled paper. The prime target group of potential purchasers therefore comprises the colleges offering the 128 courses in Fine Art, Graphic Design and Printmaking. The secondary target group would comprise the remaining colleges offering more general art and design courses.

From interviews conducted with staff in the Printmaking Department, Ruskin School of Drawing and Fine Art, it would appear that the demand from the Fine Art courses for the recycled paper for print experimentation would be satisfied by approximately 100 sheets per year.
The maximum market potential (see Littler, 1984) from the target group could be in the order of 128 x 100 sheets totalling approximately 12,800 sheets or 25 reams. Clearly not all the colleges would wish to purchase the paper and the amount purchased would vary with student numbers. Estimating potential sales of new products is notoriously difficult (see Littler, 1984) and a more extensive survey of demand is considered to be beyond the scope of this study. No estimate of potential sales to the secondary target group is attempted. It may be expected that the demand for the product would increase to at least the output from the pilot study due to sales to the second target group in subsequent years.

(d) Market prices

It is common practice for most routine screen printing to be carried out on machine-made papers with more interesting effects being achieved using hand-made wood-free based papers. It has been contended here that the recycled paper, although having unique and valued qualities, could not substitute for either of these types of paper, either for routine work or for finer quality work. Rather the recycled product is seen as complimentary to the range of papers normally used. The types of paper used for routine work are normally purchased by colleges for approximately 10-20p per sheet (1980 prices). Wood-free hand-made papers vary in quality and can be purchased for prices in the range of 50p to £3 per sheet. Hand-made recycled paper could not command the same price as hand-made wood-free papers due to its inferior consistency and durability etc but because of its own unique qualities should command a price in excess of the machine-made papers used for routine work. This was confirmed by staff of Ruskin College who priced the
recycled paper tested at approximately 20p/sheet or £100/ream (1980 prices). As with the estimation of market size a much more extensive survey should be conducted to obtain a more accurate estimate of the market price and price elasticity, but this is again beyond the scope of the study.

9.2.3 Financial Analysis

Section 9.1 demonstrated that it was technically possible to double and treble the experimentally determined output of the ATG paper making plant by increasing additional equipment and labour. The sensitivity analysis in Section 9.2.1 indicated that from the criterion of reducing unit production cost, doubling the output to approximately 66 reams/year would be optimal.

The Marketing Research Section (9.2.2) however, indicated that sales initially may be only in the order of 25 reams per year, increasing to 33 reams depending on demand from the secondary target group. With this low level of market demand the financial advantage of increasing the production output to 66 reams/year is lost, and the optimal production output becomes the 33 reams p.a. average production output achieved with one ATG paper recycling plant and two workers. The likely market price (1980 prices) may only be in the region of £100/ream; which compares with the £419/ream unit cost of production at breakeven at this output.

Clearly a simple appraisal of the projected costs and returns indicates that the project would not be financially viable. However the following sections contain a more detailed analysis and evaluation for the project.
The first part of the analysis (Section 9.2.3 (a)) portrays the projected financial information obtained during the course of the feasibility study in the form of the normal financial statements (cash flow statement, profit and loss account, and balance sheet) based on the projected first year's trading performance, using standard techniques as described in Harper (1974), Hargreaves (1983) and ICFC (undated).

The second part of this financial analysis (Section 9.2.3 (b)) makes use of much of the financial information in a calculation on the determination of the Internal Rate of Return (I.R.R.) for the project over the estimated five year life of the project.

(a) First year's trading performance

This is based on the market research data (i.e. estimated sales of 25 reams @ £100/ream) and cost data from the pilot study. In order to draw up the cash flow statement, balance sheet, and profit and loss account for the projected first year's trading of the proposed paper recycling enterprise, it is necessary first to make a number of assumptions about the timing and amounts of the expenses incurred and sales revenue received. These are summarised in Table 9.2.

Table 9.3 shows the cash flow for the 1st year's trading, and which calculates the overdraft at the end of the year. This enables first year profit and loss account (Table 9.4) and the end of year balance sheet (Table 9.5) to be drawn up.

As all these financial analyses show, the proposed enterprise would make a substantial financial loss in the first year of trading.
Table 9.2  ASSUMPTIONS FOR CASH FLOW STATEMENT (1ST YEAR)

<table>
<thead>
<tr>
<th>Item</th>
<th>annual total</th>
<th>timing of expense</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>labour</td>
<td>£11,357</td>
<td>£946/mth</td>
</tr>
<tr>
<td>start-up costs (legal, premium etc.)</td>
<td>108</td>
<td>mth 1</td>
</tr>
<tr>
<td>materials</td>
<td>61</td>
<td>£31 in mth 1, £30 in mth 6</td>
</tr>
<tr>
<td><strong>Overheads:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rent</td>
<td>400</td>
<td>£33/mth</td>
</tr>
<tr>
<td>professional fees</td>
<td>75</td>
<td>£75 in mth 3</td>
</tr>
<tr>
<td>transport</td>
<td>20</td>
<td>£10 in mths 1 and 6</td>
</tr>
<tr>
<td>insurance</td>
<td>100</td>
<td>£100 in mth 3</td>
</tr>
<tr>
<td>interest</td>
<td>468</td>
<td>£117 in mths 3,6,9,12</td>
</tr>
<tr>
<td>loan repayment</td>
<td>520</td>
<td>£130 in mths 3,6,9,12</td>
</tr>
<tr>
<td>heating</td>
<td>211 (1)</td>
<td>£80 in mth 3, £20 in mth 6, £31 in mth 9, £80 in mth 12</td>
</tr>
<tr>
<td>phone, stationery</td>
<td>395 (1)</td>
<td>£99 in mths 3,6,9 and £98 in mth 12</td>
</tr>
<tr>
<td><strong>Sales Revenue:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 mths sales @ 2.5 reams/mth at selling price of £100/ream</td>
<td>2,500</td>
<td>£250/mth in mths 3-12</td>
</tr>
</tbody>
</table>

Note (1): fixed costs plus variable costs for 25 ream output
<table>
<thead>
<tr>
<th>MONTHS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash Receipts:</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,600</td>
</tr>
<tr>
<td>Sales</td>
<td>0</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
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<td>2,600</td>
</tr>
<tr>
<td>Cash Payments:</td>
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<td>43</td>
<td>43</td>
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<td>5,100</td>
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<tr>
<td>Materials</td>
<td>946</td>
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<td>946</td>
<td>946</td>
<td>11,352</td>
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<tr>
<td>Labour</td>
<td>946</td>
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<td>9,461</td>
</tr>
<tr>
<td>Overheads</td>
<td>33</td>
<td>33</td>
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</tr>
<tr>
<td>Capital Expenditure</td>
<td>2600</td>
<td>2600</td>
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<td>2600</td>
<td>2600</td>
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<td>2600</td>
<td>2600</td>
<td>2600</td>
<td>31,800</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(1128)</td>
<td>(11,280)</td>
</tr>
<tr>
<td>Cash balance (overdraft at start)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(979)</td>
<td>(11,290)</td>
</tr>
<tr>
<td>Cash balance (overdraft at end)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(4179)</td>
<td>(41,800)</td>
</tr>
</tbody>
</table>

Table 9.3 CASH FLOW STATEMENT (1ST YEAR)
Table 9.4 1ST YEAR PROJECTED PROFIT AND LOSS ACCOUNT

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>£</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales for year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Sales:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchases (1)</td>
<td></td>
<td></td>
<td>2,500</td>
</tr>
<tr>
<td>Direct wages</td>
<td></td>
<td></td>
<td>11,357</td>
</tr>
<tr>
<td>Stock and work in progress at start of year</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Less at end of year</td>
<td></td>
<td></td>
<td>250</td>
</tr>
<tr>
<td><strong>Gross Profit</strong></td>
<td></td>
<td></td>
<td>(8,668)</td>
</tr>
<tr>
<td><strong>Overheads:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rent and premium</td>
<td></td>
<td></td>
<td>433</td>
</tr>
<tr>
<td>stationery/phone (1)</td>
<td></td>
<td></td>
<td>395</td>
</tr>
<tr>
<td>accounts</td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>insurance</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>heating (1)</td>
<td></td>
<td></td>
<td>211</td>
</tr>
<tr>
<td>transport</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td><strong>Depreciation:</strong></td>
<td></td>
<td></td>
<td>1,309</td>
</tr>
<tr>
<td>Melbourne 5</td>
<td></td>
<td></td>
<td>260</td>
</tr>
<tr>
<td>Press</td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Drying unit</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Office equipment</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td><strong>Finance charges:</strong></td>
<td></td>
<td></td>
<td>520</td>
</tr>
<tr>
<td>loan interest</td>
<td></td>
<td></td>
<td>468</td>
</tr>
<tr>
<td>overdraft interest (2)</td>
<td></td>
<td></td>
<td>1,167</td>
</tr>
<tr>
<td><strong>Net Profit</strong></td>
<td></td>
<td></td>
<td>(12,132)</td>
</tr>
</tbody>
</table>

(1) Fixed costs plus variable costs for 25 ream output.

(2) Overdraft interest calculated from cash flow statement.
    Average overdraft for year £6,487. Interest at 18% = £1,167.
Table 9.5 PROJECTED BALANCE SHEET (AS AT END OF 1ST YEAR'S TRADING)

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Depreciation</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed assets:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melbourne 5 plant</td>
<td>1,300</td>
<td>260</td>
<td>1,040</td>
</tr>
<tr>
<td>Press</td>
<td>1,000</td>
<td>200</td>
<td>800</td>
</tr>
<tr>
<td>Drying unit</td>
<td>200</td>
<td>40</td>
<td>160</td>
</tr>
<tr>
<td>Office equipment</td>
<td>100</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2,600</td>
<td>520</td>
<td>2,080</td>
</tr>
<tr>
<td><strong>Current assets:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debtors and prepayments</td>
<td></td>
<td></td>
<td>250</td>
</tr>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Current liabilities:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank overdraft</td>
<td></td>
<td></td>
<td>11,206</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(10,956)</td>
</tr>
<tr>
<td>Net Current assets</td>
<td></td>
<td></td>
<td>(8,876)</td>
</tr>
<tr>
<td>long term loan</td>
<td></td>
<td></td>
<td>2,600</td>
</tr>
<tr>
<td>Net Tangible assets</td>
<td></td>
<td></td>
<td>(11,476)</td>
</tr>
</tbody>
</table>

Note (1): month's sales revenue @ £250
(b) Internal Rate of Return Evaluation

This method of financial evaluation was briefly discussed in Chapter 2 in Part I of the thesis. It seeks to identify the discount rate at which the present value of all future cash flows, positive and negative, is equal to the investment cost of the project. The discount rate calculated is therefore a measure of the return on capital of the project and can be directly compared with the cost of capital, to assess the financial viability of the project. Discount rates in excess of the market rate would indicate a worthwhile investment.

The calculation is carried out in two parts: estimation of projected net cash flows; and the trial and error discounting of these cash flows until their Net Present Value (NPV) equals zero.

The projected cash flows, or costs and returns for the estimated five year lifetime of the project are calculated as follows:

- The fixed costs are calculated from the pilot study but do not include interest payments.

- The variable costs are based on unit variable cost x no. of units sold. Sales are estimated to be: year 1 = 25 reams, year 2 = 30, years 3-5 = 33 p.a.

- The sales revenue is based on sales price x no. of units sold.
  No account is taken of inflation or price increases.

The projected costs and returns for years 0-5 are summarised in Table 9.6.
Table 9.6 PROJECT COSTS AND RETURNS

<table>
<thead>
<tr>
<th>year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital equipment</td>
<td>2,600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed costs</td>
<td>12,385</td>
<td>12,385</td>
<td>12,385</td>
<td>12,385</td>
<td>12,385</td>
<td></td>
</tr>
<tr>
<td>Variable costs</td>
<td>337</td>
<td>404</td>
<td>445</td>
<td>445</td>
<td>445</td>
<td></td>
</tr>
<tr>
<td>Total costs</td>
<td>2,600</td>
<td>12,722</td>
<td>12,789</td>
<td>12,830</td>
<td>12,820</td>
<td>12,830</td>
</tr>
<tr>
<td>Returns:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales revenue</td>
<td>2,500</td>
<td>3,000</td>
<td>3,300</td>
<td>3,300</td>
<td>3,300</td>
<td></td>
</tr>
<tr>
<td>Net cash flow</td>
<td>(2,600)</td>
<td>(10,222)</td>
<td>(9,789)</td>
<td>(9,530)</td>
<td>(9,530)</td>
<td>(9,530)</td>
</tr>
</tbody>
</table>

From these results the net cash flows for each year can be discounted using a trial and error discount rate in order to achieve a net present value of zero. As can be seen clearly from Table 9.7, the negative net cash flows for this project could not repay the initial capital investment, quite apart from earning any return on capital.

Table 9.7 DISCOUNTING OF CASH FLOWS

<table>
<thead>
<tr>
<th>Year</th>
<th>Cash Flow</th>
<th>Discount Rate</th>
<th>Present value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-2,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-10,222</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-9,789</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-9,530</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-9,530</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-9,530</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

net present value
9.3 ECONOMIC ASSESSMENT

As described in Chapter 2, an economic assessment, as distinct from a financial assessment, of a project or enterprise involves taking into account social as well as financial/private impacts. It is a way of assessing social desirability, using social cost benefit analysis.

Section 2.2 describes an economic framework which provides an approach constructed to enable reclamation and recycling schemes to be evaluated in this way. This framework makes use of CBA techniques, evaluating the economic efficiency of the project in the first instance, accompanied by discussion and a separately argued evaluation of those environmental and social costs or benefits for which assigning monetary values has proved problematic.

Section 9.2 concluded that the proposed 'community' scale paper recycling enterprise would not be financially viable as a business, and would in fact be likely to incur substantial losses. However if sufficient social and environmental benefits exist, the enterprise could be economically viable and provide a net social benefit.

A recent analysis undertaken by OECD (see OECD (1982)) of 37 reclamation projects (all source-separation reclamation schemes), using an accounting framework similar to that described in Section 2, indicates that external benefits can be a significant factor. Of 37 schemes, it was concluded that nine were financially viable, and a further seven economically viable yielding a net social benefit when credited with estimated waste collection and disposal cost savings, and in some cases employment creation benefits.
There are a number of social and environmental benefits often credited to reclamation activities. Commonly these include:

- savings in waste collection and/or disposal costs;

- reduction in overall residuals pollution impact, in the quantity of primary material input, and of energy consumption;

- employment creation benefits.

In addition, it is sometimes claimed that recycling can serve to reduce the import bill for some materials. Although the use of reclaimed material instead of imported primary material will no doubt reduce the nation's import bill, complex accounting problems are encountered in trying to quantify this external benefit. Turner (1981) and Blackmore and Turner (1978), in examining this factor, concluded that the savings were not significant.

This economic evaluation of the pilot project results for the feasibility study of a community-scale paper recycling enterprise examines in further detail in Sections 9.3.1, 9.3.2 and 9.3.3 each of the above potential social and environmental benefits, and assesses their value in relation to the paper recycling enterprise being considered. Where practicable these social and environmental impacts are valued as costs or benefits in monetary terms, using the techniques described in Section 2.1 and 2.2 and where it is judged that impacts cannot be given monetary values they are quantified where possible and presented as separately argued issues.
Once social and environmental costs and benefits have been assessed, those given a monetary value can be included in an economic analysis, using an identical method to that used for the financial analysis in Section 9.2, and that described in Section 2.2, to provide a measure of economic efficiency or viability. This economic analysis and evaluation is described in Section 9.3.4.

9.3.1 Savings in Waste Disposal and/or Collection Costs

Waste management cost savings are perhaps the most obvious potential benefit of recycling schemes. As municipal wastes are collected and disposed of by local authorities by law, then recycling projects should always be assessed relative to other waste management options, and the least-cost option sought. Hence a recycling project may incur an overall social cost but if this is less than the social costs of other waste management options, then recycling becomes the socially desirable choice. Turner (1981) and Turner and Thomas (1982) maintain that recycling is increasingly likely to become the least-cost option, as local authorities find it increasingly difficult to find low-cost, environmentally acceptable disposal methods. Conveniently located and environmentally suitable landfill sites are becoming more difficult to find, and all other options involve significantly higher costs.

The actual savings, if any, in disposal and/or collection costs due to implementing the proposed community paper recycling scheme, depends on the waste management practice of the local authority concerned and on how the collection of waste-paper for the enterprise is to be organised. Assuming that the enterprise is to be established in Milton Keynes, the
The predominant waste disposal method used in this area by Buckinghamshire County Council is landfill, and the average cost of waste disposal was £3.4/tonne in 1979/80 (see Buckinghamshire County Council, 1981).

The proposed recycling enterprise would use just over 1 tonne of waste-paper per annum. Compared to the total domestic waste collected and disposed of in Milton Keynes per annum (BCC 1981) such small quantities would have a negligible effect on waste collection costs, and only a marginal effect on waste disposal costs. There would be a small saving in landfill space, but not in operating overheads, and the financial value of such a saving would be much less than the overall average cost of disposal. For instance, Blackmore and Turner (1978) estimated the marginal cost saving in saved landfill space created by the Oxfam Wastesaver Scheme to be 25p/tonne. It can be concluded therefore that for the proposed scheme the savings in waste collection or disposal costs are insignificant.

9.3.2 Reduced Environmental Impact

Recycling can lead to a reduction in the residuals pollution impact in the quantity of primary raw materials input, and of energy consumption, due to the substitution of reclaimed for primary raw materials. The environmental impact effects of recycling activities generally are discussed in greater detail in Chapter 2. An outline will be attempted here, of the specific effects of the proposed neighbourhood scale paper-recycling enterprise.
The environmental impact effects of this enterprise taken in isolation appear negligible in national terms. However considered in comparison with an equivalent weight of paper produced by the Paper Industry, the environmental impact of the ATG paper recycling plant is significantly less. Using 100% recycled fibre contributes towards resource conservation by substituting for virgin wood pulp fibre. Although trees are a renewable resource, heavy harvesting rates without adequate replanting is leading to a depletion of the world's forests, the detrimental environmental or ecological effects of which are not fully known. Although the 'community' scale paper recycling enterprise in question could not alone contribute significantly to forest preservation, it would, by using 100% recycled fibre compared to the average 52% used by the UK Paper and Board Industry, save an additional five trees for every tonne of paper produced (see Thomas (1977) for an explanation of how 1 tonne of paper produced from virgin wood pulp requires 10 trees); or compared to most art papers which are made from 100% virgin chemical pulp fibre, it would save 13 trees (Thomas, 1977).

In terms of overall energy consumption, the production of paper from recycled fibre appears less energy intensive than that from virgin wood pulp fibre. How substantial these savings are though, depends on the type of paper and processing in question, as discussed in Chapter 2, and in OECD (1979) and Thomas (1977). The proposed 'community' paper recycling enterprise has a low energy consumption even for a recycling plant, primarily due to the paper being predominantly air-dried, omitting one of the most energy intensive steps in the paper-making industry. One tonne of paper produced in this way, requires 5,040 MJ compared to an average 26,640 MJ for paper produced by the UK Paper and Board Industry.
The ATG paper recycling plant also requires less process water than most paper-making equipment used in industry; just under 3,000 litres of water used to produce a tonne of paper compared to an average of 90,000 litres per tonne in the UK Paper and Board Industry, (see Thomas (1977)). The level of polluting emission that would be created by the proposed community paper recycling enterprise is not known. However it is generally accepted that the pollution impact of paper making is reduced by recycling, and that this reduction is greater where recycling involves less fibre-upgrading (e.g. de-inking and bleaching), which is so in this case.

9.3.3 Employment Creation Benefits

The creation of jobs can be valued as a social cost or benefit, depending on the criteria used. In situations, such as in areas of high or structural unemployment, and where employment is provided to socially disadvantage groups, it is considered a social benefit. In quantifying the social benefit of a job so provided, the primary factor is the saving in state benefits that would otherwise be paid to the unemployed worker; other less tangible benefits are seldom given value.

The social cost of labour is generally equated with the opportunity cost of employing otherwise unemployed labour. This is the difference between the net wage at which employment is agreed and the level of state benefits to which a worker was previously entitled. Blackmore and Turner (1978) estimated the social cost of labour for the Oxfam Wastesaver and Teeside Wastechaser recycling schemes at between 20 and
40% of the wage costs, where the government is the employer; these percentages refer to a 16 year old and a married person with two children respectively. (This would be 10%-30% if the employer was not the State, as there would be a 10.75% additional saving relating to the employer's NI contributions).

In the financial analysis of the paper recycling enterprise, carried out in Section 8.2, the private cost of labour was calculated at £11,357 per annum. The social cost of labour (using the formula quoted above) for a non-government employer (assuming the labour would be otherwise unemployed) would be an average of 20% of the private cost, or £2,271.

Applying the social cost of labour to a project can only be justified if the enterprise is, not only providing jobs for otherwise unemployed labour, but also not competing with existing firms producing the same goods or service. It can be argued that the proposed 'community' paper recycling enterprise does satisfy these criteria, and that due to the decline in the UK Paper Industry (detailed in Chapter 6) and the increasing share of the market for paper products taken by imports, that stimulating the UK production of paper is not necessarily competing with the existing UK Paper and Board Industry.

9.3.4 Economic Analysis

In order to assess the economic viability of the proposed paper recycling enterprise, the social and environmental costs and benefits, evaluated in Sections 9.3.1, 9.3.2 and 9.3.3, are incorporated first
into the analysis of cost behaviour and calculations of unit production cost (as described in Section 8.2) and second with the Internal Rate of Return calculations to evaluate the project's economic IRR (as described in Section 9.2.3 (b)). In addition a sensitivity analysis is carried out to determine the selling price sensitivity in relation to the project's economic efficiency.

Table 9.8 shows the analysis of both the financial and economic costs of the proposed project. From this data the unit production cost at break-even can be calculated using the following formula:

\[
\text{unit cost at breakeven} = \frac{\text{fixed costs} + (\text{variable cost/Unit x output})}{\text{output}}
\]

Note that as this is looking at cost data the output is taken as the production output capacity of 33 reams p.a. rather than the expected initial sales level of 25 reams p.a. The economic or social unit production cost is therefore:

\[
\text{economic unit cost} = \frac{4,287 + (13.48 \times 33)}{33}
\]

\[
= £143.40/ream
\]

(or 29p a sheet)

This figure compares with the financial unit cost of £419/ream (as calculated in Section 8.2) and the likely selling price of £100/ream. No provision is made for working capital.

A rough calculation of profitability can be carried out simply by subtracting the total costs (i.e. fixed costs + (variable costs x
Table 9.8 ANALYSIS OF COST BEHAVIOUR - FINANCIAL AND ECONOMIC

<table>
<thead>
<tr>
<th>Analysis of Cost Behaviour</th>
<th>Financial</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Costs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Equipment</td>
<td>2600</td>
<td>2600</td>
</tr>
<tr>
<td>Annual depreciation charge (over 5 years)</td>
<td>520</td>
<td>520</td>
</tr>
<tr>
<td>Production and Office Costs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent and premium</td>
<td>433</td>
<td>433</td>
</tr>
<tr>
<td>Stationery (etc.) (fixed)</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Accounting &amp; professional fees</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Insurance</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Heating (fixed)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Interest on loan (@ 18%)</td>
<td>468</td>
<td>468</td>
</tr>
<tr>
<td>Labour</td>
<td>11357</td>
<td>2271</td>
</tr>
<tr>
<td></td>
<td>12853</td>
<td>3767</td>
</tr>
<tr>
<td>Add depreciation</td>
<td>520</td>
<td>520</td>
</tr>
<tr>
<td>Total fixed costs:</td>
<td>13373</td>
<td>4287</td>
</tr>
<tr>
<td>Variable Costs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationery (etc.) (variable)</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Transport</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Materials</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Heating (variable)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Total variable costs:</td>
<td>445</td>
<td>445</td>
</tr>
</tbody>
</table>

Variable cost/ream (output = 33 reams p.a.) £13.48 £13.48

Note No account is taken of working capital requirements.
output) from total returns or benefits. In this case total benefits equals the sales revenue (i.e. unit selling price x sales output). The other economic benefits associated with this project (and discussed in Sections 9.3.1, 9.3.2 and 9.3.3) were concluded to be either intangible or negligible and hence do not appear in this equation. Therefore the economic profitability of this proposed paper recycling scheme is:

\[
economic\ profitabilty = [100 \times 33] - [4287 + (13.48 \times 33)]
\]

\[
= (£1432)
\]

That is, for sales of 33 reams at £100/ream, it would be likely to make an economic loss in the first year's trading of £1432. This is considerably less than the likely financial loss, by the same calculation of £10518.

In order to calculate the Economic Internal Rate of Return for this project (as described in Section 9.2.3 (b)), first the projected cash flows, or costs and returns, for the five year lifetime of the project must be worked out. The projected economic cash flows for the proposed paper recycling project are summarised in Table 9.9. To calculate the IRR for the project, the net cash flows for each year should then be discounted in order to achieve a net present value of zero. The IRR is that discount rate, and gives a measure of the return on capital of the project. However, as the net cash flows for each year, 0-5, are negative in this case then this project could not repay the initial capital investment, apart from earning any return on capital. This project could not therefore be considered a worthwhile economic investment, although the projected losses are considerably
smaller than those shown in the financial evaluation in Section 9.2.3 (b).

Table 9.9 PROJECTED ECONOMIC COSTS AND RETURNS

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital equipment</td>
<td>2600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed costs</td>
<td>3299 3299 3299 3299 3299</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable costs</td>
<td>337 404 445 455 455</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total costs</td>
<td>2600 3636 3703 3744 3744 3744</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales revenue</td>
<td>2500 3000 3300 3300 3300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net cash flow</td>
<td>-2600 -1136 -703 -444 -444 -444</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This analysis shows therefore that in economic efficiency terms the proposed paper making project is not viable, or socially desirable. However, the projected economic losses are considerably smaller than the projected financial or private losses, and hence the sensitivity of these economic viability calculations to selling price needs to be considered to discover how significant an increase in selling price is required before the project becomes viable. The market research described earlier in Section 9.2.2 concluded the estimated market size was initially 25 reams p.a. growing to 33 reams in the first three years of operation, and hence sensitivity to increasing production output is less relevant in this case.
Selling price sensitivity is examined by comparing projected profits using a range of selling prices in the expression:

\[
\text{Profit} = \text{selling price} \times \text{sales output} - (\text{fixed costs} + \text{variable costs} \times \text{production output})
\]

The results of this analysis are summarised in Table 9.10 and show that the selling price would need to increase by almost 100% to nearly £200 before the project would begin to make a profit, assuming sales of only 25 reams p.a. If sales could be increased to the production capacity of 33 reams p.a., then a selling price of £150/ream would generate a profit for the project. However even £150 represents a significant and unlikely increase in selling price for the art paper produced.

Table 9.10 **SELLING PRICE SENSITIVITY**

<table>
<thead>
<tr>
<th>Selling price</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assuming sales of 25 reams p.a.:</strong></td>
<td></td>
</tr>
<tr>
<td>£100</td>
<td>£2,232</td>
</tr>
<tr>
<td>£150</td>
<td>£982</td>
</tr>
<tr>
<td>£175</td>
<td>£357</td>
</tr>
<tr>
<td>£200</td>
<td>£268</td>
</tr>
<tr>
<td><strong>Assuming sales of 33 reams p.a.:</strong></td>
<td></td>
</tr>
<tr>
<td>£100</td>
<td>£1,432</td>
</tr>
<tr>
<td>£150</td>
<td>£218</td>
</tr>
</tbody>
</table>
In a discussion of the potential of 'community'-scale paper recycling as a 'community' enterprise, the most important conclusions, in the first instance, are those relating to financial and economic viability. That the proposed enterprise would not be financially viable as a straightforward commercial business as demonstrated in Section 9.2.3, of necessity limits what role, if any, such an activity can play in the community. The economic assessment carried out in Section 9.3 concluded that neither would the proposed enterprise be economically viable, or socially desirable in economic efficiency terms. The economic unit production cost at break-even point was calculated at £143/ream (or 29p/sheet) which compares with the estimated likely selling price of £100/ream (or 20p/sheet). The financial unit cost at break-even point of £419/ream indicates the extent of the social benefits associated with the project, but which were not significant enough to change a financial loss into an economic profit. The economic sensitivity analysis then carried out showed that a significant increase in selling price would be required, even when combined with a small, but realistic, increase in production output, before the enterprise would generate any economic profit.

Section 9.3 concluded that the proposed 'community'-scale paper recycling enterprise would generate social benefits in respect of waste disposal cost savings, reduced environmental impact and by employment creation. Of these only the employment creation benefits
were quantified and included in the economic viability calculations. The waste disposal cost savings were estimated and considered insignificant; however the environmental impact benefits were considered significant, with one tonne of 'ATG' paper requiring five fewer trees, 6000 kWh less energy and 87,000 litres less water than the average demand for 1 tonne of UK produced papers, but that these benefits were not readily quantified in monetary value.

If, however, the environmental impact benefits of waste paper recycling were considered significant enough to warrant government intervention, then the situation relating to the economic viability of the proposed enterprise could be altered. The influence of government policy on economic efficiency is an important one. It provides a link between private and social costs and benefits; and can shift the balance by regulations, fiscal measures and product charges. However, the question of whether or not such policy changes are merited requires further analysis, and is considered beyond the scope of this study.

Within the current economic framework therefore the only immediately obvious function that 'community'-scale paper recycling could potentially fulfil in a community is a general environmental education role, and through this possibly in addition provide some short-term, subsidised employment.

Section 10.1 discusses the groups in a community, and in particular in Milton Keynes who might become involved in such a 'community'-scale paper recycling project, with these central aims. In Section 10.2 the type or size of 'community' that such an activity is most relevant to is further explored, as is the question of what role it could play in promoting community self-reliance.
Chapter 11, or Part III of this thesis, then attempts to relate these specific conclusions to the wider questions asked in Part I, concerning the appropriateness of a Community Technology approach to the reclamation and recycling of domestic wastes.

10.1 COMMUNITY INVOLVEMENT

From a fairly early stage in this project, the question of who, or what groups, in a community, and in particular in Milton Keynes, might benefit from being involved in the proposed 'community'-scale paper recycling enterprise or project, was considered. Through a process of discussions with a number of community groups in Milton Keynes, and assessment of the emerging evidence from the case-study as it progressed, five types of interest group were identified as potential participants. These groups were concerned with employment, education, play, environmental and voluntary/charity activities.

Voluntary/charity organisations looking to raise funds through recycling activities will often collect and sell waste paper. They might consider diversifying this activity into recycling some or all of that paper themselves, if capital expenditure on the required machinery could be justified by the funds raised from its use. Labour would be free in this situation, but is usually in short supply which may cause problems with producing sufficient output. A voluntary/charity group would need to run the ATG paper recycling plant for two days per week, in order to generate a small profit, and recoup its capital investment in the plant. This conclusion is based on the following calculation, using the analysis of cost behaviour figures (as shown in Table 9.8):
Fixed costs: £

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual depreciation charge</td>
<td>520</td>
</tr>
<tr>
<td>Interest on loan @ 18%</td>
<td>468</td>
</tr>
<tr>
<td>Other fixed costs @ estimated 40% of those for proposed enterprise</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>1318</td>
</tr>
</tbody>
</table>

Variable costs: £13.48/ream (assume the same as for proposed enterprise)
Output = 160 sheets/wk = 16 reams p.a.
Sales price = £100/ream

Therefore Profit = (Output x Unit Sales price) - (fixed costs + [variable cost x output])

= £66 p.a.

Two days per week however is likely to be too large a regular time commitment for a voluntary/charity group to consider feasible.

If the capital cost of the machinery could be reduced by using second-hand equipment and by the group building some parts themselves, then such a paper recycling project begins to look more attractive to voluntary/charity groups.

Environmental groups, such as Friends of the Earth, (FOE), might also be interested in using a paper recycling project as a fund-raising activity, using voluntary labour, or might look to other frameworks in which it could be established, such as government sponsored 'job-creation' schemes. Their general concern with environmental benefits of recycling and with environmental education would make this activity of particular interest to these groups. They may wish to establish a project to promote the environmental educational aspects of recycling,
providing sufficient money can be raised through the sale of recycled paper to cover the capital costs of the equipment. This would seem feasible, as shown by the figures quoted above. This possibility was discussed with the Milton Keynes FOE group, and with the Urban Studies Centre, a Milton Keynes charity to promote environmental education.

The FOE group, although interested in participating in a paper recycling project, felt it had too few resources, (people and money) to be able to get the proposed 'community'-scale enterprise off the ground alone.

They also expressed concern that their efforts were expanded to maximum result, and that in this respect felt that campaigning for the local authority to establish a more comprehensive reclamation and recycling scheme might prove more effective than running a 'community'-scale paper recycling project themselves. The Urban Studies Centre also showed interest, and investigated some sources of funds to raise capital for a recycling centre project, which would incorporate an ATG paper recycling plant. Having had no success with fundraising for this project by early 1982 they lost interest.

Educational and play organisations were identified as potential participants in a paper recycling project for two reasons. One being the education function that such a project could play, in that the practical involvement in recycling waste paper into a useful product offers opportunities to introduce many issues concerning the environment, wastes, resources, materials, science and technology and art. The other reason is that children and young adults were likely to be one group of potential users of the paper produced; and although
educational groups include adult education, the vast majority is aimed at children and young adults.

Considerable interest was shown by two teachers at the Bridgewater Hall Comprehensive School, situated at Stantonbury Campus in Milton Keynes. One of the teachers had responsibility for introducing Third World issues into the curriculum and saw 'community'-scale paper recycling as an activity which would effectively convey issues about appropriate technology to the students. The other teacher working in the design department (which covers art and technology activities) aimed to establish this activity as a student design project. The school purchased some of the basic equipment such as the refiner unit, and made available other equipment suitable for pressing and drying, already in the school. At the time of writing the project had not yet run, but was hoped to be included in the 4th form curriculum, in future.

Another organisation which showed interest in setting up a paper recycling project, was the Milton Keynes Play Association. A number of play organisations around Britain have in the last few years, been involved in organising Resource Centres, and the Milton Keynes Play Association, in exploring the possibilities of setting up a Resource Centre in Milton Keynes, considered including a 'community'-scale paper recycling project as one part of it. Resource Centres, or 'scrap projects', as they are sometimes called are based on the concept of reusing waste materials for play. The waste materials are generally donated and collected together, sorted and made available to groups, including schools, play groups, youth and drama clubs etc for arts/crafts work and for play. Resource Centres are usually financed by a membership fee, which allows the member organisation to come and freely take the materials it needs.
Due to a lack of commitment from Milton Keynes Borough Council, the proposal to set up a Resource Centre was eventually dropped by the Play Association. However, before this happened, the co-operation of Milton Keynes Neighbourhood Care YOP scheme was sought jointly by the Milton Keynes Play Association and ATG to further assess the potential of the ATG paper recycling plant, with a particular view to its future use in the proposed Resource Centre. This project provided the basis of the pilot study.

Although this initial involvement of the YOP scheme was intended as a limited experiment to test the viability of a paper recycling project, as part of a Resource Centre project, it became apparent that this activity could run viably as an independent YOP project. The job creation aspects of 'community'-scale paper recycling are not vast, but it could provide useful work for a YOP team combined with another activity. This was the situation that developed with the Milton Keynes Youth Council YOP scheme, who took up and run a recycling project as an activity combined with printing work.

YOP schemes cannot be evaluated financially by the framework used in Sections 8.2, 9.2 and 9.3 as they do not trade; however they do need to balance income and expenditure. YOP schemes were receiving in 1980 all their labour costs plus £400 p.a. per trainee allowance to cover overheads. This works out at £1,000 per year, or about £20 per week, for the paper recycling project using one YOP team of five trainees plus a supervisor for half their time. The production costs (less labour costs) of running a community paper-recycling enterprise (see Table 9.8) are £2016 p.a. The financial viability of a YOP scheme undertaking this activity would depend on whether or not production
costs in excess of the trainee allowance could be met by sales revenue, and how the capital cost of equipment is raised. The break even sales price necessary to meet production costs in this case is £31 per ream, considerably less than the £100/ream likely selling price.

'Community'-scale paper recycling could therefore be a financially viable project for a government sponsored Youth Opportunities Scheme.

10.2 APPROPRIATE SIZE OF COMMUNITY

The framework developed in Chapter 5 related recycling technologies to an appropriate scale of community by reference to the quantity of waste generated by that community. This measure has been used loosely throughout this feasibility study in referring to the ATG paper recycling plant as a 'community'-scale technology based on the initial theoretical operating data for the Melbourne 5 plant. In this section the concept of the appropriate size of community that this technology relates to is assessed in more detail.

A paper recycling enterprise based on the ATG plant would use approximately 1 tonne of waste paper per annum; this amount could be collected by a source separation scheme from a population of between 40 and 70 (see Chapter 4 and Table 4.10). A community this size is referred to by Boyle (1978), as a group of dwellings, and is smaller than a neighbourhood, or community.

However, relating the size of the recycling enterprise to the size of community that could generate sufficient reclaimed materials through a
source separation scheme for it to operate, is only one measure of appropriateness. Another which should be considered is the size of community which would provide sufficient demand for the products of this paper recycling enterprise. This however is more difficult to define given the wide range of potential products and potential users.

The potential product market aimed at in the financial and economic assessments in the feasibility study, was for art quality papers, and specifically speciality printing papers in art departments and colleges. This market was considered at a national level in order to generate sufficient demand to match the output of the proposed enterprise.

The proposed paper recycling enterprise would be faced, in this situation with a choice of 'exporting' goods to a wider market, or diversifying its range of products produced, to include sugar paper, and writing and packaging papers, in order to serve a smaller community.

Sugar paper used by schools is a potential product market which was explored in Section 8.3. If the proposed enterprise were to supply this market then it could probably satisfy the demand from between five and nine neighbourhoods, assuming approximately one half of the demand for sugar paper from schools was met by this enterprise. This would be approaching the size of a community-scale enterprise.

The average paper consumption in the UK, according to Thomas (1977a) was 130 kg per person per annum. Of this 26 kg was printing and writing paper, 55 kg packaging papers and board, 26 kg newsprint and 7 kg tissues. If the ATG paper recycling plant were able to produce only 10% of the printing, writing and packaging paper needs of a community,
then it could produce sufficient product for a neighbourhood, with a population of around 125 people. Obviously if more than 10% of the demand for these papers could be satisfied then a smaller community could be served.

Any attempt to correlate the size of community with scale of technology must also assume something about the degree of self-reliance in that community. What role could the proposed ATG paper recycling enterprise be expected to play in promoting community self-reliance, could it fulfil the demands of an essentially self-reliant community? Self-reliance can be interpreted with reference to the production and consumption of material goods, and services, or as economic self-reliance. The benefits of communities not only being social units but productive, self-governing units are outlined in Morris and Hess (1975). Awareness of a community as an economic unit should play an important role in increasing political power in that community. 'Community' enterprises recycling paper, and exporting the product to a wider market, could help the development of this economic self-reliance, providing these enterprises were economically viable in themselves. However, as this does not appear to be the case for the proposed paper recycling enterprise then its role must essentially be outside considerations of economic self-reliance.

It is apparent from the above analysis that the proposed ATG paper recycling enterprise could, in a typical community in Britain, use the waste paper generated from a group of dwellings, and could produce sufficient product for a much larger community, whether supplying 10% of printing, writing and packaging papers for a neighbourhood, or sugar and 'art' papers for a community. In an essentially self-reliant
community, however, this situation would differ in two important respects. Firstly the enterprise is likely to attempt to satisfy as wide a range of the community's paper needs as is feasible. As this may be greater than the 10% figure quoted above, then the enterprise may be considered in an essentially self-reliant community to be appropriate at a 'group of dwellings' scale in respect of both the supply of waste paper and demand for the finished product. Secondly, this recycling enterprise should not be considered in isolation, when considering an essentially self-reliant community, and other processes using waste paper, such as for insulation manufacture, or as a fuel, or producing paper goods, should be included in any scenario of appropriate or optimal resource use.
PART III

CONCLUSIONS AND DISCUSSION
CHAPTER 11

PAPER RECYCLING AS A 'COMMUNITY' ENTERPRISE

This research project set out to investigate the appropriateness of, and opportunities for, developing a Community Technology approach to the reclamation and recycling of domestic refuse. This question was approached on three different levels of generality. The wider questions considered whether reclamation and recycling can be considered suitable activities as Community Technology; whether these activities are compatible with the principles of Community Technology, such as being ecologically sound and amenable to small-scale, decentralised development and control. On a more specific level, the question was posed as to which reclamation and recycling technologies might be considered most appropriate to community-scale activity. Both these areas were explored in Part I of this thesis. The third level on which the question was considered was the most specific, and concerned the technical and economic viability of establishing a 'community'-scale paper recycling enterprise. This was undertaken as a feasibility study, of a specific technology or process, in a community context, and recorded in Part II of this thesis.

11.1 THE APPROPRIATENESS OF A COMMUNITY TECHNOLOGY APPROACH TO RECLAMATION AND RECYCLING

Community Technology approach refers to the development and/or adoption of technologies which serve the needs of, increase the self-reliance of, and are amenable to direct control by, small communities and the individuals in them. The importance of developing new technologies, and assessing existing technologies for their appropriateness, was seen as a
central factor in the analysis used by proponents of Community Technology. It is based on a belief that technology can play a significant role in bringing about social and political change, and that technological change, and social and political change must occur together.

Any definition of the community that Community Technology refers to, was consistently avoided in the literature, except by Boyle (1978) whose classification based on population size is used throughout this work. He defines community as having a population of a few thousands, up to 10,000; a neighbourhood as having a population of a few hundred, up to 1,000; and a district as having a population of a few tens of thousands, up to 100,000. Community Technology was interpreted as relating to 'communities' or groups of people of less than 10,000, that is to a community or neighbourhood in the Boyle classification.

Another important theme found in the Community Technology approach is that technology should not exploit the environment. In this respect, reclamation and recycling activities were demonstrated as being appropriate to a Community Technology approach, in that they result, in general, in overall benefits to environmental quality. These are brought about by energy savings, reductions in raw materials used and waste materials generated, and in lower levels of pollution.

11.2 OPPORTUNITIES FOR 'COMMUNITY'-SCALE RECLAMATION AND RECYCLING OF DOMESTIC REFUSE

Current reclamation and recycling activities in Britain, together with some examples from Europe and USA, were examined with particular
reference to those operating at a 'community' scale, or with potential to do so.

It was concluded from an assessment of the current debate on resource recovery versus source separation, that source separation is the more appropriate technology for neighbourhood and community scale reclamation activities. Resource recovery, by mechanical separation and energy recovery techniques, is typically designed to serve populations of between 200,000 and 1 million, and invariably involves high capital expenditure. Source separation schemes were found to operate in much smaller communities, and that greater environmental benefits accrued from recycling, in preference to energy recovery from, solid wastes.

Most source separation of domestic wastes in Britain is carried out by Local Authorities or by voluntary/charity groups, through both house to house collections and by individuals taking separated wastes to collection points. Investigation of the major problems encountered by these schemes indicated a number of barriers to their successful operation. These include lack of available, or stable, markets; the cost of transport to available markets, and in some cases high collection costs. These provide some explanations of the current minimal reclamation of domestic wastes, which only accounts for about 1% of the total disposed of.

Experience of a number of source separation schemes in the USA reinforced these findings, although the availability of suitable markets was a less severe problem, for the particular schemes considered. It was also evident that the US offered greater and more varied experience of neighbourhood and community based reclamation schemes. In particular
of schemes run as independent enterprises, although the majority of these received some government subsidies.

Assessment of this experience of reclamation schemes in Britain and USA, and of the available literature on participation rates, yields of materials and the economics of reclamation schemes, suggests that a neighbourhood could expect to generate less than 40 tonnes of source separated reclaimed materials per annum. This, it was concluded, was too small to support an economically viable enterprise, employing even one person part-time. A community of around 5,000 collecting up to 200 tonnes per annum, however, was considered large enough to support a source separation scheme employing between one and three people. Whether or not the resulting source separation schemes were economically viable was left inconclusive, being dependent on the availability of suitable markets for the materials collected.

Some US source separation schemes were found to be searching for ways to integrate their reclamation activities with recycling processes in order to overcome some of the economic problems associated with the availability of markets for reclaimed materials. This was considered an area of particular interest in developing a Community Technology approach to reclamation and recycling.

A preliminary survey of existing community-scale recycling activities revealed a significant number of small businesses in repair and renovation, and to a lesser extent reuse. Recycling as a manufacturing or processing activity appeared to be carried out primarily in larger plants drawing on quite extensive areas for their reclaimed materials. However, some opportunities for smaller scale recycling activities were
identified, and were related to the size of the community likely to generate sufficient waste material by a source separation scheme. The majority of these processes, including those for glass, plastics and metals recycling and some paper recycling activities, appeared appropriate to district scale or larger communities. Only three of the technologies identified in this work could be described as 'community' scale that is appropriate to either neighbourhoods or communities. All three were concerned with recycling waste paper.

The information available on the effects of scale on economic and technical viability was found to be minimal, severely limiting the scope of this investigation of opportunities for 'community' scale recycling activities. In particular, little could be concluded on the potential for developing smaller units of production of existing recycling processes. Hence this survey only served to indicate some possibilities known to exist.

11.3 'COMMUNITY'-SCALE WASTE PAPER RECYCLING

Waste paper recycling, identified as an activity which was potentially appropriate to developing neighbourhood or community-scale enterprises, was chosen as a specific area of further research for this project. It was apparent from preceding discussion that further research work is needed concerning a number of reclamation and recycling activities that might be considered to be appropriate as Community Technologies. Waste paper recycling was chosen as the area of further investigation in this project because it was both a manufacturing recycling technology and appeared from initial research to offer opportunities for 'community'
scale development. Manufacturing recycling processes were chosen as an area of interest because of the identified importance of developing local market opportunities for reclaimed materials. This was considered an important prerequisite of successful community reclamation schemes.

A more detailed investigation of waste paper recycling in Britain identified the context into which any community-based activity would have to fit, and highlighted several additional reasons why this type of recycling activity might be considered appropriate to a community technology approach.

Large, unused supplies of waste paper are currently available primarily from domestic and some commercial sources. These represent a compatible source of raw material for community-based recycling due to the very dispersed way in which they arise. Another factor favouring the development of community-based paper recycling is that it need not necessarily be in competition with the existing British paper industry. The latter was described as in a situation of decline with an increasing proportion of paper consumption satisfied by imports.

The instability of the waste paper market currently causes considerable problems for reclamation schemes, and attempts to create alternative market opportunities for waste paper can only be welcomed by these schemes. Hence the development of 'community' waste paper recycling may in turn be able to improve the opportunities for operating 'community' reclamation schemes.

All three of the 'community' scale waste paper recycling technologies identified required further research to evaluate more fully the technical
and economic feasibility of establishing them as 'community' enterprises. A preliminary investigation of the scale of operation of each process indicated what size of community it was most appropriate to.

The Melbourne paper recycling plants, with a theoretically rated output of about 0.04 tonnes per day, would, it was calculated, operate at a neighbourhood scale, as it would use the amount of waste paper which could most probably be collected by a source separation scheme from between 400 and 700 people.

The pulp packaging units produce between 0.1 and 1 tonne per day and use a similar quantity of waste paper, which corresponds to the amount of waste paper which could be collected from between about 1,000 and 10,000 people; that is to a community scale. On the borderline between community and district scale is a '1 tonne per day' paper recycling operation, the third option considered appropriate as a 'community' based activity.

It was concluded that a detailed feasibility study of one of these technologies was needed to fully evaluate its potential as a 'community' enterprise, and to further explore the hypothesis set up in the research that 'paper recycling can be a technology appropriate to the development of neighbourhood or community based enterprises'. It was considered desirable that this feasibility study would involve practical operation of the technology in a community context, to facilitate both technical and economic assessment and involvement with community organisations. The scale of operation and costs of equipment indicated that the Melbourne plants, operating at a neighbourhood level, was accessible to such a participation project, whereas the other community scale processes
were not. The Melbourne 5 process was therefore chosen for a detailed feasibility study for this reason, given that preliminary economic analysis suggested that it was potentially economically viable, if only marginally so. The latter conclusion was based on the assumption that employing two people, producing 0.2 tonnes of paper per week, it could bring in a revenue of somewhere between £80 and over £1,000 per week, depending on the quality of the product and the market opportunities.

11.4 A 'COMMUNITY'-SCALE WASTE PAPER RECYCLING ENTERPRISE

The major conclusion reached, as a result of the case study of the modified Melbourne 5 (or 'the ATG') paper recycling plant was that it would not operate, within the current economic and social context in Britain, as a financially viable independent enterprise. The principle cause of this situation was identified as the very high labour cost per unit product output.

The Melbourne 5 paper recycling plant was found, early in the operating tests carried out, to have an actual operating capacity of much less than had been expected. Although technical improvements were carried out, the product output was not significantly improved, and resulting in an operating capacity of only 0.02 tonnes of product per week; just 10% of the 'claimed' capacity. It was concluded that this low product output was a basic limitation of the design, which would not be improved without radical changes in the concept of the plant.

Preliminary expectations of the possible marginal profitability of a 'community' enterprise based on the Melbourne 5 plant were based on
this claimed capacity. Financial analysis based on operating experience, predicted a sizeable loss, due to the significantly lower than expected output.

The most suitable product was concluded to be art paper, in particular as speciality printing papers for silk-screen printing. With a likely selling price of £100/ream (1980 prices) and an output of 33 reams p.a., the likely annual revenue is £3300. A rough estimate of profitability can be gained from the equation:

\[
\text{Profit} = \text{total revenue} - \text{total costs (i.e. fixed costs + variable costs x output)}
\]

With the total costs for the proposed enterprise calculated at £13818, the annual loss is likely to be in the region of £10518.

In view of the reduced output capacity of the Melbourne or ATG plant, it was necessary to reassess its appropriateness as a neighbourhood scale activity. In terms of the size of community which could generate sufficient waste paper from a source separation scheme, (the major measure of appropriateness used in this research), the ATG plant is appropriate to a community of 40-70 people. This is referred to by Boyle (1978) as a 'group of dwellings', and order of magnitude smaller than a neighbourhood. Another measure of appropriate scale was discussed, and considered of equal merit, although much more difficult to quantify precisely. This referred to the size of a community which would provide sufficient demand for the products of a recycling enterprise.
Producing speciality printing papers for art departments and colleges, the proposed enterprise would need to supply a national market. However, if drawing paper for schools was the target market, then it was concluded that the ATG plant could supply the demand from several neighbourhoods up to a small community. If a wider market, for example 10% of the printing, writing and packaging paper demands of a community, were aimed at then it was estimated that this enterprise might supply a neighbourhood of only 100 or so people.

The economic or social, as well as financial, costs and benefits of the proposed paper recycling enterprise were also explored. Benefits were found in respect of the waste disposal cost savings, which were however very small; reduced environmental impact; and through employment generation. The environmental benefits could not be considered significant nationally for a single enterprise of this scale, although if a large number of neighbourhoods or communities adopted this technology, the effects on environmental quality would be worthwhile.

The employment created by a 'community' paper recycling enterprise can be considered a social benefit, valued by the social cost of labour. The latter has been calculated for a non-government employer at 20% of the actual cost, and if included in the analysis substantially improves the viability of this enterprise, such that the economic unit cost at break-even is calculated at £143/ream; compared with the financial unit cost at break-even of £419 per ream when the full cost of labour is included in the analysis.

A further aim of this feasibility study concerned the community context, and the role that such an enterprise could play in promoting greater
community self-reliance. This aim was reconsidered and revised in view of the conclusions drawn on the financial and economic viability of a 'community'-scale paper recycling enterprise. It was obvious that this role must lie essentially outside considerations of economic self-reliance, and opened up the question of whether, in this case, a role existed. The economic assessment showed that the proposed enterprise would be likely to incur an economic loss in the region of £1400 p.a., considerably less than the financial losses expected. However the economic assessment also identified environmental impact benefits which the project was not able to quantify and hence remain outside this evaluation. If their social benefit were substantial then an economic benefit could accrue to the proposed enterprise.

Exploration of possible non-economic roles focussed on two areas. These were environmental education and the provision of employment. A number of community organisations were identified as potential participants in a paper recycling project, including charities, environmental groups, educational and play organisations and government sponsored job creation schemes. Practical involvement with a Manpower Services Commission sponsored Youth Opportunities Programme scheme confirmed the viability of the short-term job creation role. No long-term employment potential without permanent subsidy, however, seemed feasible.

An original intention of this research project had been to explore employment creation in conjunction with educational (and play) roles within the community, as part of a joint project with both a play organisation and the YOP scheme. However, the project did not develop in that direction, exposing some conflict between the aims of the different organisations. It was concluded, though, that in different
circumstances these two roles were compatible, and that aspects of them could be fulfilled by the proposed 'community' paper recycling project.

11.5 A QUESTION OF SCALE?

The feasibility study, in the process of evaluating the technical and economic feasibility of establishing a 'community'-scale paper recycling enterprise, also reflected back on some aspects of the broader levels of the question which is the central theme of this research: whether the Community Technology approach is appropriate to reclamation and recycling activities.

It reinforces the general conclusions reached in Chapters 1 and 2 that recycling activities are compatible with a Community Technology approach in that they are both ecologically sound and accessible to decentralised control. 'Community'-scale paper recycling could, it was shown, significantly reduce the environmental impact due to paper production. It is also a technology which is accessible to control; sometimes expressed as 'low specialisation' (Dickson, 1974) or 'bias towards simplicity' (Boyle and Harper, 1976). Minimal training is needed to operate the ATG paper recycling plant; and, as was evident from the technical evaluation, no specialist or complex equipment is employed in its design.

The simplicity of this technology also serves to highlight some potential conflicts in the Community Technology approach. The low product output per worker, a result of this simplicity, creates a severe problem for the overall economic viability of this process. It
also affects another stated aim of Community Technology, the 'desire for meaning at work' (Boyle, 1978) or that 'work (be) undertaken primarily for satisfaction' (Dickson, 1974). This aspect of fulfilling work was not very apparent in respect of the 'community' paper recycling process, which involved some mundane repetitive tasks, although creative control over the final product quality was maintained. Thus the simplicity of this technology is too strong an element in the design, to the detriment of other Community Technology aims. A better balance could be achieved by development of a less labour intensive process.

The feasibility study results also emphasised the difficulties faced in attempting to generalise about appropriate scales of activity for reclamation and recycling projects, and demonstrates a considerable need for much more detailed information about the viability of specific technologies and projects. One aspect relating to scale raised by the feasibility study was the question of whether the economic non-viability was due to the design of the plant or was a function of the scale of operation?

In attempting to answer this question, consider whether in theory a neighbourhood could support a paper recycling enterprise if the product output per worker could be raised. Based on feasibility study experience, to cover production costs, an enterprise would need to produce 69 reams of paper per annum per person, or approximately 2 tonnes per person per year to be viable. It is feasible that a neighbourhood could collect up to 26 tonnes of waste paper per annum and if the above production output could be achieved, then it could feasibly support such an enterprise.
However, there is little evidence that modifying existing small scale paper making equipment could enable a product output of 2 tonnes per person per annum, when the proposed enterprise would produce only 0.4 tonnes per person per annum. Barbier (1981) quotes an average output in the UK paper industry of 48 tonnes per annum per worker, but using a considerable amount of capital equipment. Paper-making on 'community' level using currently available technology is nearer the class of hand-made paper-making than mechanised. It may be possible to operate a viable hand-made paper enterprise on a 'community' scale, employing one or two people, but it would seem that only if high price, high quality specialist art papers are produced.

It can be calculated that in this specific case, the design of the technology involved introduced the major problems for its economic viability. The question of design or scale though is not a clear choice, in that it can be seen that scale also plays a part in the above case, in limiting possible technological options.

Is it possible then to define an appropriate scale for waste paper recycling, taking a Community Technology approach? Neighbourhood scale may be considered too small for this technology. Appropriate scale critically depends on the technology involved, the output per worker and the value of the product, and as it would appear that most paper products have a low product value, a higher product output than could be achieved with the recycling technology in question would be necessary to achieve economic viability. But what might be an appropriate scale for paper recycling; community, district or even larger scale? The feasibility study confirmed the impossibility of answering this question, demonstrating that each specific process or
technology must be investigated in detail before conclusions on its appropriateness can be drawn.

This highlights the considerable need for further research in the form of feasibility studies of specific recycling processes, to establish their technical and economic viability. The participatory and community context although an important and integral aspect of this feasibility study, should probably be investigated in further projects only once technical and economic viability is established. Additional technical research and development into the possibilities of developing small-scale paper recycling equipment is required. The Parsons 2 tonne per day plant was the smallest equipment being considered or developed in Britain at the time of this research (and that was being designed for sale to Third World Countries). There is a large gap in the available technology between this and the Melbourne machines. If this could be filled with a more automated, mechanised plant than the Melbourne, with a consequent higher output per worker, but smaller and less capital intensive than the proposed Parsons plant, then this may prove the most appropriate community technology for paper recycling.
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APPENDIX 1

PRODUCTION TEST RESULTS

The following tables summarise the results of the production trials carried out on the ATG paper recycling machine and described in Chapter 8. The first series of tests were undertaken with the cooperation of the Milton Keynes Neighbourhood Care Youth Opportunities Programme (YOP) scheme, and the second shorter production test with members of the Open University Alternative Technology (AT) Group.

The output and quality of the paper produced and the hours worked for both trials are recorded in tables A1-3. Each individual task performed in the production was also timed and the average times recorded in table A4. From this information an optimised production flow chart (Figure A1) was drawn up for 1 full day's production by two people. This is based on each batch pulped producing four refiner batches each of which makes five sheets of paper; a post of 20 sheets (equivalent to one pulper batch) is then pressed and hung up to dry. The optimum production per day calculated from this chart is 90 sheets; or 13 sheets per hour (assuming a seven hour production day). This becomes 12.5 useable sheets of sugar paper quality per hour production assuming a 4% rejection rate; and 11.5 useable sheets of art paper quality per hour of production, assuming a 10% rejection rate. Therefore two people working 4\(\frac{1}{2}\) days per week producing paper, and assuming the other \(\frac{1}{2}\) day is spent on administrative tasks, would produce a total of 405 sheets of paper per week; i.e. 393 useable sheets of sugar paper quality or 365 useable sheets of art paper quality per week.
### Table A1 RECORD OF YOP PROJECT PRODUCTION TRIALS: OUTPUT, QUALITY AND PERSON HOURS WORKED

<table>
<thead>
<tr>
<th>Week no</th>
<th>No of trainees</th>
<th>Time worked (hours)</th>
<th>Person-hours worked</th>
<th>Total no of sheets paper made</th>
<th>Quality of paper Grade</th>
<th>Reject %</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 3 4</td>
<td>23.5%</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>17</td>
<td>9 4 3</td>
<td>19.0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>16</td>
<td>16 3 3</td>
<td>14.0</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>22</td>
<td>15 1 19</td>
<td>54.0</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4.5</td>
<td>18</td>
<td>35</td>
<td>6 9 8</td>
<td>35.0</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>23</td>
<td>6 9 8</td>
<td>35.0</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>21</td>
<td>10 3 3</td>
<td>14.0</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>53</td>
<td>22 22 9</td>
<td>17.0</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>21</td>
<td>5 10 6</td>
<td>28.0</td>
</tr>
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<td>11</td>
<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>31</td>
<td>8 13 10</td>
<td>32.0</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>42</td>
<td>14 20 8</td>
<td>19.0</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>24</td>
<td>10 11 3</td>
<td>12.5</td>
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<td>14</td>
<td>5</td>
<td>4</td>
<td>20</td>
<td>48</td>
<td>22 18 8</td>
<td>17</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>43</td>
<td>12 22 11</td>
<td>26</td>
</tr>
<tr>
<td>16</td>
<td>5</td>
<td>3.5</td>
<td>17.5</td>
<td>30</td>
<td>5 18 7</td>
<td>23</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>3.5</td>
<td>10.5</td>
<td>31</td>
<td>9 16 6</td>
<td>19</td>
</tr>
</tbody>
</table>
Table A2  SUMMARY OF HOURS WORKED, OUTPUT AND QUALITY OF PAPER PRODUCED BY THE YOP PROJECT*

<table>
<thead>
<tr>
<th>Average no. of trainees</th>
<th>3</th>
<th>Paper reject rate</th>
<th>19% for paper of sugar paper quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hours worked</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total person hours worked</td>
<td>146</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of sheets/paper produced</td>
<td>368.0</td>
<td>No. of sugar quality sheets of paper produced (grades I + II)</td>
<td>297.0</td>
</tr>
<tr>
<td>Average Output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of sheets/person hour worked</td>
<td>2.5</td>
<td>No. of sugar paper sheets/person hour worked</td>
<td>2.0</td>
</tr>
<tr>
<td>Total no. of sheets/hour of production</td>
<td>8.5</td>
<td>No. of sugar paper quality sheets/hour of production</td>
<td>7.0</td>
</tr>
</tbody>
</table>

* Weeks 4, 5 and 11 discounted as atypical
Table A3 RESULTS OF PRODUCTION TEST WITH MEMBERS OF AT GROUP

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of workers</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Hours worked</strong></td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Total person hours</strong></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total no. of sheets</strong></td>
<td>57.0</td>
</tr>
<tr>
<td><strong>of paper produced</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Average Output</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total no. of sheets/</strong></td>
<td>6.5</td>
</tr>
<tr>
<td><strong>person hour worked</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Paper reject rate</strong></td>
<td>4%</td>
</tr>
<tr>
<td>(for paper of sugar</td>
<td></td>
</tr>
<tr>
<td>paper quality)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of sugar paper</strong></td>
<td>55.0</td>
</tr>
<tr>
<td>**quality sheets of paper</td>
<td></td>
</tr>
<tr>
<td>**produced (grades I + II)</td>
<td></td>
</tr>
<tr>
<td><strong>Average Output</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No. of sugar paper</strong></td>
<td>6.0</td>
</tr>
<tr>
<td><strong>quality sheets/person</strong></td>
<td></td>
</tr>
<tr>
<td><strong>hour worked</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No. of sugar paper</strong></td>
<td>12.0</td>
</tr>
<tr>
<td><strong>quality sheets/hour</strong></td>
<td></td>
</tr>
<tr>
<td><strong>of production</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Paper reject rate</strong></td>
<td>10%</td>
</tr>
<tr>
<td>(for paper of art paper</td>
<td></td>
</tr>
<tr>
<td>quality)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of art paper</strong></td>
<td>51.0</td>
</tr>
<tr>
<td>**quality sheets of paper</td>
<td></td>
</tr>
<tr>
<td>**produced (Grade I)</td>
<td></td>
</tr>
<tr>
<td><strong>Average Output</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No. of sheets of art</strong></td>
<td>5.5</td>
</tr>
<tr>
<td><strong>paper quality/person</strong></td>
<td></td>
</tr>
<tr>
<td><strong>hour worked</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No. of sheets of art</strong></td>
<td>11.0</td>
</tr>
<tr>
<td><strong>paper quality/hour</strong></td>
<td></td>
</tr>
<tr>
<td><strong>of production</strong></td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Time to Complete (in mins)</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Fill former tank</td>
<td>30</td>
</tr>
<tr>
<td>Empty former tank</td>
<td>30</td>
</tr>
<tr>
<td>Pulping (1 batch)</td>
<td>90</td>
</tr>
<tr>
<td>Refining (1 batch)</td>
<td>15</td>
</tr>
<tr>
<td>Forming sheets (1 post = 20 sheets = 4 batches)</td>
<td>60</td>
</tr>
<tr>
<td>Pressing (1 post)</td>
<td>30</td>
</tr>
<tr>
<td>Hanging up to dry (1 post)</td>
<td>15</td>
</tr>
<tr>
<td>Sorting and finishing</td>
<td>30</td>
</tr>
</tbody>
</table>
Fig A1  OPTIMISED PRODUCTION FLOW CHART: For 1 Day’s Production by 2 People

<table>
<thead>
<tr>
<th>TIME</th>
<th>PULPING</th>
<th>REFINING</th>
<th>FORMING</th>
<th>PRESSING</th>
<th>DRYING</th>
<th>FINISHING</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>batch A1 ready</td>
<td>A2</td>
<td>fill tank</td>
<td>A1</td>
<td></td>
<td>press soft dry paper</td>
</tr>
<tr>
<td>9.30</td>
<td>batch A in storage</td>
<td>A3</td>
<td></td>
<td>A2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B ready to use</td>
<td>A4</td>
<td></td>
<td>A3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>B in storage</td>
<td>C</td>
<td></td>
<td>A4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td></td>
<td></td>
<td>B1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.30</td>
<td>B2</td>
<td></td>
<td></td>
<td>B2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.00</td>
<td></td>
<td></td>
<td>break 15 mins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.30</td>
<td>B4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.00</td>
<td>C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>TIME</td>
<td>WORKER 1</td>
<td>WORKER 2</td>
<td>WORKER 1</td>
<td>WORKER 2</td>
<td></td>
<td></td>
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<td>-------</td>
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<tr>
<td>1.30</td>
<td>I</td>
<td>I</td>
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<td>I</td>
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</tr>
<tr>
<td>2.00</td>
<td>D</td>
<td>E</td>
<td>D</td>
<td>E</td>
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<td></td>
</tr>
<tr>
<td>2.30</td>
<td>C</td>
<td>D</td>
<td>C</td>
<td>D</td>
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<tr>
<td>3.00</td>
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<td>C</td>
<td>E</td>
<td>C</td>
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<td>3.30</td>
<td>F</td>
<td>E</td>
<td>F</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.00</td>
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<td>G</td>
<td>I</td>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.30</td>
<td>D</td>
<td>I</td>
<td>D</td>
<td>I</td>
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<td>I</td>
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<td>empty tank</td>
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</tr>
<tr>
<td></td>
<td>break 15 mins</td>
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</table>

Fig A1 Continued: