

ROBBIE BURNS' MOUSTACHE:
PRINT KNOWLEDGE AND PRACTICE

by

G.A.P. HARDSTONE



THESIS PRESENTED FOR THE DEGREE OF PhD
THE UNIVERSITY OF EDINBURGH

1996



DECLARATION

I, Gillian Anne Patricia Hardstone, declare that this thesis has been composed by myself, and that the work contained herein is my own.

Signed :

G.A.P. HARDSTONE

Date : 19/8/96

ABSTRACT

This thesis presents a detailed account of what printworkers know, the way in which they know it, and what they do with that knowledge in order for production to happen : the substantive and cognitive content of print knowledge, its distribution and mobilisation. It looks at everyday industrial practice in terms more usually reserved for the knowledge of scientists, engineers or other professionals, and finds that they are also useful for characterising the substantive and cognitive content of knowledge used in a largely "blue-collar" manufacturing environment.

Drawing on work from the sociology of scientific knowledge, the history and sociology of science and technology, and other relevant fields, the thesis reviews existing frameworks for conceptualising and analysing knowledge and practice, and the power relations inherent therein. It discusses the applicability (and limitations) of these frameworks to current everyday manufacturing production activity in the light of the empirical data, in order to increase understanding of technological knowledge and practice. Fieldwork was carried out in three firms in different sectors of the industry, using a variety of data collection methods including interviews, participant observation and action research/consultancy. Data are presented ethnographically, in the form of case studies.

The thesis argues that social, economic, technical and political factors both structural and local shape the content and distribution of print knowledge and power within and between firms, creating both the industry's established technological communities and its day-to-day technological networks. It suggests that there are two main types of mobilisation process in print production, recursively related through institutionalisation : DEFINITION, when "common knowledge" is mobilised by individuals who belong to a technological community; and PROBLEM-SOLUTION, which requires the "collective mobilisation" of diverse personal knowledge (underpinned by common knowledge) by technological networks of heterogeneous composition. The non-human world, in the form of texts, tools and machines, is crucial to both processes and to the relation between them.

The thesis concludes that technological knowledge is a collective socio-technical process, and that the content, distribution and mobilisation of knowledge cannot be considered in isolation from one another. A framework for analysis encompassing all three elements needs to be developed. Working from existing frameworks which link knowledge content with distribution, it suggests a way of conceptualising the mobilisation of knowledge in relation to its distribution.

ACKNOWLEDGEMENTS

This thesis represents the outcome of a collective mobilisation of knowledge - the achievement of a temporary state of definition. The following individuals and organisations made significant contributions to the problem-solving process. Without them, it would not have been possible, and I thank them all :

The Economic and Social Research Council (funders); Janette Webb and James Fleck (PhD supervisors); Wendy Faulkner (Doctoral Programme advisor); the case study firms : Freedom Press (RIP), Weirs Web and Trinity Press, and all who work(ed) in them; the British Printing Industries Federation; St. Brides Printing Library (Nigel); Robin Day (who saved my disk); Edinburgh University Audio-Visual Service and Bindery; and all friends and colleagues 1990 - 1996.

This thesis is dedicated to Jo Smith, Adrian Friedli, John Gill and John Rae, whose love and friendship over the last few years have sustained me more than they will ever know.

'There was and there is a romance of the workshops... It had in it the tang of sweat and the reek of hot oil; the good smell of spread ink and stacked paper, of pungent resin and mellowed leather; the flash of poured metal and flying sparks; the glow of furnace and kiln and oven and of the drooping gas jets with blue and hissing naked flame.

'In our day there has been added another chapter... There is the very stuff of romance in the unceasing devotion of white-coated priests and white-frosted acolytes to deities of humming steel in our great cathedrals of industry; those hungry deities, whose oblations are the burden of great ships and the spoil of continents; those beneficent deities, who ceaselessly perform beneath sunshine roof or daylight arc the miracle of transmuting raw elements into treasuries of baled and crated wealth; mysterious deities withal, whose Office of Hours is a creeping line on a graph, whose missal is written in esoteric symbols and cryptic equations by lamas of a new cult, whose festivals are saturnalia of intake and output figures that attain the fantastic monotony of starkly incredible strings of noughts' (Corrigan, 1944:18)

CONTENTS

1. INTRODUCTION

- 1.1. Subject and aims of the thesis
- 1.2. Rationale
- 1.3. Robbie Burns' moustache
- 1.4. Chapter summary

2. THINKING ABOUT KNOWLEDGE AND PRACTICE

- 2.1. Introduction
- 2.2. Knowledge in general
- 2.3. Privileged domains of knowledge
- 2.4. Frameworks for technological knowledge
- 2.5. The social shaping of knowledge
- 2.6. Constructivist networks of knowledge
- 2.7. Foucauldian power/knowledge
- 2.8. Disciplinary techniques and knowledge
- 2.9. Summary and research questions

3. METHODOLOGY AND RESEARCH DESIGN

- 3.1. Methodological issues
- 3.2. Research design
- 3.3. Data collection methods
 - 3.3.1. Participant observation
 - 3.3.2. Interviews
 - 3.3.3. Texts and visuals
 - 3.3.4. Action research
 - 3.3.5. Secondary data

4. PRINTING IN BRITAIN

- 4.1. Views from outside
- 4.2. Sectors, markets and products
- 4.3. Processes and technologies
- 4.4. Capital investment and subcontracting
- 4.5. Managing production
- 4.6. Networking and training
- 4.7. Economics

5. THE CASE STUDY FIRMS

- 5.1. Freedom Press
- 5.2. Weirs Web
- 5.3. Trinity Press

6. FREEDOM PRESS

- 6.1. Obtaining work : defining feasibility and desirability
 - 6.1.1. Job feasibility
 - 6.1.2. Customer desirability
- 6.2. Job specification : defining product and process
- 6.3. Planning the job : problem-solving networks
 - 6.3.1. Internal networks
 - 6.3.2. External networks
- 6.4. Planning production : collective problem-solving

7. WEIRS WEB

- 7.1. Obtaining work : defining a job
 - 7.1.1. Feasibility
 - 7.1.2. Technical specification
- 7.2. Planning work : pre-production problem-solving
 - 7.2.1. Planning the job
 - 7.2.2. Planning production
- 7.3. Routine operation : defining production standards
 - 7.3.1. Web crews, presses and common knowledge
 - 7.3.2. Finishers, machinery and lack of common knowledge
- 7.4. Trouble-shooting : production problem-solving
 - 7.4.1. The benefits of collaboration
 - 7.4.2. Mobilisation routines

8. TRINITY PRESS

- 8.1. Assembling knowledge : defining the plant
- 8.2. Planning production : defining product and process
- 8.3. Routine operation : defining production
 - 8.3.1. Set-up
 - 8.3.2. Makeready and run
- 8.4. Preventing problems : defining machinery
 - 8.4.1. Pre-emptive strategies
 - 8.4.2. Fire-fighting

9. CONCEPTUALISING PRINT KNOWLEDGE AND PRACTICE

- 9.1. Introduction
- 9.2. What printworkers know : domain knowledge
 - 9.2.1. Categorising print knowledge
 - 9.2.2. Features of domain knowledge
 - 9.2.3. Visual and tactile knowledge
 - 9.2.4. Design instrumentalities
 - 9.2.5. Non-technical print knowledge
- 9.3. How printworkers know their worlds : domain cognition
 - 9.3.1. Categorising print cognition
 - 9.3.2. Features of domain cognition
 - 9.3.3. Tacit knowledge revisited
 - 9.3.4. From cognitive components to socio-cognitive structures
- 9.4. Who are the printworkers ? communities and networks
 - 9.4.1. Technological communities

- 9.4.2. Technological networks of the firm
- 9.4.3. Technological networks of individuals
- 9.4.4. The relationship between communities and networks
- 9.5. What printworkers do : putting knowledge into practice
 - 9.5.1. Activities which mobilise knowledge
 - 9.5.2. Knowledge-mobilising situations and milieux
 - 9.5.3. Definition and problem-solution
 - 9.5.4. Moving between domains of knowledge
- 9.6. Creating networks : mobilising knowledge
 - 9.6.1. The social shaping of knowledge mobilisation networks
 - 9.6.2. Actor-networks, or networks of actors ?
 - 9.6.3. Foucauldian perspectives on knowledge mobilisation
 - 9.6.4. Conceptualising the knowledge mobilisation process
- 9.7. Summary

10. CONCLUSION

- 10.1. Synopsis
- 10.2. Findings and conclusions
- 10.3. Limitations of the thesis and suggestions for further research
- 10.4. Rounding off

APPENDICES

- I. Print personnel interviewed
- II. Outline interview schedule

GLOSSARY

BIBLIOGRAPHY

VIDEOTAPE : A videotape (VHS) showing the litho printing process accompanies this thesis.

CHAPTER 1 - INTRODUCTION

1.1. SUBJECT AND AIMS OF THE THESIS

This research investigates everyday production in the printing industry in terms of knowledge. The research has three main aims : to produce an empirical account of print production knowledge and practice; to examine the applicability of certain existing conceptual and analytical frameworks in that context; and to explore the idea that knowledge is a collective socio-technical process. In order to achieve this, it addresses the following questions : what do people in print firms - shopfloor, clerical and managerial workers - know about production ? How is that knowledge shared between them, and what makes them "printworkers" ? And what does that knowledge enable them to do in order for production to happen ? The thesis therefore deals with the content, distribution and mobilisation of everyday print knowledge. That knowledge pertains to a specific domain - printing - and is carried by all who operate within that world. Its practitioners have an identity not restricted to those deemed "skilled" or "expert". So this thesis is not about skill or expertise, although it deals with a body of knowledge not carried by the general population.

But why write a thesis about print knowledge ? Personal factors provided the original impetus. My own experiences as a printworker suggested that it would be interesting and appropriate to examine the importance of knowledge in everyday printing activity. There's nothing quite like the sound and smell of a printworks, and the buzz and excitement of production. But for any of this to happen, from when customers phone for quotations to the final product sitting neatly packed ready for delivery, a vast spread of knowledge comes into play amongst those involved. And only printworkers carry this knowledge. Having worked in a print cooperative, I was interested in exploring whether some form of collective knowledge made production possible, and whether this

applied in other print contexts too. So I have written about people whose knowledge I share and whose language I speak, and about materials and machines that used to be part of my day-to-day working environment. But although I am at home "in the print", I am now a researcher - an insider and an outsider. I have become a "translator" (Vincenti, 1990) between those two worlds, and this project is the outcome.

Print is a medium for mass communication, a means of transmitting to large numbers of people the messages conveyed by texts and images, in tangible and portable form, durable over space and time. It is so ubiquitous and all-pervasive in Western culture that we tend to take its production for granted. A brief consideration of the uses of printed matter and their many forms provides a good introduction to an industry that is equally varied and complex in terms of markets, products and processes.

Print is used for the DISSEMINATION of information and opinions. Products most frequently associated with this function are newspapers, magazines and non-fiction. It provides ENTERTAINMENT, in the form of fiction, comics, playing cards and board games; and DECORATION : wallpaper, calendars, posters and prints. Other uses for print only became a significant source of income for printers in the 20th century, and are intrinsic to a system of capitalist production (Reynolds, 1989). Print is still - despite television - a major ADVERTISING medium. Apart from advertisements in newspapers and magazines, the industry produces billboard posters, direct mail, leaflets, and point of sale material. Printed media such as banknotes and cheques serve as CURRENCY; they are used to LEGITIMATE the identity of parties involved in contracts, in the form of business cards, letterheads, credit or membership cards; while items such as business forms or advice notes RECORD and CONFIRM transactions. Labelling and packaging IDENTIFY products and services, as well as conveying INSTRUCTIONS for use. Should purchasers wish to pass on the goods, the industry prints GIFT-GIVING paraphernalia : wrapping paper, greetings cards and gift tags; as well as personal stationery and postcards for INFORMAL

COMMUNICATION.

The printing industry is concerned with the production of all forms of printed matter : the processes whereby a single original is created in terms of overall form and style, but not content; and reproduced as multiple identical (textbooks) or near-identical (credit cards) copies, usually onto paper or board, although other materials can be used. From the 1970s onwards, most sectors of the industry have undergone a succession of socio-technical changes in production methods. These developments and upheavals are ongoing (see ch.4), currently centring on increasing automation, computer-based production and production management control systems, and on digital technologies for image production and reproduction. These may have implications for the content, distribution and mobilisation of domain knowledge. The status of the industry is felt to be ambiguous, since most firms are not involved in initial decisions to produce the work, nor (generally) in the distribution of the finished product, 'we are a service industry yet we manufacture tangible products' (Fairbrass, LW 22/5/91:5).

As an industry, print is economically significant. It was claimed (LW 17/9/91) that printing was the fourth largest industry in Britain, involving more than 10,000 firms, and employing more than 160,000 people, even after recession, rationalisations and redundancies, and generating revenue of approximately £18bn in 1990/91 (LW 3/9/91). Yet the industry is almost entirely composed of firms generating annual turnover of less than £1m (LW 15/5/91:21) and employing less than 25 people (PIRA, 1992). There have always been many small firms in the industry, but its structure changed dramatically during the 1980s, with a significant trend towards fragmentation. While the number of larger companies remained roughly stable in the 1980s at around 4500, the number of smaller firms soared from about 7500 in 1982 to over 16,000 in 1989 (PIRA, 1992). This was partly through the rise of high street "instant print" shops, and partly as a result of printers, some made redundant during the early 1980s recession, setting up in business for themselves as the economy revived and a Conservative

government extolled the virtues of entrepreneurship. Many of these firms were to close down during the period of my fieldwork : 1991 - 1993.

There has as yet been no detailed empirical account or conceptualisation of everyday production activity in terms of technological knowledge at the level of individual firms. This research seeks to address that omission. Production-related print knowledge provides a good example of technological knowledge, in the broad sense of the word, in that it involves not only technical, but also social, economic, political and geographical aspects of a specific industrial activity. Many sectors of the printing industry exhibit high product and process variety, hence the knowledge needed for production will be wide-ranging and varied.

The printing industry provides fruitful material for a firm-level study of knowledge distribution and organisation, because of its structure. The level of capital investment required in plant and machinery combined with product and process variety mean that smaller firms (the majority) are likely to form extensive inter-organisational links with materials suppliers, subcontractors and process specialists. Intra-organisational links between production departments are also significant. The range of occupational groups among printworkers, and recent changes in technology, industrial relations and systems of print training adds to the complexity of knowledge distribution.

Finally, print production is an activity which clearly involves a range of people working together for a tangible end result, and it is thus a good site for investigating the mobilisation of technological knowledge, and to assess whether or not this process could be termed "collective" in any sense.

There are more general practical reasons why a thesis dealing with production knowledge at the level of the firm and the industry might be of interest. Knowledge is crucial to the everyday working

of all organisations, but is often taken for granted or ignored until crises occur or changes are made, such as the introduction of new technologies. Business applications of computer systems which attempt to capture knowledge or rely on it for their implementation might also benefit from greater general understanding of everyday technological knowledge in industry, and how it is acquired and put into practice.

1.2. RATIONALE

This research is inter-disciplinary, by design and of necessity. Its starting point was empirical - how to make sense of and account for a complex but apparently mundane process : everyday print production knowledge and its practice. No single body of literature exists for tackling these questions, so this thesis has drawn upon work from several fields of enquiry, some of which do not usually find themselves juxtaposed, in order to conceptualise and analyse the content, distribution and mobilisation of print knowledge in a way that addresses all three aspects coherently and preserves their interdependence. This approach implies two things : that existing ways of conceptualising knowledge (and production) are inadequate in the empirical context of this research; and that there are useful conceptual and theoretical combinations to be achieved through disciplinary syntheses, specifically with regard to technological knowledge and practice.

Accounts of manufacturing production from operations management (Muhlemann et al., 1992) or broadly sociological (Blauner, 1964; Cockburn, 1983) perspectives are rarely conducted in terms of knowledge. The focus of the former is usually technical¹, whilst the latter's interest in production technology is primarily social. This research takes the view that production is a socio-technical

1. As is most print-specific academic research.

process, to which knowledge - carried by people and embodied in the non-human world - is crucial. Although this research employs some of the substantive concepts of operations management such as product, process, volume and variety in the presentation of the case study material, these descriptive frameworks are insufficient on their own for understanding print knowledge.

It is in the broad area of science and technology studies, which encompasses a variety of disciplinary perspectives including sociology, history, economics and philosophy, and which has, to some extent, been concerned with knowledge, that literature is found which addresses the empirical and theoretical concerns of this thesis, if only in part or by extension. Research into technological innovation has also been interested in knowledge. It is in these fields that my research aims to contribute to (or reopen) a number of debates regarding the content and distribution of everyday technological knowledge, in the light of evidence from the printing industry.

The content of technological knowledge can be approached in substantive terms - what is known about a particular domain of activity; and in respect of its cognitive aspects - the ways in which the features of that world are perceived by those who inhabit it. Some of the above literature has addressed these aspects of technological knowledge by extrapolation from theoretical arguments about scientific knowledge (Dosi, 1984; Laudan 1987) unsupported by detailed empirical evidence. Other work has concentrated on "high-technology" industries and the sources and content of knowledge required for innovation (Faulkner, 1993) or technological change (Georghiou et al., 1986); implicitly positing these as distinct from the everyday practice of "normal" (Hughes, 1987) technological knowledge. A further focus of enquiry has been on bodies of professional knowledge carried by homogeneous occupational groups often considered "expert", such as design engineers (Vincenti, 1990) or scientists (Whitley, 1975; Weingart, 1976). Just how different (or perhaps similar) is the "normal", everyday knowledge carried by printworkers who might never see themselves as experts

or professionals ?

A diversity of work deals with the cognitive aspects of knowledge, which include tacit knowledge (Polanyi, 1958, 1967; Zuboff, 1988) and "instrumentalities" (de Solla Price, 1984). Science and technology studies literatures have examined these too, drawing a particular distinction between formal and tacit knowledge. Several writers (Whitley, 1975; Weingart, 1976; Fleck, 1988; Vincenti, 1990) have produced taxonomies of scientific, engineering or technological knowledge, which might be useful for categorising the content of printworkers' knowledge. Fleck's (1988) concept of "socio-cognitive structures", which makes the social nature of knowledge and cognition explicit, may be highly relevant to the content of print knowledge, and also provide the starting point for a consideration of its distribution.

Debates concerning the distribution and organisation of technological knowledge have centred on the idea of "technological communities" (de Solla Price, 1982; Vincenti, 1990), which are characterised as broader and more numerous in their membership than scientific communities, but still similar. Again, this concept has arisen from an extrapolation of the findings of studies of scientific organisation (Crane, 1972; Knorr-Cetina, 1981; Whitley, 1984) into technology studies. Detailed empirical evidence from industry has so far been lacking to resolve whether this notion of technological "community" is actually relevant to individual firms' and workers' everyday knowledge and practice. Other concepts, such as networks including non-human elements as well as people, might be more appropriate, given the fact that materials, tools and machinery are essential to print production. Then there is the question of how membership of technological communities or networks is acquired and maintained. Orr's work (1986, 1987, 1990) on "war stories" may be of some assistance. Furthermore, how should the operation of communities and networks be analysed ?

Given that knowledge is a basis for action, and is intimately bound up with practice, the question that springs to mind next is "what

do printworkers do with their knowledge ?". But the science and technology studies literature that deals with knowledge does not examine everyday industrial production. Rather, it tends to concentrate on the generation and application of (new) knowledge to the innovation process. Otherwise, mention of the practice of technological knowledge seems to be largely subsumed into discussions about its overall purpose (the production of goods and services) as compared to that of scientific knowledge.

So there is no body of science and technology studies, or innovation studies literature with which to engage directly regarding the collective practice, or "mobilisation", of everyday technological knowledge by practitioners within firms. This research gathers empirical evidence about the situations in which print knowledge is mobilised and the type of collectivity these exhibit. Combining this with ideas about knowledge content and distribution, it creates new conceptual categories to describe and account for the socio-technical processes that occur when printworkers put their knowledge into practice.

In the light of those categories, this research explores how these knowledge mobilisation processes might be analysed. Within the field of science and technology studies, there is a tension between two epistemologically conflicting perspectives, which can be broadly characterised as structuralist and constructivist. An example of the former is "social shaping" theory (Mackenzie and Wajcsman, 1985), which argues that scientific and technological developments are shaped by a complex of social, economic, technical and political factors which relate to an existing social order. On the other hand, constructivist theories, such as Callon's (1986) "actor-network" theory, which attempt to treat human and non-human participants even-handedly, stress the contingency of scientific and technological outcomes on the actors involved, which may be individuals, organisations, governments or non-human elements (such as scallops, bacteria, or lightbulb filaments), and acknowledge no pre-existing social structures. Both approaches might have something to contribute to an analysis of the everyday mobilisation

of print knowledge. This research is just as likely to discuss industry sectors, markets and occupational groups as pantone books, densitometers and blanket cylinders¹.

However, although there have been rapprochements between these two positions within the field of science and technology studies (Bijker and Law, 1992; Williams and Edge, 1992), it is difficult to imagine a synthesis or consensus emerging from within this area. This research therefore shifts discipline again to philosophy, and considers the work of Foucault (1977, 1984) on the institutionalisation of power/knowledge relations as a means of analysing the content, distribution and mobilisation of technological knowledge in print organisations. This appears to be one way of bridging the gap between social structure and contingent, individual agency, which may be relevant to the empirical material of this thesis.

None of the above is intended to suggest that this thesis aims to produce a unified synthesis of so many diverse perspectives for analysing technological knowledge and practice in organisations. That would be far beyond the scope of this research. The intention is to synthesise ways of conceptualising print knowledge and practice in terms of its content, distribution and mobilisation, and to suggest the analytical frameworks which might be most useful for understanding each of these aspects. Where this does not seem possible, this research will discuss the various analytical perspectives, indicating their strengths and shortcomings in the light of the empirical material.

1. See Glossary (or text and diagrams) for an explanation of all technical terms. Printing, like any other domain of knowledge, has a language of its own, and this will be discussed later.

1.3. ROBBIE BURNS' MOUSTACHE

And finally to the title of this thesis. Apart from grabbing the reader's attention, what is its purpose ? Printworkers tell great stories, but rarely for no reason. The tale of Robbie Burns' moustache (fig.1.1) was recounted to me by the platemaker at one of the case study firms. Whether it is true or not does not matter. It is the kind of story experienced printworkers would tell apprentices. It contains an important lesson which would never be forgotten or ignored in the way a more straightforward admonition might be : NEVER graffiti or doodle¹ on your makeready or waste sheets, because your run might be short and these could save you from a reprint or shortage. By the time this thesis is complete, the full significance of Robbie Burns' moustache will be apparent.

Fig.1.1. ROBBIE BURNS' MOUSTACHE

'When I was serving my time in the tin printing, we were producing shortbread tins, and it was Robbie Burns' head on the lid of this petticoat tails shortbread tin. Now what used to happen in those days was the sheet of tin used to go through an oven to dry the ink. Because obviously, unlike paper, the tin wouldn't absorb the ink to dry it. It had to be done by evaporation. And in those days, long before UV drying, the sheet of tin used to go through a big, long oven. And the man used to pick up the sheet before it went out to inspect it for blemishes, colour and everything. And there was an inspection table, and [then] each man used to put the sheet to one side, because it might get a wee bit scuffed.

So, to cut a long story short, there were these eight heads of Robert Burns on this sheet of tin, and someone with one of those big black pens puts a moustache on him. I've got to tell the full tale so you realise what I'm saying. He just doodled on one of the tins. A week later, they find there's so many short to make up the full quantity. So the natural thing is to go through all the rubbish to find any good ones. Somebody goes to the printing press, and here was this stack of waste sheets still. Because what we used to do, with tin printing - just like paper, you tend to turn the sheet over and put it through as waste - they were always left there and they could always be used as waste, just to build up your colour, etc. But of course, someone from the equivalent of the

1. However tempting... And it is.

bindery thought "oh, here's a dozen good sheets"....

This is true. The odds on this happening is unbelievable. The director of MacVities walked into his local shop and there's a big row of these petticoat tails on the shelf, and there's Robbie Burns with a beard and moustache in the middle of it. So he actually asked if he could buy that tin ! He asked if he could buy that tin to take away with him. And here the story unfolds. And that's how it actually happened. The printer could actually remember doing it as a wag, and he owned up. Because there were all these sheets and then "oh well, we're short", and noone had seen it. Except the managing director of MacVities had seen it, and he bought the tin out of the shop. But that's a fact, though. But there was great apologies from the Company. Not many Robbie Burns with beards and moustaches !' [platemaker, Weirs Web].

1.4. CHAPTER SUMMARY

This introduction has outlined the subject and aims of the thesis, and reasons why these are of interest from theoretical, empirical and practical perspectives. In the next chapter (2), academic literature from a number of areas relevant to the thesis is reviewed, and more detailed research questions formulated. Chapter 3 deals with methodological issues and the design of the research project, including site selection and data collection. A structural overview of the printing industry, based on interviews and archive research, is provided in chapter 4, and it is in this context that the individual case study firms are introduced in chapter 5. The following three chapters (6, 7 and 8) present the majority of the primary empirical material in ethnographic format. In chapter 9, relevant conceptual and theoretical aspects of the literature are further discussed and analysed in the light of the case study evidence, and some answers to the research questions are suggested. The final chapter (10) of the thesis states the main conclusions, summarises its substantive and theoretical findings, assesses some of its limitations and proposes areas for future research.

2.1. INTRODUCTION

This chapter examines frameworks for conceptualising and analysing technological knowledge, and whether these might be applicable to day-to-day production in print firms. The main bodies of work addressed lie in the area of science and technology studies, and include the sociology and philosophy of scientific knowledge; the history of science and technology; structuralist "social shaping" theory, constructivist sociologies of technology (in particular, "actor-network theory"), the sociology of knowledge, and Foucauldian approaches to knowledge. I also examine work dealing with technological innovation and implementation from a number of disciplinary perspectives which touches on specific aspects of knowledge relevant to production technology.

I begin by looking at knowledge in general terms. Focusing down, I look at arguments claiming and disputing that technological knowledge is akin to scientific knowledge and can be theorised in similar ways in terms of its content and distribution. The chapter then reviews taxonomies of knowledge which might be relevant to everyday print production. It weighs up the merits of analysing the distribution and mobilisation of technological knowledge during everyday print production in the light of existing social structures, as opposed to starting from a consideration of the individual actors involved in controversies around a particular technology. Finally, I examine Foucauldian modes of analysis, and what they might imply about the content, distribution and mobilisation of print production knowledge.

2.2. KNOWLEDGE IN GENERAL

Dictionary definitions of knowledge (Collins, 1986) reveal a diversity of interpretations : personal and social; theoretical and experiential; objective and subjective; fact and feeling. They suggest that knowledge has both content and distribution, and can be mobilised for thought or action, individually or collectively. The importance of personal, internalised experience as an essential part of knowledge suggests that when knowledge originates at a theoretical level, "theory can only be learned by practising its application : its true knowledge lies in our ability to use it" (Polanyi, 1967:17). Knowledge enables us to reason and act beyond our previous state.

Knowledge has been defined as the certainty that phenomena are real (this table is real), in that they have an absolute existence independent of our volition (I cannot wish it away), and have specific characteristics which can be perceived by us (it has four legs of approximately the same length and is made of wood) (Berger and Luckmann, 1966). Whilst philosophers and postmodernists have debated the existence of "reality" and whether it is ever possible for us to "know" anything, most people tend to take both knowledge and reality for granted.

A more critical approach suggests that our knowledge of reality is mediated by individual perspectives and experience, "we shape all knowledge by the way we know it" (Polanyi, 1967:77.) and is subject to multiple external influences. In other words, whilst the knowledge we each have is unique in its combinations and the constructions which we place upon it, it can still be shared and understood by others, despite problems defining and delimiting the "social" and the "personal",

"Our practical knowledge must be mostly accurate, since otherwise our world would fall apart..... At a fairly low level, individuals who share the same social practices must most of the time understand each other correctly, even if a small minority of them

in universities spend their time agonising over the indeterminacy of discourse" (Eagleton, 1991:13).

Anthropologists have suggested that our everyday knowledge, which we tend to take for granted, is culturally bounded. For example,

'the Dinka experience of colour is mediated through cattle first and the rest of nature next... the whole of their aesthetic and social experience is so profoundly embedded in a bovine idiom that it is even misleading to distinguish their knowledge of cattle from their knowledge of themselves as if each were not the medium of the other' (Douglas, 1973:27),

and some philosophers claim that culture structures the way we order our knowledge of the material world,

'the fundamental codes of a culture - those governing its language, its schemas of perception, its exchanges, its techniques, its values, the hierarchy of its practices - establish for every man, from the very first, the empirical orders with which he will be dealing, and within which he will be at home' (Foucault, 1989)

So knowledge is shared by all who live within a particular culture, whether tribal, regional (Faris, 1973) or institutional (Roth, 1973; Venables and Clifford, 1973), and is itself shaped by that culture. Although the knowledge related to a specific domain of technological activity, such as printing, is not known by the general population, it is shared by people operating within a particular firm or industry (though perhaps not by all). Culture may not be the only difference between and within various groups' knowledge. Social, political and economic structures, and factors such as gender, class, or race are implicit in the anthropological literature. Knowledge could also be socially constructed by people with "shared symbolic universes" (Berger and Luckmann, 1966). In printing, occupational groups, industry sectors, and organisational structures may shape the knowledge of individuals and groups, although factors such as class or gender may play a role in determining who is allowed to become a novice in the first place (Cockburn, 1983;1985;1993).

2.3. PRIVILEGED DOMAINS OF KNOWLEDGE

Knowledge that is widely held and freely available may not even be recognised as knowledge, but relegated to the status of "common-sense". I turn now to the literature which discusses more specialised forms of knowledge whose distribution among groups or individuals is restricted ^{and} may be privileged, either as knowledge per se, or as "expertise" (see 2.5.). One area which has been a focus for academic enquiry is scientific knowledge, which has been assumed to differ significantly from other activities or types of knowledge. A substantial literature has developed which seeks to open up this scientific "black box". Could this help conceptualise technological knowledge in printing? One factor of note is that the literature on science and scientific knowledge displays a tension between structuralist and constructivist accounts. This is paralleled in the emergence of structuralist "social shaping" theory and constructivist theories about technology (see 2.5. and 2.6.). Hence debates in the field of science studies cross over or have repercussions for a reading of the literature on technology.

One reason why looking at printing with scientific knowledge and practice in mind might be useful is that science and technology are recursively interconnected activities and bodies of knowledge. Although some industries and technologies have closer links with science (and hence scientific knowledge) than others (Basalla, 1986), the traffic in theory and practice has never been all in one direction (de Solla Price, 1987). Hence frameworks developed for scientific knowledge might be useful for conceptualising everyday technological knowledge. Faulkner (1993) has pursued this possibility in terms of the scientific and technological knowledge used for "high-technology" industrial innovation, and her work provides a useful review of literature debating the science-technology relationship.

Microsociologists of science and technology have even collapsed the two into "technoscience" (Latour, 1986), and con-fused them as both

'socially constructed cultures... The boundary between them is a matter for social negotiation and represents no underlying distinction' (Bijker et al., 1987). For constructivists, the two can be considered part of a socio-technical "seamless web" (Hughes, 1987). On the other hand, Vincenti's (1990) work on engineering design knowledge makes a case for scientific and technological knowledge to be considered as distinct and separate, albeit overlapping, bodies of knowledge. So there is debate about their similarities and differences, and attempts to theorise technology by extrapolation from science should be made with care, as the limitations of analogies between or fusions of science and technology emerge when parallels are pushed too far.

Some philosophers of science, such as Laudan (1987), have attempted to apply theories about scientific knowledge and practice to technology. Economists (Nelson + Winter, 1997), philosophers (Dosi, 1984) and historians (Constant, 1986) of technology have sought to apply Kuhnian "paradigms" of scientific development in the search for a theory of technological development. Kuhn himself warns that this approach may not be useful without modification to fit particular circumstances, "Though scientific development may resemble that in other fields more closely than has often been supposed, it is also strikingly different" (Kuhn, 1962).

Apart from being specialised, domain-specific and not shared by the general population, how has scientific knowledge been characterised, and what assumptions about technological knowledge have been made by analogy or contrast ? Firstly, what of their purpose ? The goal of scientific knowledge has often been seen as the production of knowledge in its own right - scientific enquiry as an end in itself. But science is not a hermetically sealed activity untainted by external considerations. What about policy-oriented research ? Economic metaphors (Edge, 1974-5; Bolter, 1986) have been increasingly employed to conceptualise aspects of the organisation of scientific knowledge : the symbolic capital of ideas exchangeable for tangible resources; investment in fields carrying low risk but expectations of high return (Latour and

Woolgar, 1986); and barriers to entry (Latour, 1985). Their use may reflect changes over time in funding patterns and scientific organisation, and practitioners' perceptions of a transition from barter to market competition. Technological knowledge on the other hand, can be seen as having external goals, such as the production of outputs such as goods, services or profits. It is not an end in itself. However, this is not to say that people who work with technologies never seek knowledge for its own sake or for the sheer pleasure of it.

Whilst writing and publication of results are important means of communication for research scientists (Latour and Woolgar, 1986), with publication seen as the process whereby scientific facts are validated verbally (Knorr-Cetina, 1981; Latour and Woolgar, 1986) and visually (Law and Whittaker, 1988), managers in industry mainly communicate orally, and often face-to-face (Stewart, 1967; Zuboff, 1989). In production terms, a result is a completed job which speaks for itself. Technologists have been described as reluctant to write or publish their findings for fear of industrial espionage or revelation of trade secrets (de Solla Price, 1982), and yet wishing to read others' work as a means of gaining information. At the same time, there is significant informal communication between firms, and technological knowledge is also passed on through what von Hippel (1988) calls "knowledge leakage", as personnel move around an industry. This has been contrasted with scientists wanting to produce papers, but not to read the work of others (de Solla Price, 1982), although the number of publications by research and development departments of large firms exceeds that of some universities. These issues may bear on intra- and inter-firm relations in printing, and the kinds of knowledge exchanged.

The idea that scientific knowledge is objective, deals with absolute truth and is hence not open to scrutiny, has been strongly questioned from a number of standpoints (Bloor, 1976; Barnes and Edge, 1982) and in relation to a variety of scientific activities, such as laboratory practice (Knorr-Cetina, 1981); the construction of scientific facts through publication (Latour and Woolgar,

1979,1986); and formal proofs of safety-critical software (Mackenzie, 1990). However, the belief that scientific knowledge is composed of purely theoretical or formal elements (albeit socially shaped or constructed) has not yet been sufficiently challenged, according to J.Fleck (1988). Senker (1992) suggests that formal knowledge acquired during training serves afterwards as a framework for making sense of subsequent experience, and that tacit and practical knowledge about science and technology is just as important in "high-tech" industrial innovation.

The view that scientific paradigm shifts happen by cognitive leaps (Kuhn, 1962) has been criticised as perpetuating the myth that science is a largely cerebral activity. Such shifts could also be attributed to changes in the technologies used by scientists, thereby allowing recognition that science is a practical craft (Ravetz, 1973; de Solla Price, 1987), in which "instrumentalities" (de Solla Price, 1984) - knowledge about using tools and instruments, which is largely tacit - are extremely important. Scientists are practical reasoners not possessed of a unique rationality by virtue of their activities; they are "tinkerers" (Knorr-Cetina, 1981), in the same way that Harper (1987) describes the Saab-mechanic's work as "bricolage". However, implying that scientific knowledge and practice are 'just another form of social life' (Knorr-Cetina, 1981:137) may be an excuse to black-box them by association with the everyday knowledge we take largely for granted.

A similar emphasis on the intellectual aspects of technological knowledge (perhaps arising from a view of technology as applied science) has led some writers to a portrayal of technology AS knowledge (Laudan, 1987). This view has been echoed by others, 'technology is really the sum of knowledge... which allows things to be done, a role which frequently requires the use of machines, and the information they incorporate, but conceivably may not' (Macdonald, 1983:27). Although this definition questions an emphasis on technology as hardware, it ends up black-boxing technological knowledge instead.

Some philosophers of scientific knowledge have stressed the predominance of tacit (as opposed to formal) elements in technological knowledge (see 2.5) : if these cannot be articulated, never mind the perceived problems of sharing them, then there is no point in further investigation. Laudan (1987) suggests that tacit knowledge, being unarticulated, physical and visual is inaccessible to academics because they are trained to examine written, verbal texts. Laudan (1987) also seems to imply that tacit knowledge is illogical and unstructured. Some kind of value judgment about the relative status of formal and other forms of knowledge may be in play here.

Nevertheless, tacit and visual knowledge have been seen as crucial for both science and technology by some writers who recognise their cognitive significance, 'Depiction, picturing and seeing are ubiquitous features of the process by which most human beings come to know the world as it really is for them' (Fyfe and Law, 1988:2) or because empirical evidence, such as the prevalence of diagrams and drawings in technical texts, suggests that technological knowledge has a strong visual content (Ferguson, 1977). Others have pointed to the use of visual depictions as a rhetorical device in science, 'elements which add to the popularity of analogy and metaphor in persuasive discourse, for example the pictorial element in referring to those things of which one has a concrete mental picture' (Knorr-Cetina, 1981:67); or as a means of closure of scientific and technological controversies (Latour, 1985) : they are 'the hinge which connects the intractable world with the docility of the printed page... the representatives of endless awkward objects and processes that are left behind in the laboratory' (Law and Whittaker, 1988:161). So both scientific and technological knowledge have strong tacit and visual elements.

Scientific knowledge has been seen as shared by members of particular communities, albeit those of a discipline or smaller field of study (Whitley, 1984), in the sense that 'the sociological notion of community connotes both normative, and more broadly

speaking, cultural integration, as well as some form of cooperation and dependency' (Knorr-Cetina, 1981:69). Domain-specific scientific knowledge is in part deliberately acquired during a period of apprenticeship, and constitutes 'the tested and shared possessions of the members of a successful group... the novice acquires them through training as part of his preparation for group membership' (Kuhn, 1962:191), as well as through practical research experience. The concept of scientific knowledge and practice as culturally and socially bounded in terms of communities has been developed by several writers, and characterised, for example as : "thought collectives" (Ludwig Fleck, 1979); "scientific communities" (Kuhn, 1962); "invisible colleges" (Crane, 1972) and "transscientific fields" (Knorr-Cetina, 1981).

At the same time, there have been debates about the usefulness of such terms which concentrate on the intellectual aspects of scientific activity. Knorr-Cetina (1981) disputes that Kuhn's idea of "communities" is relevant to laboratory research practice, arguing that "transscientific fields" based on economic and other "resource relationships" are more useful concepts. Questions of what actually happens in laboratories, such as the division of labour or work organisation, are obscured by the notion of scientific "peer groups". This may serve to conceal the actual hierarchy within and around research sites - if all scientists are equal, some are more equal than others (Knorr-Cetina, 1981). Perhaps the situation of research scientists in a laboratory does not differ so greatly from that of production workers in industry as might be supposed.

If it is problematic to talk of "scientific communities", it seems even more difficult to consider "technological communities" as analogous, as the latter are likely to be more fragmented and differentiated (de Solla Price, 1982; Vincenti, 1990; Faulkner, 1993), even if technological communities have restricted by some writers to include only those who generate technologies, rather than those who produce or use them (Laudan, 1987). However, in the context of the thesis, for example, such communities might include

production workers, engineers and management within an organisation; equipment and materials suppliers, subcontractors and customers at the inter-organisational level; and (perhaps) finance, consultancy and policy-making bodies beyond the organisation : what could be described as an industry's "socio-technical constituency" (Molina, 1993). Hence, technological knowledge is likely to be diffused among a broader range of actors than scientific knowledge. Insofar as it relates to an established technology in general use, that knowledge is also likely to be carried by a far larger number of people in more organisations, and not only when new or problematic technologies are being developed and implemented. How is membership of such a community established and maintained, and who are the "outsiders" (Bauman, 1978) ?

At the same time, formally constituted groups such as industrial or occupational associations which might be expected to serve as a locus for technological community may not fulfil their anticipated purpose (Vincenti, 1990). For example, Clark (1990) found that membership among production managers of professional bodies such as BPICS - the British Production and Inventory Control Society - showed a very low take-up in Britain, and its meetings were largely populated by representatives of PIC software suppliers. The relevance of the concept of "communities" to technological knowledge and practice needs to be explored further, and this research will assess its usefulness in the light of empirical data from the printing industry.

However, for all the difficulties referred to above, it is in the literature on technology influenced by the study of scientific knowledge that cognitive aspects of technology, otherwise largely unexplored, have been recognised (if not wholly addressed) on a footing with technical, social, economic and political factors, all of which are seen as inextricably linked (Knorr-Cetina, 1981; Laudan, 1987), but which appear to be left implicit.

2.4. FRAMEWORKS FOR TECHNOLOGICAL KNOWLEDGE

People working in print production "know" many things. Is it possible to categorise ways of knowing, or to create a framework within which to conceptualise them? One outcome of research into the sociology of scientific knowledge (SSK) was the development of various taxonomies of the knowledge components of scientific organisation and communication. Whitley (1975, in Mendelsohn et al., 1977) defined these as research practices; techniques; explanatory models; speciality concerns; and metaphysical values and beliefs, whilst Weingart (1976, in Mendelsohn et al., 1977) produced a hierarchy of cognitive elements including conceptual schemes; artifact paradigms and classical problem solutions; acknowledged scientific achievements; and metaphysical paradigms and values. Taxonomies could be useful for analysing technological knowledge, but those above are too specific to scientific practice, not necessarily applicable to technology, and insufficiently detailed for the purpose of this thesis. Moreover, these taxonomies, whilst incorporating (albeit implicitly) social arrangements, seem to be based on assumptions of the existence of some form of scientific "community", which may or may not be Kuhnian, but would almost certainly not fit with what has been suggested about the nature of technological communities (see 2.3.). Other than by implication these taxonomies appear not to question or address the distribution of knowledge.

With regard to engineering knowledge, Vincenti (1990) combines an SSK-influenced division of knowledge into explicit (formal) and tacit elements (Winter, 1987) with categories of declarative (knowing what) and procedural knowledge (knowing how) (Winograd, 1975). If all knowledge can be both procedural and declarative (Diaper, 1989), this distinction may not be very useful. Vincenti's framework identifies technical engineering knowledge as both formal and tacit. This could be seen as reinforcing a belief that engineering is a halfway house between science and technology, and hence that it is fitting for engineering knowledge to be a mix of

formal and tacit elements, leaving unchallenged the view that scientific knowledge is primarily formal and technological knowledge largely tacit. However, Vincenti's observation that most kinds of substantive knowledge involve a mixture of cognitive components is useful, confirming the work of Fleck (1988).

Fleck's (1988) conceptual framework of "socio-cognitive structures", developed originally as a taxonomy of scientific cognitive components, may be more general but also more relevant to a technological context. He suggests that knowledge exists as "SOCIO-COGNITIVE STRUCTURES", having both cognitive content and a concomitant distribution among social groups, or "CARRIERS". These structures are composed of various COMPONENTS or types of knowledge : META-KNOWLEDGE (Whitley, 1975; Weingart, 1976); FORMAL KNOWLEDGE; INFORMAL or heuristic KNOWLEDGE; TACIT KNOWLEDGE (Polanyi, 1967); CONTINGENT KNOWLEDGE (Fleck, 1983); and INSTRUMENTALITIES (de Solla Price, 1984).

A mixture of these components comprises the knowledge related to a particular DOMAIN (area of activity). Moreover, it is possible to carry more than one cognitive component simultaneously. For example, when mixing a batch of printing ink, one may have formal knowledge about the proportions of each basic colour required, derived from training or specified as exact percentages by a Pantone book, combined with informal rules of thumb encountered at work, and refined by practice and experience into tacit, internalised knowledge. Components, domains and people (carriers) come together in SITUATIONS occurring within particular environments, or MILIEUX.

Fleck's particular contribution to this taxonomy is the recognition and inclusion of contingent, or context-specific knowledge, as a separate cognitive component vitally important for innovation (Fleck and Tierney, 1991) and day-to-day "technology-practice" (Pacey, 1983). Contingent knowledge

'covers a host of items that can make or break an application

including : close familiarity with the production processes involved and the idiosyncrasies of the existing machinery; an acquaintance with a set of industrial contacts necessary to get a job completed; an appreciation of the abilities and attitudes of the personnel involved; and an understanding of the working environment and the industrial relations climate' (Fleck, 1983).

This element was previously referred to in the literature almost in passing, 'locally developed know-how concerning "what works" in certain problem-"situations"' (Knorr-Cetina, 1981:41). This is perhaps not surprising, as contingent knowledge (together with tacit knowledge) would appear to be an example of what have been termed "subjugated knowledges" : 'disqualified as inadequate to their task or insufficiently elaborated : naive knowledges, located low-down on the hierarchy, beneath the required level of cognition or scientificity' (Foucault, 1984:82). However, the importance of such local factors in general has been noted, perhaps unsurprisingly, in constructivist accounts of technology,

'the process of building a project may be treated as the elaboration of a LOCAL NETWORK - that is, the development of an array of the heterogeneous set of bits and pieces that is necessary to the successful production of any working device' (Law and Callon, 1992).

Fleck's framework seems sufficiently generalisable to be applied to technological knowledge, as well as providing detailed characteristics of the various cognitive components. According to this taxonomy it is possible to perceive/know about the same thing in a number of different ways (rather like declarative and procedural knowledge), for example, as a generalisable rule of thumb and as its contingent, context-specific application. This plurality might be useful when discussing technological knowledge in a production context, where the "community", if such exists, is composed of heterogeneous elements (Sorensen and Levold, 1992) which might carry knowledge as a variety of cognitive components.

The concept of "socio-cognitive structures" (Fleck, 1988) implies that diverse knowledge can be carried collectively within groups, as well as on a personal level by individuals, and that the existence of the group is essential to the practice (or

mobilisation) of that knowledge : the whole is more than the sum of its parts. This is supported empirically by Orr's studies (1986, 1987, 1990) of Xerox service engineers' "war stories", told and retold to create and preserve "community memory" of how to solve problems and as a way of proving and celebrating their identity as technicians. But how far is knowledge collective rather than personal, and does this apply equally to its content, distribution and mobilisation ?

It depends what is meant by "collective". In its more specialised sense of individuals owning in common or acting in cooperation, this may be problematic for several reasons. If "technological communities" are seen as very diffuse and heterogeneous (see 2.3), this may inhibit a view of technological knowledge as collectively held, partly because the content of carriers' knowledge will vary so much, partly because it is widely distributed, and partly because its carriers have diverse agendas, some of which may involve keeping their knowledge secret.

Similarly, if most organisations have a formal structure that is hierarchical (Constant, 1987) rather than collective (Williamson, 1980), and are composed of groups and individuals with conflicting and competing viewpoints, interests and goals, this might make it difficult to see them as mobilising knowledge cooperatively at the internal level. Moreover, if firms are thought to operate under conditions of economic competition (and mythical perfect information), then they cannot perhaps hold knowledge collectively in relation to other organisations, which might entail cooperation, and an acknowledgement that the distribution of knowledge is uneven. Finally, the view that inequalities in society are reflected and reinforced by the distribution of knowledge more generally may work against seeing knowledge as collective, although not that knowledge is collectively held within specific communities. However, collectivity need not necessarily imply sharing, cooperation or commonality. It may merely be taken to mean "forming an aggregate whole", which makes the concept of mobilising collective knowledge easier to apply.

Fleck's (1988) framework leaves open the basis on which knowledge might be mobilised, as what happens in domains, situations or milieux is left unspecified, as are the identity of and the relations between carriers. This might be in accordance with what could be broadly termed a structuralist analysis, whereby the distribution or division of knowledge within society or organisations could be seen as analogous to concepts of the social division of labour. As with the division of labour, wider social, political and economic relations would determine which domains or forms of knowledge were more highly valued or most easily acquired (Fleck and Tierney, 1991), although not which ones were ultimately of most practical use for making a technology "work".

Within the sociology of technology, again as a spin-off from the sociology of scientific knowledge, there have been more recent quasi-taxonomic frameworks, intended as tools 'for making sense of, and operating on the sociotechnical world' (Bijker and Law, 1992:107), such as "technological frame" (Bijker, 1987). Bijker's conceptual framework includes the resources, concepts, and techniques used in any community, 'a combination of the explicit theory, tacit knowledge, general engineering practice, cultural values, prescribed testing procedures, devices, material networks, and systems' (Bijker and Law, 1992:301). Intended to be 'simultaneously social AND technical' and to bridge the perceived divide between structure and action, technological frame includes actors' meanings, including those they articulate about relations between other actors of which they are aware. Although knowledge figures in all the elements of "technological frame", this taxonomy does not specifically address its content, distribution and mobilisation.

"Technological frame" additionally includes relations of which the actors are not aware - 'relations that may be embodied, as in the case of skills, or form part of their environment, as in the case of such resources as the power supply or the details of software that they use to build their spreadsheets' (Bijker and Law,

1992:302). There would seem to be a methodological difficulty here : if Bijker follows the actors and listens to them speak, how does he propose to deal with tacit knowledge if 'we can know more than we can tell' (Polanyi, 1967:4), or with relations of which actors are unaware and hence presumably cannot speak ?

The above taxonomies refer to what scientists, engineers and technologists know about, as well as how they perceive it. In other words they deal with substantive as well as cognitive aspects of knowledge. However, either they appear too particular to scientific activity to be applicable to technology, or too general to be an adequate means of categorising the details of the domain-specific knowledge carried by printworkers. In cognitive terms, Fleck's (1988) framework comes nearest to achieving this, in that his cognitive components in themselves imply substantive knowledge about domains of activity.

Other research might be useful to address the question of what printworkers know about the domain they inhabit - their substantive technological knowledge. Vincenti's (1990) historical study of design engineering knowledge and aeronautical innovation provides six categories of technical knowledge which might prove adaptable to everyday production practice : fundamental design concepts, criteria and specifications, theoretical tools, quantitative data, practical considerations, and design instrumentalities. His observations that some substantive knowledge may belong in more than one category, or may change category over time are interesting, as they parallel Fleck's (1988) contentions that the cognitive components of knowledge alter with practice, and that a carrier may perceive the same phenomenon in different ways simultaneously. It would be interesting to see whether Vincenti's substantive categories of engineering knowledge can apply to printing, although they may not be sufficient on their own, as printworkers' worlds are not purely technical but also social, economic, political and geographical.

Faulkner's (1993) paper on the sources and kinds of knowledge used

in innovation, and the results of mobilising that knowledge, draws on Vincenti's (1990) taxonomy, as well as pulling together work done on categorising technological knowledge by Gibbons and Johnston (1974) on the content of information transferred from academic research into industrial innovation; by the economist Winter (1987), and by Dosi (1988) on aspects of knowledge which influence the inter-firm transfer of technology; and the concept of socio-cognitive structures (Fleck and Tierney, 1991). From these, Faulkner constructs five overall types of knowledge used in innovation : knowledge relating to the natural world (including artefacts); knowledge related to design practice; knowledge related to experimental R&D; knowledge related to the final product; and knowledge about knowledge. All but the third seem relevant to print production knowledge, though they are not as detailed as Vincenti's (1990) categories, and thus not as useful here. They do not, however, have so explicitly technical an emphasis as his.

Both Vincenti (1990) and Faulkner (1993) imply that innovation is an activity distinct from everyday production, a view that has been debated (Fleck, 1992). Are these taxonomies applicable to the knowledge used in everyday manufacturing, particularly in an industry such as printing not commonly perceived as "high-tech" or professionalised ?

2.5. THE SOCIAL SHAPING OF KNOWLEDGE

Structuralist analyses of science and technology, such as social shaping theory also touch on the content and distribution of technological knowledge. Mackenzie and Wajcman (1985) see know-how and tacit knowledge as one of three "levels" at which technology is constituted, the others being physical objects or artifacts, and activities or processes. It could be suggested that there is feedback between the three levels, and that technological knowledge comprises knowledge about objects/artifacts and activities/ processes, and that this "learning by using" (Rosenberg, 1982) is

in turn re-generated by experience and use of those activities or artifacts. In other words, social shaping theory suggests that the content of technological knowledge is primarily procedural because its stress on "know-HOW" and tacit knowledge. However, social shaping theory appears to take tacit knowledge for granted despite stating its importance : it remains silenced !

So what is tacit knowledge, and why should it be so important in terms of technology ? Polanyi (1958; 1967) sees tacit knowledge as a kind of subperception, rooted in the human body; a means of interpreting the world, by converting the impact between bodies and other things that arise, occur or exist into our understanding of their meaning. He considers the body the instrument and the subject of all practical and theoretical knowledge gained from our perception of the world beyond it.

Polanyi explains tacit knowledge using the analogy of reading : "focal awareness" is like reading a text written in a language in which one is not fluent - you notice the words. With "subsidiary awareness", like reading one's native language, the text becomes transparent. With familiarity, "focal" awareness becomes "subsidiary", and knowledge becomes tacit. When we are familiar with tools (manual or intellectual), there is a change in our perception, a 'personal assimilation by which we make a thing form an extension of ourselves through our subsidiary awareness of it' (Polanyi, 1958:61), through instrumentalising 'certain things and actions in the service of some purpose' (Polanyi, 1958:62), which is often of a problem-solving nature (Polanyi, 1967). Tacit knowledge can therefore be summarised as 'knowledge that accrues to the sentient body in the course of its activity' (Zuboff, 1988:40), and can include methods or artefacts in its creation and expression.

Tacit knowledge, according to Polanyi, is a two-stage cognition whereby awareness of something, for example, a combination of muscular acts or the features of a face (the "proximal" term of tacit knowledge) is followed by a cue for action (the "distal"

term), for example, recognition of the face or performance of the act itself. The role of the body is central to this mode of knowing, 'when we make a thing function as the proximal term of tacit knowing, we incorporate it in our body - or extend our body to include it - so that we come to dwell in it' (Polanyi, 1967:16). Not only objects, but also ideas can be perceived tacitly through experience, 'to interiorise is to identify ourselves with the teachings in question, by making them function as the proximal term of a tacit knowledge, as applied in practice' (Polanyi, 1967:17). Hence production workers will carry tacit knowledge about production based on their physical experience of the process, but both they and non-production workers may also have tacit knowledge about production processes acquired from experiencing ideas about production.

No wonder tacit knowledge is seen as so important in a technological context by social shaping theorists. If technology is seen as largely practical, then a knowledge that is grounded in practice (such as activities and processes) must have a significant part to play in the development and use of that technology (Harper, 1987). The idea of tacit knowledge springing from familiarity with tools used for a purpose makes it particularly attractive to apply this concept in an industrial context. This point is made by Polanyi himself, 'even in the modern industries, the indefinable knowledge is still an essential part of technology' (Polanyi, 1958:52).

Since tacit knowledge is somehow associated with the human body, it is easy (and wrong, according to Polanyi) to assume that it is peculiarly the province of manual workers, and hence to claim, as does Laudan (1987), that the automation of production technologies, or a transition from manufacturing to service industries will destroy that knowledge, or reduce its importance. Zuboff (1988), concurring with Polanyi, demonstrates the importance of the body in white-collar work. Managers have tacit knowledge about what to do with their bodies as managers : management as physical presence. Hence it could be argued that recent technological developments

such as production automation and the use of computer-based production management systems might diminish the importance of managerial tacit knowledge if managers no longer need to manage by physical presence.

However, Zuboff (1988:23) suggests that for both blue- and white-collar work, 'the application of technology that preserves the body may no longer imply the destruction of knowledge; instead it may imply the reconstruction of knowledge of a different sort'. This might imply a general change in its cognitive content, for example, from less to more formal components; or a change within tacit knowledge in the proximal and distal terms of that knowledge, for example in a shift from on-press to off-press controls, or from management by walking around to management through computer-mediated surveillance. It might indicate something more fundamental (see 2.9), 'In becoming the target for new mechanisms of power, the body is offered up to new forms of knowledge' (Foucault, 1991:155). Not only may the body gain new forms of (tacit) knowledge, but it may also BE known in new ways - perhaps at a price. What has happened to tacit knowledge in printing ?

But tacit knowledge and "know-how" are not the only components of technological knowledge (Fleck, 1991), particularly in relation to production workers and managers. Social shaping theorists do not expand further on the cognitive content of technological knowledge, being more concerned with the shaping and influence of particular technologies as a whole by and on existing and emergent social, economic and political structures and power relations. They focus on the 'development, deployment and use' of those technologies (Winner, 1985). Technology is seen as not only socially shaped, but society-shaping, a reciprocal process between the technical and the social involving both structural and more localised relationships. Perhaps then, technological knowledge, as part of technology, can be considered similarly socially shaped and society-shaping (see Berger and Luckmann, 1967). If its distribution among individuals and groups is uneven, this may reflect, reinforce or alter existing patterns of social organisation. Knowledge does not necessarily

confer power on its carriers (think of Cassandra at the siege of Troy). In the light of Fleck and Tierney's (1991) comments on expertise (2.5) and Foucault's (1984) definition of "subjugated knowledges" (2.4), the converse appears equally likely : power allows what counts as knowledge to be defined, and is crucial to an understanding of its creation and practice. Social, economic or political valuations placed on certain kinds of knowledge may lead to their characterisation as "skill" or "expertise", which are revealed as socially shaped in literature related to, or found congenial by, social shaping theorists (Fleck and Tierney, 1991; Fincham et al., 1994).

Skill implies the ability to translate knowledge into practice under a wide range of conditions. For example, it is one thing to ride a horse round an indoor paddock on a leading rein, but quite another to ride cross-country, 'there can be no skill where everything is completely predictable... skill is a response to the unexpected and unpredictable ...it does not exist without some mental involvement', (CSS, 1989). Skill is associated with dexterity - manual, verbal and mental - and may be improved by repeated performance, which supplies feedback from the experience for assimilation into the practitioner's existing knowledge, as tacit knowledge interiorised through practice, which Harper (1987) terms "deep knowledge".

The significance of skill in a technological context has been explored by labour process theorists (Braverman, 1974; Kraft, 1977), from a perspective which sees new technology as a means whereby the fluctuations and uncertainties of production arising from variable human performance are reduced by an increase in externally imposed controls over work, in order for capital to extract ever more surplus value from labour. As their control over their activities is reduced, the labour force is thereby progressively and inevitably deskilled to produce (in theory) cheaper, more compliant workers, through increased task fragmentation and decreased spans of control, in accordance with Taylorist principles. Other research has suggested that the reality

of new technology implementation is far more complex (Fleck et al, 1989; Friedman and Cornford, 1989). Skill as a social construct may depend on who is doing the work, and how their labour and knowledge are valued in society. From a feminist perspective, Cockburn's work (1983; 1985) suggests that gender and economics inform debates about deskilling.

Expertise can be seen as a combination of knowledge with experience and reputation, invested with social status or recognition, and commanding a higher market value than "non-expert" knowledge. Such expertise may be created for a variety of reasons :

'the power of groups of practitioners to "define the situation" may flow from a tight labour market situation; from the exploitation of a traditional recognised status; or from a high economic demand for the specific outputs they control' (Fleck and Tierney, 1991).

Barnes (1986) develops the concept of "authorities-on" which can be usefully be compared here. "Authorities-on" are empowered to speak about their subject; they are expected to be familiar with it and to understand it correctly; but they are not expected to be directly connected with it. To claim expertise on the other hand lays oneself open to having to prove it through practice in a way that admitting to knowledge or experience does not. Expertise carries connotations of needing to be continually refreshed and updated. It is domain-specific, and the more specialised the area, the more likely expertise is to be granted. At the same time, those who define another person as an expert would not presume to set boundaries to that person's field of expertise, 'certain practitioners can claim that they "own" a particular form of expertise. and can impose on other groups their own definition of what.. constitutes legitimate expertise' (Fleck and Tierney, 1991). Do socially shaped attributions or definitions of skill and expertise operate among printworkers ? Even if they do not, certain forms of printing knowledge may be privileged above others, thereby affecting the content, distribution and mobilisation of knowledge in this domain.

However, whilst structuralist theory may help account for the distribution of technological knowledge, is it the most useful or the only way to analyse it at the level of the organisation, particularly in the context of day-to-day operations ? How to explain the micro-level interactions between individuals, small groups and the technological systems within which they operate ? Williams and Edge (1992) suggest that there may be 'possible synergies between different frameworks'. The following section explores some of these frameworks, although there would be epistemological problems with any attempt to reconcile them with structuralist accounts.

2.6. CONSTRUCTIVIST NETWORKS OF KNOWLEDGE

Technological knowledge might be distributed and mobilised in other ways, as well as according to relatively stable, wider social structures, particularly at the intra- or inter-organisational level, where local, contingent factors will enter the picture. A (social) constructivist perspective may have something to contribute to a discussion of issues at this level, despite its limitations from a structuralist standpoint (Williams and Edge, 1992; Collins and Yearley, 1992) : lack of broader social analysis, and political relativism (Russell, 1986); drawing undue parallels between science and technology; over-extrapolation from a micro to a macro level of analysis (Williams and Russell, 1988); and lack of historical context.

For example, its refusal to use existing social structures as a basis for explanation gives it a fluidity which may help capture the dynamics of everyday situations,

'what we normally call "the social" or "the economic" is, like technology, both heterogeneous and emergent; and [...] what we normally think of as social relations are also constituted and shaped by technical and economic means... technology, the social world and the course of history should all be treated as rather messy contingencies' (Bijker and Law, 1992:8).

In particular, the concept of the formation and continual recreation of networks (Hughes, 1983; Callon, 1986) may be useful when considering the application or "mobilisation" of technological knowledge during production. Such alliances as are formed may be of short duration and not necessarily explicable by reference to external factors. Networks or circuits may be fruitful metaphors for describing the relations between Fleck's "carriers" of knowledge (1988).

Hughes' (1987) holistic approach, drawing on systems theory, stresses the importance of an integrated analysis of physical artifacts, institutions and their environment, which together make up technological systems. Given what has already been said about the disparate and heterogeneous nature of technological communities, this kind of framework might be capable of handling their complexity, a possibility explored by Sorensen and Levold (1992). Further, Callon's "actor-network theory" (1987) attempts to dissolve the distinction between human and natural actors, giving all equal prominence, 'We should consider symmetrically the efforts to enrol human and non-human resources' (Latour, 1986). It is left open whether the human actors in question are individuals, groups or institutions, which might allow for flexibility in accounting for the distribution of knowledge among technological communities and organisations.

Consideration of both human actors and the non-human world might be useful when examining technological knowledge in a production context, and perhaps especially relevant to a consideration of "instrumentalities" - 'once technical objects are stabilised, they become instruments of knowledge' (Akrich, 1992) - and tacit components, which involve the interiorisation of objects. A more systematic inclusion of the material world may be possible through the adoption of such a methodology, in order to produce an account which deals even-handedly with the social and the technical,

'artefacts form an important part of systems... they do not stand apart as means or tools to be directed by social interests. Rather

they should be seen as forming an integral part of such systems, interwoven with the social, the economic and the rest, and their form is thus a function of the way in which they absorb within themselves aspects of their seemingly non-technological environments' (Law, 1986:236).

On the other hand, this is one place where structuralist and constructivist analyses of technology clash. All actors in a network are not equal, 'In the process by which structuring decisions are made, different people are differently situated and possess unequal degrees of power as well as unequal levels of awareness' (Winner, 1984); "reverse salients" (Hughes, 1983) are identified by those who have the power to articulate what constitutes a "problem" from their point of view; in the identification of "relevant social groups" and moments of "closure" (Bijker and Pinch, 1987), power is always relevant, not only occasionally; and conflicts are not always resolved in consensus, 'a technological solution may be imposed without consensus amongst the various groups involved' (Williams and Russell, 1988).

And where are the boundaries of such networks to be drawn ? Which social groups are relevant, and who is to decide this ? Latour (1986) suggests keeping an open mind, 'we have to be as **undecided** as the various actors we follow as to what technoscience is made of... and make the list, no matter how long and heterogeneous, of those who do the work' (Latour, 1987). This does not necessarily compensate for the researcher's own "blind spots", particularly if a role is given to the researcher's 'intuitive ideas about what set of relevant social groups is adequate for the analysis of a specific artifact' (Bijker, 1992). Not adding one's own actors to the network to prove a point (Bijker, 1992) is one thing, but failing to recognise the existence of key actors is more serious.

Bijker's (1992) self-confessed exclusion of women from his earlier consideration of the development of the fluorescent light is a case which points up the potential shortcomings of an approach so heavily reliant on tracking down written historical materials, although he states that he eventually discovered his omission from records left by another of the actors. Whose views tend to be

circulated and preserved in textual form; whose accounts / representations of history are considered valid, or, indeed, survive the passage of time ? Bijker himself (1992) admits that the researcher may encounter problems in deciding who is speak on behalf of a social group once it has been identified as "relevant". The adequacy of a social constructivist approach has been challenged for not setting social groups in sufficient context, and for not providing enough detail to distinguish between different members of those groups (Rosen, 1993), despite its emphasis on "thick description".

Another aspect of where to set boundaries to networks centres on issues of spans of control. Although Hughes illustrates that technological systems extend beyond the firm, and require a whole network of people and artefacts to function (1983), he suggests that social, economic and political factors outside the control of the organisation should not be considered part of the technological system, although they may affect it (1987). Is this an attempt to avoid considering the possibility of pre-existing social structures ? However, not all constructivists go so far : Bijker's "technological frame" (1987) explicitly includes external factors which actors may not control. In an industrial context, an organisation may have dealings with other firms or groups of people over which it does not exert control, but which may be part of its knowledge networks. Perhaps organisational knowledge extends beyond the boundaries of the organisation.

Furthermore, when does a microsociological approach suggest that network boundaries be drawn ? Bijker and Pinch (1987) posit that networks are fixed after closure has occurred, and hence that the translation process is finite. This appears to amount to momentarily opening the black box, only to shut it again. Whether or not "closure" has actually occurred might itself be matter for debate (Williams and Russell, 1988; Cockburn, 1992), both for the actors involved, and for researchers. Stabilising actor-networks at this point might imply a temptation to reify them, when their existence could be considered more as an ongoing and continually

renegotiated process.

A further issue is whether a microsociological approach can be applied to the day-to-day, and generally "workable" use of established production and production management technologies. Constructivist accounts tend to produce historical studies of technological development, and to concentrate on moments of "interpretative flexibility" about the form these new technologies should take (Hughes, 1983; Bijker and Pinch, 1987). Others examine technological systems that failed, or failed to be adopted (Law and Callon, 1992; Carlson, 1992), because they consider that 'controversy surrounding failure tends to reveal processes that are more easily hidden in the case of successful projects and institutions' (Law and Callon, 1992:22).

This choice of subject is explicitly stated by Latour, 'We study science *in action* and not ready made science or technology; to do so, we either arrive before the facts and machines are blackboxed or we follow the controversies that reopen them' (Latour, 1986). Constructivists have been criticised for being deliberately selective in this respect (Russell, 1986). Would everyday, non-catastrophic production problems respond to this treatment, and what about less problematic aspects of managing production? These could be seen as "technology in action" even though the actual machines have been blackboxed and are no longer controversial *per se*. We shall see.

Some micro-sociologists of technology perpetuate the view that technological problem-solving is more usually 'concerned with re-ordering the material world to make it more productive of goods and services' (Hughes (1987:53), whereas scientific problem-solving is intended to generate knowledge. Hughes suggests that only inventors outside firms have 'an elementary interest in problem-solving as an end in itself' (1987:58). But is Callon's (1986) process of "translation", with its four stages of "problematization", "interessement", "enrolment" and "mobilisation" by a "major actor" creating a network of passive agents a viable model for production

problem-solving within print firms ? Why do agents allow themselves to be enrolled ? This model implies power and knowledge relations between actors and agents, but how might these be analysed ?

Constructivists adopt a range of perspectives on power, whilst rejecting what Latour (1986) terms the "diffusion model", which suggests that orders are obeyed because their source is powerful. What this source might be, and why it should be intrinsically powerful is not brought into question. The extent to which commands are diffused is seen as related to the degree of resistance from the social fabric through which they pass. Constructivists also reject the idea that power can be possessed and retained by individuals whose position derives ultimately from and within a given social structure.

Generally, the constructivists' preferred analytical framework for examining power is that of the "translation" model (Callon, 1986; Latour, 1986), which treats power as a two-way relation, rather than as a commodity to be owned or traded, or as something imposed by one person or group of people on another. If people or things respect orders or pass them on, it is because they have their own reasons, positive or negative, for so doing. If they did not have these, orders would have no force, although it would be wrong to assume that commands will be transmitted and executed faithfully,

'"power" is always the illusion people get when they are obeyed... without ever suspecting the different reasons others have for obeying and doing something else; more exactly, people who are "obeyed" discover what their power is really made of when they start to lose it. They realise, too late, that it was made of the wills of all the others' (Latour, 1986:268-9).

Knowledge as a basis for action requires a reason for that action to be performed, or an interest in the outcome, in either individual or group terms. As a constructivist, Latour (1986) considers that such an interest could be based on class or other social groupings, provided that it is not implied that social structure determines these. Here the tension between structure and agency surfaces again : 'the structure of social interests is not

stable, but is a function of discursive conditions and outcomes of struggle' (Law, 1986:12), as opposed to a Marxian or Weberian view which would see social class interests as relatively fixed over time, and as providing reasons for action. Such questions have been discussed at length by sociologists of knowledge¹, but what matters ^{here} is that knowledge and interests should provide convincing reasons for action (Hindess, 1986).

Hence such alliances can be viewed as creating networks of human and non-human actors which are contingent on circumstance and potentially finite in duration, 'power is a composition of actors temporarily enrolled in the schemes of the powerful, and who accordingly lend their efforts to his / her project' (Law, 1986:17 in Law, 1986). This points up the seemingly paradoxical nature of power : it does not enable you to act; but when you exert it, others (both human and non-human) act on your behalf as agents (Latour, 1986) and consent, more or less precariously, through their collective action to attribute power over something or someone to you. This appears close to an anti-realist, "Tinkerbell" model of power - Tinkerbell being the fairy in "Peter Pan" who ceased to exist if noone believed in her - whereby a refusal to acknowledge or enter into power relations will somehow automatically make them disappear. Is power socially constructed, or just constructed ? Therein lies one of the shortcomings of a purely microsociological (and atheoretical) account of power which sidesteps structural questions,

'Latour assumes that those who are powerful achieve that power by boxing others in, borrowing from them, and misrepresenting them. The object is to uncover those strategies of misrepresentation. In his approach, "why" questions are thus converted into "how" questions... the desire to avoid reduction leads authors such as Latour and Pinch to dissolve the distinction between description and explanation' (Bijker and Law, 1992:292-293),

perhaps not entirely successfully (Williams and Russell, 1988; Williams and Edge, 1992). If 'power can "summarise the consequence

1. See Law (1986) for a review of these debates.

of a collective action, [but] cannot also *explain* what holds the collective action in place' (Latour, 1986:265), what does hold power relations in place, in ways that are not utterly contingent ?

And what of knowledge itself ? Constructivists are almost silent on this point. It is possible to assume that if they see the technical and the social as continually and mutually constructed and reconstructed, then the same applies to technological knowledge. However, just as they are 'remorselessly sceptical' (Williams and Edge, 1992) about attributing causality to "society" or "nature", 'we can never use... Nature to explain how and why a controversy has been settled... we cannot use Society to explain how and why a controversy has been settled' (Latour, 1986), so they refuse to examine the cognitive,

'Before attributing any special quality to the mind or to the method of people, let us examine first the many ways in which inscriptions are gathered, combined, tied together and sent back. Only if there is something unexplained once the networks have been studied shall we start to speak of cognitive factors' (Latour, 1986).

It may be that only some constructivist concepts or frameworks are useful to an understanding of the practice of technological knowledge in organisations, and more specifically those, such as actor-networks and translation, which may help describe its mobilisation. Although more recent work in this field has conceded that perhaps 'certain social groups are stable enough to be used as some kind of explanatory scenery... Perhaps all empirical studies depend upon some such backdrop... After all, everything cannot be deconstructed simultaneously' (Bijker and Law, 1992:293), who is to decide which these are to be ? Although Mackenzie (1988) has suggested that the macro/micro divide is a 'false dichotomy' there are still epistemological differences between structuralist and constructivist analyses of technology. This may make it difficult to intertwine them in an account of the content, distribution and mobilisation of technological knowledge in printing.

2.7. FOUCAULDIAN POWER/KNOWLEDGE

One writer who seeks to encompass both social structures and contingent action and to fuse macro and micro levels of analysis is Foucault, whose work on power and knowledge (1967, 1973, 1977, 1984) may be relevant to this research. Foucault's focus and starting point is power, although he makes its connection with knowledge very explicit. His "analytics of power" address the persistence of power relations over time, and appear to be a (sometimes unacknowledged) influence on constructivist positions, although his work deals specifically with power relations in the context of localised accounts of their more durable, institutionalised manifestations, such as asylums, hospitals and prisons (Foucault, 1967; 1973; 1977). The Foucauldian position is that power should be

'conceived not as a property, but as a strategy... one should decipher in it a network of relations, constantly in tension, in activity, rather than a privilege that one might possess... one should take as its model a perpetual battle rather than a contract regulating a transaction or the conquest of a territory. In short this power is exercised rather than possessed; it is not the "privilege", acquired or preserved, of the dominant class, but the overall effect of its strategic position - an effect that is manifested and sometimes extended by the position of those who are dominated' (Foucault, 1977:26-7).

Although power relations are unstable and always potentially reversible, they have been transformed in modern society into general patterns of domination (Foucault, 1991). This does not mean that micro analyses can become macro merely by "scaling up". Even if state power is rooted in innumerable individual exercises of power, these are coordinated and consolidated through institutions, practices and knowledge claims, not all of which are state-influenced. Moreover, power relations are not the only kind of relations between actors, nor are they purely economic, and they are not their own rationale,

'there are no general reasons for submission to power relations... individuals submit to them for a large variety of reasons which

cannot be encapsulated within the binary opposition between internal and external enforcement. Just as power relations are open-textured so too are the reasons for submission to them' (Cousins and Hussain, 1984:242).

But obedience is only ever partial and provisional, and there are no relations of power without resistances (Foucault, 1984). The ideal of "docile bodies" (Foucault, 1977; Law, 1986) and a network of passive agents is never entirely fulfilled or possible. Power relations can be sustained by mutual consent and need, as well as entailing elements of coercion (Cousins and Hussain, 1984) or lack of choice. They supply actors with structures within which to operate, and with greater or lesser degrees of freedom for action within those structures,

'we may think of powers continually at work with the objective of further restricting the discretion of their agents whilst those agents continually and ubiquitously develop the scope of their sphere of discretion within the very system of rules or instructions which is conceived of as a restriction upon them' (Barnes, 1986:193).

Rule-systems provide actors with structured frameworks for cognition premised on their freedom to think, which enable them to simultaneously extend their knowledge. Foucault makes the implicit presumption that power relations leave space for action, 'Foucault affirms... that power is only power... when addressed to individuals who are free to act in one way or another. Power is defined as "action on others' actions"... it presupposes rather than annuls their capacity as agents' (Gordon, 1991:5). Yet it is impersonal, 'Power has its principle not so much in a person as... in an arrangement whose internal mechanisms produce the relation in which individuals are caught up' (Foucault, 1991:202). Hence this view of power might accommodate both human actors and the non-human world.

Power and knowledge relations could be seen as different aspects of the mobilisation of the same networks. Power can be seen not as a "thing-in-itself", but as a reciprocal relation performed as a collective action between multiple, heterogeneous human actors with diverse motives and the non-human world, in temporary, continually

renegotiated networks, some of which become institutionalised in certain ways over time. Are networks of power and networks of knowledge analogous ? It could be suggested that knowledge too is a reciprocal relation performed as a collective action; that what matters is not so much the individual/group carriers of knowledge as the relations between them. Maybe knowledge is only mobilised as a basis for action when multiple, heterogeneous human actors and non-human objects come together in temporary, continually renegotiated networks. Knowledge relations could be seen as providing carriers (Fleck, 1988) with structures to operate within, and as enabling them to make sense of and order the world (see 2.2). Some knowledge relations may become institutionalised or codified (Douglas, 1984) in certain ways over time, and in this sense knowledge can be accumulated and stored, just as institutionalised power relations may be self-perpetuating.

So how and why does Foucault link knowledge and power ? The relation between the two is complex and difficult¹. The problems of

font

1. Power and knowledge are both connected with motive and action. Power has connotations of enabling groups or individuals to do things in much the same way as knowledge : "power to" act as opposed to "power over" others (Parsons, 19??). If power relations are performed by collective action resulting from the mobilisation of knowledge, an vice versa, a model could be posited for the dialectic between power and knowledge :

Knowledge + interests \longleftrightarrow action \longleftrightarrow power relations

This would account for "learning by doing" on the one hand, and power relations defining what "counts" as knowledge on the other. Power relations may provide actors with interests either in maintaining or in resisting them through future action. They may also delimit what is feasible or thinkable through the very structuring of knowledge itself (not just of action),

'The authority must know what is to be done, and in response to what, and the power must know what the authority knows. The system of power and authorities must also necessarily represent a distribution of knowledge... [which] may be thought of... as a set of instructions or rules according to which the authority is required to act... and crucial to the business of limiting the discretion of the authority' (Barnes, 1986:185).

the power-knowledge dialectic have been annulled (or perhaps avoided) by Foucault (1977; 1984), who collapses them into a single relation, "power/knowledge", which produces "discourse" : the practices, language, texts and what it is possible to say, do and know about a particular domain. Instead of circular or recursive relations existing between power, knowledge and action, power/knowledge relations within institutions become integral to action through discipline, 'a way of making power relations function in a function, and of making a function function through these power relations' (Foucault, 1977:206-7), their congruence more evident in some situations than in others, 'superimposition of the power relations and knowledge relations assumes in the examination all its visible brilliance' (Foucault, 1977:185). However, power is still the implied precursor of knowledge, 'knowledge follows the advances of power, discovering new objects of knowledge over all the surfaces on which power is exercised' (Foucault, 1977:204). The apparent relegation of knowledge to a supporting role would seem to negate the centrality of the power/knowledge fusion to Foucault's (1977) analytical framework¹.

...Continued...

Furthermore, actors' knowledge may have a bearing on their interests, and their interests may enter into what knowledge they choose or are able to mobilise. Finally, any such model should be seen as dynamic rather than static, with none of its components treated as given, since a change in one may alter all the others.

1. This is echoed in the literature which draws on Foucault's work to explore issues of power and control in various business-related areas such as accounting (Loft, 1990); information technology (Zuboff, 1988) and "just-in-time" production (Sewell and Wilkinson, 1992). Such emphasis on power has two main consequences from the perspective of this thesis. Firstly, it risks excluding non-human actors from analysis, other than as disciplinary tools or techniques somehow exempt from or immune to such relations by virtue of their non-humanity. This could be seen as removing the technical from scrutiny thereby encouraging determinist accounts of technology. It could be argued that what matters are relations between people, and that it does not matter so much what we do with or to objects, since they have no sense, feeling or humanity. On the other hand, relations between human and non-human should be of utmost concern and question to us and not solely in ergonomic or environmental terms, as how we treat the non-human world may be indicative of how we treat each other (Heilbroner, 1967; Edge, 1974-5). Secondly, emphasis on th

2.8. DISCIPLINARY TECHNIQUES AND KNOWLEDGE

According to Foucault, the place to which knowledge follows power is the body. Within institutions such as prisons, hospitals and factories, power and knowledge are fused through disciplinary techniques for organising the body and its actions in both space and time. Those which arrange the body spatially include enclosure, partitioning, the establishment of functional sites, and the ranking of individuals in relation to each other; those which operate in terms of time include the timetable, the temporal elaboration of the act, the correlation of body and gesture, the body-object articulation, and the exhaustive use of time. These techniques are aimed at producing "docile bodies", 'not only so they may do what one wishes, but so they may operate as one wishes, with the techniques, the speed and the efficiency that one determines' (Foucault, 1977:138), and be known to do so. This could be taken as applying not only to the bodies of human actors, but to tools and machines (the machine-body), and combinations thereof

...Continued...

surveillance aspects of discipline, particularly in its "panoptic" forms, and hence on the more obvious power/ element of power/knowledge, has tended to exclude the /knowledge element from equally detailed consideration. Surveillance may be a useful concept for explaining the intensification of managerial control over the workforce (Sewell and Wilkinson, 1992) facilitated by forms of new technology such as computer-based process control systems or networked corporate communication systems (Zuboff, 1988), but this leaves out the idea that

'although surveillance rests on individuals, its functioning is that of a network of relations from top to bottom, but also to a certain extent from bottom to top and laterally; this network "holds" the whole together and traverses it in its entirety with effects of power that derive from one another : supervisors, perpetually supervised' (Foucault, 1977:176-7)

It also personalises power relations and re-polarises them into management-workforce conflict, whilst the Panopticon is important as the exemplar of a mechanism that 'automatises and disindividualises power' (Foucault, 1977:202). Moreover, to focus solely on Foucault's use of Bentham's design is like reducing all Marx's work to a discussion of ownership of the means of production.

(the "body-machine complex"). The knowledge constituted by these disciplinary techniques is likely to be tacit knowledge (Polanyi, 1967) and "instrumentalities" (de Solla Price, 1984).

Spatial techniques could be thought to contribute to domain-specific, site-specific (contingent), functional or hierarchical distributions of knowledge, and perhaps to the preservation of "trade secrets" or to a firm's "know-how". They suggest a division of knowledge analogous to a Taylorist division of labour, whereby workers' knowledge is individualised and fragmented : 'break up collective dispositions', without redundant overlaps : 'break dangerous communications', yet which paradoxically requires them to work collectively in order to mobilise that knowledge : 'set up useful communications' (Foucault, 1977:143). But in a production context, establishing what these are may be problematic,

'In the factories... the principle of individualising partitioning became more complicated. It was a question of distributing individuals in a space in which one might isolate and map them; but also of articulating this distribution on a production machinery that had its own requirements' (Foucault, 1977:144).

Disciplinary techniques that operate temporally may be seen as constituting cognitive components, particularly tacit knowledge which is rooted in physical experience (see 2.5), 'time penetrates the body, and with it all the meticulous controls of power' (Foucault, 1977:152). For example, the rhythm and repetition of scheduled activities as indicated by time, place and signals such as bells produce interiorised knowledge of when and where certain acts are required; and the language in which instructions are couched as to what to do and how long it should take create power relations at the same time as they are tacitly comprehended,

'All the activity of the disciplined individual must be punctuated and sustained by injunctions whose efficacy rests on brevity and clarity; the order does not need to be explained or formulated; it must trigger off the required behaviour and that is enough... it is a question not of understanding the injunction but of perceiving the signal and reacting to it immediately' (Foucault, 1977:166).

Through disciplinary techniques for extracting more and more

productive moments from time, power relations permeate the body and its gestures, and define its relation with other actors, both human and non-human, 'over the whole surface of contact between the body and the object it handles, power is introduced, fastening them to one another. It constitutes a... body-tool, body-machine complex (Foucault, 1977:153). Thereby, power relations in institutions may be considered to enter into knowledge relations thought personal, inarticulable, and hence inalienable in other contexts : the self-employed rural Saab-mechanic's tacit and instrumental knowledge (Harper, 1987) is not disciplinary, however deft and economical his movements.

Assessing the effectiveness of such techniques relies on the use of "simple instruments of disciplinary power" : hierarchical observation, normalising judgment, and the examination, with the aim of 'composing forces in order to obtain an efficient machine' (Foucault, 1977:164). Through various surveillance mechanisms (the best-known being based on Bentham's Panopticon), information is collected about the body's activities,

'an intense, continuous supervision... ran right through the labour process; it did not bear - or not only - on production (the nature and quantity of raw materials, the type of instruments used, the dimensions and quality of the products); it also took into account the activity of the men, their skill, the way they set about their tasks, their promptness, their zeal, their behaviour' (Foucault, 1977:174).

This too produces docile bodies : mobile, durable and combinable (Latour, 1987) texts and images that record and represent (Law, 1986) the messiness of reality, enabling it to be known, mastered and used (Foucault, 1977) in ways that would not otherwise be possible : 'many things can be done with this paper world that cannot be done with the world' (Latour, 1987:232). Such knowledge facilitates definition and standardisation.

Firstly, it can be collated and analysed. Texts and images, being two-dimensional, are portable and sortable at any time, whilst people and objects are usually less amenable to this treatment, and

it would cause disruption in a production context, 'the accumulation of documents, their seriation, the organisation of comparative fields making it possible to classify, to form categories, to determine averages, to fix norms' (Foucault, 1977:190) against which new data can be measured and compared. Every individual person or thing becomes 'a case which at one and the same time constitutes an object for a branch of knowledge and a hold for power' (Foucault, 1977:191). Tabulation and summarisation of data allow individuals to be located, coded, and ranked against each other, and thereby "formalised" within power/knowledge relations, 'the table was both a technique of power and a procedure of knowledge' (Foucault, 1977:148),

Secondly, it can be re-presented and promulgated. Visual representations (texts and images) can be seen as technologies for simplifying, discriminating and interrelating objects, whereby new classes of objects are created whose boundaries, characteristics and properties are simpler than (and may differ from) those of the originals (Law and Whittaker, 1988). These can be related and compared to other such objects. At the same time, representations can claim to speak on behalf of the originals, which are silenced by their own complexity. Only the official, unitary view is allowed to survive; dissent becomes impossible, 'not only are the voices taken away, but the memory that they might have spoken otherwise has been lost' (Law and Whittaker, 1988:179). In the blocking out of alternative versions and the definition and establishment of "true" knowledge, power relations are mobilised.

But how does this paper world of power/knowledge interact with the original ? Is it even relevant to day-to-day print production ? What if there are no prescribed standards and data is not collected, tabulated and represented ? Formalised, codified knowledge is not sufficient to make machines run (Harper, 1987; Orr, 1986; 1990), nor for production to happen. It may be docile, but is it any use ? The need for contingent and tacit knowledge arising from situated physical experience persists precisely because representations are simplified : the model is not the thing

itself,

'The [service] documentation is not a pure or complete representation of the machine and its prescriptions, but must be regarded as a mechanism in and of itself. It is a device by which someone attempts to provide information to the technicians, but the information is selected and arranged according to the documentation designers' interpretation of what is necessary for the tasks which they wish the technicians to perform' (Orr, 1990:5)

Norms only suggest how people or objects ought to behave in relation to a prescribed standard. They do not cover what Orr (1986:9) terms 'the machine's perversity' or 'the extremes... of human behaviour with machines' (Orr, 1986:6). Hence institutionalised power/knowledge relations may break down in a problem-solving context, and may be inadequate as a means of explaining what then occurs. On the other hand, problem-solving may be an activity which creates or renegotiates power/knowledge relations. Or perhaps everyday print production knowledge and practice cannot usefully be analysed in Foucauldian terms in the context of this research, although some concepts, such as discourse, may be useful.

2.9. SUMMARY AND RESEARCH QUESTIONS

This chapter examined the literature from a number of disciplinary areas in order to assess how technological knowledge in the context of an organisation's production activities might be conceptualised and analysed theoretically.

Starting from a general consideration of knowledge (2.2), it focused on accounts of more specialised domains of knowledge, such as science (2.3), with which technological knowledge has been compared. It found that whilst technological knowledge might share aspects of scientific knowledge, there was debate about how far parallels could be taken and a lack of empirical evidence to resolve this, particularly in terms of its application to

industrial production and the concept of "technological communities". The chapter then reviewed a variety of taxonomies developed in different disciplines for characterising knowledge (2.4) in terms of its cognitive and substantive content. It also considered the extent to which some taxonomies tackled the distribution of knowledge, whether it could be described as individual or collective, and in what sense the latter could be understood. It concluded that most taxonomies were either difficult to apply to technological knowledge in a production context, or that while useful, were insufficient on their own for analysing and understanding the practice of such knowledge.

Sections 2.5 and 2.6 then explored structuralist and constructivist approaches to analysing the development, deployment and use of technology, to see if these might be useful in accounting for day-to-day technological knowledge and practice. The importance of tacit knowledge and concepts such as expertise and skill were highlighted (2.5), as were the significance of material objects and the usefulness of networks (2.6) for capturing the heterogeneity and contingency of the production context. Tensions between structuralist and constructivist modes of explanation were noted, as well as the need to examine microsociological accounts of power, left largely implicit in constructivist analyses of technology.

Literature from the sociology of knowledge on the relation between knowledge and power with reference to action and interests was discussed. This suggested the possibility that networks of power and knowledge and the processes by which they operate might have similar characteristics and be amenable to simultaneous analysis, and their fusion by Foucault as "power/knowledge" was examined (2.7). Finally, the institutionalisation of power/knowledge as disciplinary techniques and instruments was considered (2.8) as a means of pushing the analysis of knowledge and power further, and of reconciling macro and micro levels of explanation to encompass both structure and agency. The potential significance of discourse, language, and documents such as forms, texts and images as carriers of power/knowledge was noted.



All the work surveyed provided useful pointers or raised interesting research questions. Even drawing on such disparate sources, an overall structure for addressing substantive issues evolved : that of the content, distribution and mobilisation of technological knowledge. The research questions which came out of a reading of the literature can all be subsumed under these headings. Competing (but perhaps complementary) frameworks for conceptualising and analysing the content, distribution and mobilisation of knowledge emerged from diverse literatures : structuralist, constructivist and Foucauldian approaches, although none appears to offer the potential for a wholly satisfactory account.

These then are the research questions : what is the substantive and cognitive content of print knowledge, and how are we to conceptualise them ? How might we to account for its distribution within and between firms ? How, when and why might print knowledge be mobilised in a production context ? And can the content, distribution or mobilisation of such knowledge be termed "collective", in a communal, cooperative or aggregate sense ? Which aspects of the theoretical frameworks discussed are appropriate for conceptualising and analysing technological knowledge in the context of a firm's day-to-day operations ?

Chapter 4 describes the printing industry as a whole and provides a history of the recent technological changes that have occurred, from a broadly structuralist perspective. Chapter 5 locates the individual case study firms within this overall setting. This transition from the general to the specific is followed by the case studies themselves (chapters 6, 7 and 8). But first, chapter 3 examines relevant methodological issues, and describes the selection of sites and design of empirical data collection methods appropriate to the research questions.

This chapter deals with two interconnected aspects of method relating to the research questions framed at the end of the preceding chapter. Firstly, it examines methodological issues not already raised in the context of literatures discussed in the previous chapter (3.1), and secondly, it describes the translation of such concerns into a practical research design (3.2) resulting in the collection of data (3.3), together with a consideration of some of the literature that deals specifically with (social) research methods. To put it another way, this chapter weaves together the abstract and the concrete.

It deals largely with the methodological theory and research method of this thesis in their "finished" form. This representation speaks on behalf of the original - a complex, iterative and often confused process here simplified, linearised, and rendered docile on the printed page. The academic research process in general may be more uncertain than is often admitted, although this translation effect has been commented on by a number of researchers (Bresnen, 1988; Buchanan et al., 1988; Law, 1994),

'research accounts in academic journals depart considerably from the research practices of their authors. They offer instead a "reconstructed logic" (Silverman, 1985:4) which brings the illusion of order to what is usually a messy and untidy process' (Buchanan et al., 1988:54).

3.1. METHODOLOGICAL ISSUES

'a consideration of methods of social inquiry cannot be isolated from a consideration of theory. Specific research questions are underpinned by more general theoretical paradigms... which have in-built assumptions about the nature of the social order and how it can be "captured" and explained' (Jupp and Norris, 1993:39)

It is assumed that knowledge of the world is possible, and hence that it is possible to know and understand others' knowledge in some way, although the status of that knowledge or any account of

it as "real" or "true" may be contested. This could be described as a broadly constructive-realist perspective. These assumptions underlie the research questions outlined at the end of the preceding chapter, which bear on the content, distribution and mobilisation of technological knowledge, and the extent to which any of these processes can be considered collective in everyday print production situations.

It was suggested (2.8) that knowledge could be conceptualised as a reciprocal relation performed as a collective action among multiple, heterogeneous human and non-human carriers assembled in temporary, continually renegotiated networks, and that this process is shaped partly by structural factors, partly by contingency, and partly by the institutionalisation of contingencies over time. In methodological terms, how might the research questions be addressed in the light of such a contention, given that it is proposed to investigate them in the context of production activities within an organisational setting, located in the printing industry in the early 1990s ?

At one level, combining and modifying elements of diverse analytical frameworks does not cause immediate problems of method. The exploration of knowledge as a continuing process rather than as a static entity, and in terms of "what", "how" and "why", suggests that qualitative rather than quantitative methods would be most useful. Most of the literature surveyed pursues a similar approach to questions framed in terms of "how" and "what", albeit with differing views of what constitutes a plausible explanation for "why", and how this should be achieved. However, there are different kinds of qualitative method.

Constructivists suggest a phenomenological approach (Knorr-Cetina, 1981), based on "thick description" (Bijker and Pinch, 1986), whereby describing "how" and "what" serves in its own right as a means of explaining "why". Although attractive in its simplicity as a methodology, description may not always be a sufficient explanation without some underlying analytical framework upon which

to hang the data. Such an approach might also conflict with the incorporation into the account of structural considerations (Williams and Russell, 1989) or socio-economic elements (Rosen, 1993) no matter how rich the description, since the latter requires some ordering of the data by reference to external factors. Nor does the method of thick description account for how data might be ordered by reference to internally-generated concepts, or how these might be arrived at.

It has been said that to achieve this 'the qualitative researcher has no real alternative to pursuing something very close to grounded theory' (Turner, 1988:112). Glaser and Strauss's (1967) "grounded theory" methodology allows the data to suggest conceptual categories and their properties, and the relations between them, in order to generate theory. However, a method that concentrates on theory-generation might not be so useful for trying out or combining existing conceptual frameworks in new contexts, albeit in a less positivistic sense than hypothesis-testing. The "comparative analysis" aspect of Glaser and Strauss's work might be more relevant for this purpose, allowing the validity of frameworks to be verified, the limitations of their applicability established, and their variation under different conditions examined. Modifications based on empirical evidence could then be proposed. The "constant comparative method" (Glaser and Strauss, 1967) both within and between sites also seemed a useful tool for dealing with the large amounts of data anticipated from multisite fieldwork.

However, the adoption of either a phenomenological or a grounded theory method was problematic in the context of this research for a variety of reasons. Firstly, I intended to address structural as well as contingent issues, and to experiment with existing analytical frameworks and combinations thereof. Secondly, by the time fieldwork commenced, I had surveyed the literature, chosen sites, and formulated detailed research questions and data collection methods at site level, which reflected broad conceptual concerns, although I did not have overall research questions or a clear idea of the thesis. On the other hand, doing fieldwork had

its own internal momentum which had little to do with theory and everything to do with practice. Thirdly, grounded theory alone may work where fieldwork is conducted at a comparatively leisurely pace (as with anthropological studies), since there is time to think and compare in situ, but this is difficult when access is finite and restricted in other ways, as it can be in industrial and other "closed" settings. This pressure made "constant comparative analysis" somewhat unworkable. Comparison between and within sites did occur, but only after the majority of data collection finished was this possible in any systematic way. The solution adopted was to combine the two approaches.

A further consideration was the form these qualitative methodologies should take, in terms of writing up the empirical data analytically. Given the organisational emphasis of the research and its concentration on the current rather than historical use of production technologies, ethnography appeared appropriate, both to the subject matter and the overall methodology. Ethnography can be defined as a detailed analytical description of small groups of people, aimed at understanding the perspectives of the people involved, 'the claim to integrate description with theory is one of the most distinctive characteristics of ethnography' (Hammersley, 1990).

According to Hammersley, there are three main reasons for this emphasis : firstly, theory may emerge inductively from description, so ethnography would be compatible with grounded theory; secondly, an understanding of events in the context in which they occur is seen as important, with description playing an explanatory role, hence it could also be compatible with a phenomenological approach; and thirdly, descriptions of unfamiliar settings can provide interest and a form of vicarious experience for the reader as they see the world from the different viewpoints of the people involved.

In the context of this thesis, there may be problems with such a definition. Hammersley emphasises the importance of people and their perspectives. Constructivists seek to let the actors speak,

and in the case of living actors, ethnography would be a way of achieving this. But if Callon's (1986) methodological principles are followed, the researcher has to deal even-handedly with both humans and non-humans, and should attempt to develop a new vocabulary which can do duty for both (Callon, 1986; Akrich and Latour, 1992). Is an ethnography of machines (Woolgar, 1989) possible or worthwhile? Some of the results (Woolgar, 1989) point up the difficulties of giving a textual voice to the non-human world. The thesis has not, therefore, tried to address the complex and difficult issue of language in practice.

Secondly, the emphasis on participants' perspectives sits more easily with a grounded theory or a phenomenological approach, and perhaps less so with a structuralist account or with the attempt to combine existing theoretical frameworks, where the agenda is already to some extent set. The assumption that theory emerges inductively from such a method is only part of the process if 'all forms of research, qualitative and quantitative, are based upon a complex admixture of deductive and inductive procedures' (Turner, 1988:111). The interplay between the data and the literature mentioned above in connection with attempts to pursue "grounded theory" would seem to support this view.

Finally, whilst the setting of this research may be unfamiliar to the reader, and description therefore necessary to facilitate and enhance comprehension, there is a risk of providing too much detailed information and not enough analysis. An inverse difficulty arises with incorporating the writer's own experience of the printing industry into such an account and at the same time being able to see what was familiar through fresh eyes, and to make it "strange".

Notwithstanding, an ethnographic approach has been adopted for the presentation of the primary site-generated data. This is couched in terms of the conceptual frameworks, and unites elements of structuralist, constructivist and Foucauldian perspectives. Data on the printing industry have been presented as a historical account

reconstructed largely from secondary sources, in order to provide the background structure necessary for the reader to set the primary data in context.

3.2. RESEARCH DESIGN

'Theory defines what is problematic and also provides prescriptions as to how such problems are to be conceptualised. In turn, this generates guidelines as to unit and level of analysis, the form of data to be generated, the questions to be asked of such data, the form of analysis and interpretation to be adopted' (Jupp and Norris, 1993:39)

As stated in the previous chapter, the overall research questions were both empirical : "what is the content and distribution of technological knowledge within and between organisations in a production context, and how is this mobilised ?" ; and theoretical : "which conceptual and analytical frameworks are appropriate for understanding this process ?". These questions had implications for the research design adopted.

Since the focus of my research was technological knowledge in an organisational context, it was appropriate that the unit of analysis should be the firm, or a relatively autonomous production site. Organisational and other researchers have commented on the problems of site selection and access. Buchanan et al. (1988) suggest that an "opportunistic" but ethical and rigorous approach employing "devious strategies" needs to be adopted in seeking out sites for field research, especially during periods of economic recession, and given that certain organisations may become "over-researched" and wary of offering access for research. At two of my sites, an "action research" / consultancy approach for part of the period of fieldwork was used to assist access, and this is discussed in 3.3.5.

Schofield (1993) argues against choosing data collection sites on the basis of convenience or ease of access, and suggests that in

order to assist the generalisability of qualitative research results, the "typicality" of a site should be considered. This raises questions of what constitutes "the typical", what dimensions of typicality might be most relevant in each research context, and whether every site, however typical of its kind, differs significantly from all others in ways that make straightforward generalisation problematic.

One solution Schofield (1993) proposes is the combination of typicality (however defined) with "thick description" (Geertz, 1973; Bijker and Pinch, 1986), providing sufficient detail about each site so readers can make a more informed judgment when comparing one site with another. The other solution is the use of "multisite case studies" as a means of generating stronger working hypotheses about other such cases, albeit with some loss of rich detail, and potential problems of internal validity the more sites are studied and the less time spent at each. In this instance, Schofield also suggests that consonant data from heterogeneous sites would produce findings more useful for understanding other sites than those produced from several sites exhibiting strong similarity. This thesis examines three heterogeneous case study sites in different sectors of the printing industry.

The choice of firms co-evolved with the research project. The original intention was to look only at medium-sized general jobbing printers, using sheetfed large offset litho technologies. This sector was chosen for several reasons. Firstly, it was substantial in terms of the number of firms involved (although not in terms of total industry turnover) (see ch.4). Secondly, it was the sector in which I had personal experience and knowledge of both production management and production technologies, and with which I felt comfortable and confident as a researcher from a technical as well as a social perspective. Thirdly, firms in this sector tend to form "clusters of association" with suppliers, customers and subcontractors. Given the contention that organisational knowledge may extend beyond the legal boundary of the firm to include external carriers of knowledge if arrangements exist to mobilise

it, general jobbing print seemed an interesting context in which to explore this idea.

I also wanted to explore collective aspects of production knowledge. As previously mentioned (2.8), this concept as it appears in the microsociological literature is lacking in ideological significance. Nevertheless, it seemed useful to look at a site where the principle of collectivity was a conscious political choice, and its application made explicit. If production knowledge were held in common, evenly distributed or mobilised collectively, it would be most likely to occur in organisations such as worker cooperatives.

Potential research sites suggested themselves through industry contacts; snowballing; chance remarks by colleagues; undergraduate industrial visits; and serendipity. However, gaining access proved difficult, and the recession did not help. Firms were in no mood to accommodate a researcher. Initial plans were rethought in the light of what was possible, which was why I eventually included direct mail and newsprint firms. In the end, the three case study firms - Freedom Press, Weirs Web and Trinity Press¹ (tables 3.1 to 3.3²) - fell into place as a set of comparative units.

Freedom Press (table 3.1) was a general jobbing printshop. It had extensive networks of suppliers, subcontractors and customers with which it shared and mobilised technological knowledge in order to produce a wide variety of printed products. This would enable me to explore the idea that networks of knowledge extend beyond the formal boundaries of the firm and encompassed heterogeneous actors, and that their composition was continually renegotiated and reshaped in response to the contingencies of production. It was

1. These are not their real names. Pseudonyms were adopted to protect the firms' identities, as some of the data gathered were commercially sensitive.

2. These tables are found at the end of this chapter.

also a worker cooperative.

Weirs Web (table 3.2), was chosen as a counterbalance to Freedom. It was larger in terms of turnover, number of people employed, size of premises, and production output, and its formal management structure was hierarchical. I was interested to see whether the idea of collectively carried and mobilised knowledge could be applied in such circumstances, and how it might differ from a smaller, more overtly collective site. Did the firm have arrangements for mobilising knowledge collectively, on either a formal or informal basis ? Weirs had expensive web-fed offset litho presses which ran much faster than sheetfed, and this generated financial and time constraints which might affect the mobilisation process. Since most of Weirs' work was jobbing rather than contract, it might be expected to have similar external networks to Freedom's, although its product range was narrower, which might simplify job specification and reduce the variety of production processes employed in-house and by subcontractors.

Trinity Press (table 3.3) printed newspapers. Like Weirs, it was large in terms of turnover, number of people employed, size of premises and production output. Its management structure was also hierarchical, albeit flatter and with an overt emphasis on shift-centred "teamwork", which might enhance collective mobilisation of knowledge within the firm. By contrast with the other two firms, all its work was done to long-term contracts, and the production schedule was therefore known in advance, as well as the approximate job specifications. Did this regularity create common knowledge ? Moreover, very little subcontracting was undertaken, which might affect the external knowledge networks it needed to make production happen. The nature of its products and their typical turnaround introduced additional time constraints into production. Arrangements for mobilising knowledge collectively might vary depending on the speed required.

The three firms chosen were drawn from a single domain, printing. They exhibit a wide range of structural similarities and

differences which might bear on the content, distribution and mobilisation of production knowledge. The most salient are those which affect the composition of the knowledge networks, such as customer identity, product and process variety and the incidence of subcontracting; those which affect the relations between carriers of knowledge, such as organisational structure, firm size, geographical location and physical layout; and those which bear directly on the mobilisation process, such as the speed of production technology and turnaround times. It is, however, difficult to categorise factors as affecting only one aspect of the process. The contingencies of production and its management at each site might give rise to similarities and differences in knowledge content, distribution and mobilisation within and between firms. Furthermore, a combination of structural and contingent factors might interact to institutionalise the networks and their operation. There were many potential variables involved, only some of which proved relevant. This meant that if certain patterns of content, distribution and mobilisation recurred among the three sites, the results should enhance understanding of technological knowledge across the printing industry as a whole.

Fieldwork was carried out over a period of 18 months. Visits to Freedom were spread over a period of 6 months, and a total of 10 weeks was spent on site. This was subdivided into blocks of 1-2 weeks each, which allowed time between site visits for transcription and planning. Weirs fieldwork extended over 9 months, and consisted of a preliminary visit, and two blocks of 4 and 5 weeks fieldwork with briefer follow-up visits. The visit to Trinity was of 2 weeks' duration.

3.3. DATA COLLECTION METHODS

As well as the selection of case study firms, data collection methods had to be decided in order to acquire data with which to answer the research questions, bearing in mind what was possible at

potential fieldwork sites. I wanted to generate data not solely about people, but also about inanimate objects, in order to be able to produce an analysis not only in social, but also technical terms. A "scattergun" technique of data collection offered an appropriate degree of flexibility, and the possibility of "triangulating" data within and between each site. This entailed using a variety of methods, including two standard ethnographic techniques : "participant observation" and the "semi-structured interview". These were adjusted to suit addressing the research questions in an industrial setting ("closed site") and the fact that I was going in explicitly as a researcher ("role overt") who had previously worked in the printing industry.

3.3.1 Participant observation

Observation and some degree of participation were essential to the project in terms of following the actors (Latour, 1987; Bijker and Pinch, 1986), but instead of following them through archival material, I was able to follow them through their day-to-day production activities. If knowledge is a basis for action, I needed to see what people did, where they did it, and what other people and objects were involved in their work, as well as what they said they did, when interviewed (see 3.3.2 below). This was not to highlight potential discrepancies between the two data sources, although this in itself could have been interesting, but because knowledge is often not expressed verbally, but emerges rather through action.

Tacit knowledge in particular is often not made explicit, and people may not realise they have it, if 'we know more than we can say' (Polanyi, 1967). The observation had to involve some degree of participation (although this sometimes consisted of my own prior experience of the industry) because it has been suggested that this is the only way to understand tacit knowledge, by what Polanyi, referring to the work of Dilthey and Lipps, called 'indwelling... a far more precisely defined act than is empathy, and it underlies

all observations' (Polanyi, 1967:17), or a 'passionate participation in the act of knowing' (Polanyi, 1958:16).

It is thus possible to understand somebody else's tacit knowledge, even if this cannot be articulated, 'Man's skilful exercise of his body is a real entity that another person can know, and know only by comprehending it, and... the comprehension of this real entity has the same structure as the entity which is its object' (Polanyi, 1967). By undergoing a similar experience on site, and by drawing on my own past experience and knowledge, I hoped to gain insight into the nature of print knowledge. What I discovered during fieldwork at Freedom through my involvement with making production happen was that my tacit knowledge had become rusty, and in some respects I was in the position of a novice. Through my mistakes and omissions, I was acutely reminded of, and then remembered what I had forgotten. At Weirs and Trinity, I learnt about web printing partly through comparing the process with sheetfed, both to myself and in discussion with people working at the sites, some of whom also had sheetfed knowledge. I acquired contingent knowledge about the firms over the duration of fieldwork, but particularly in the first week or two at each site, much as with starting a new job.

As I was not taking up formal employment, my ability to participate in day-to-day work was limited by legal and practical considerations. At Freedom, where I had previously worked for some years, and was known and trusted, I could (and did) fetch and carry, answer the phone, deal with estimate requests, shrink wrap pallets, do hand-finishing work and other simple tasks. These were not adequate vantage points in themselves. I therefore "job-shadowed" managers and workers in all departments at all sites. I also tracked non-human elements - jobs and documents - through the production system, and observed tools and machinery at rest and in action. Here, my own experience of and interest in printing machines, processes and products was invaluable for understanding what was happening and talking to people about it. This was also a good vantage point for watching people and perhaps less threatening than direct observation. In industry, memories of the time and

motion study die hard. The practice was referred to several times in relation to my presence on site, not always jokingly.

By generating and incorporating into my analysis data that dealt reasonably even-handedly both people and inanimate objects, and that dealt with both the technical and the social, and did not restrict the subject matter of the data collected, I also followed Callon's ⁽¹⁹⁹⁶⁾ methodological principles (Callon, 1986), aimed at integrating the technical and the social,

'the observer must consider that the repertoire of categories which he uses, the entities which are mobilised and the relationships between them are all topics for actors' discussions. Instead of imposing a pre-established grid of analysis upon these, the observer follows the actors in order to identify the manner in which these define and associate the different elements by which they build and explain their world, whether it be social or natural' (Callon, 1986:201)

Fieldnotes of my observations were made either at the time or as soon afterwards as possible : at lunchtime, on the way home, and in the evenings, and were subsequently transcribed. They consisted of details about who was doing what, when, where, and why; what tools and machinery were involved; the progress of jobs; descriptions of scenes; conversations entered into or overheard; and anything else I found interesting or potentially useful : all typical features of social situations that can be observed (Spradley, 1980).

3.3.2 Interviews

Semi-structured interviews were conducted with as many people as possible at each site, and not restricted to management, workers in production departments, or those whose knowledge was valued as "expert", in order to account for multiple perspectives and to gather data on "subjugated" knowledges (Foucault, 1977). If the mobilisation of knowledge was collective, I should interview everyone. This was not possible for practical reasons at the larger sites (Weirs and Trinity each employed over 100 people), but I reached a compromise I considered acceptable by interviewing

representatives from all departments (production and other) at all levels of the hierarchy, with different work histories, and a range of ages and depth/breadth of knowledge. This was at least in part achieved at Weirs by discussing my requirements with various people who then "fixed me up" with a supply of interviewees whom I briefed beforehand about the overall aim of my research, the broad topics to be covered in the interview, and to whom I had attempted to explain (by reference to the example of trying to fix a car) the concept of socio-cognitive structures (Fleck, 1988). At Freedom, it was possible for me to interview everyone at least once, with the exception of workers absent on sabbatical leave; and at Trinity, I interviewed all managers and non-crew workers, and all the crew members on shift during fieldwork. A list of workers interviewed at each site is provided in Appendix I.

The structure and location of interviews varied between sites. At Freedom, the first site visited, I was able to start with unstructured interviews and progress to more (semi-)structured interviews over a period of time, as clearer themes and issues emerged. In my performance of interviews as a research method, I followed a "grounded theory" approach, although this became more difficult as time passed.

Interviews at Freedom were conducted in individual departments, with the exception of the pressroom, which was too noisy. Interviews with printers therefore occurred in the kitchen area. The location of interviews was chosen to facilitate interviewees' descriptions of what they did in the setting that they did it, and with the relevant artefacts to hand. Once I had arrived at a list of areas for discussion during semi-structured interviews that was workable, I used it at subsequent sites, with modifications as necessary (Appendix II). Interviews lasted between 30 and 90 minutes.

At Weirs, the length of time available for each interview was generally, though not always, limited by the demands of production to 30-45 minutes, and in this situation a structure was invaluable

for respecting those constraints. In addition, prior to the interview, I provided each person with a summary of the issues I hoped to discuss with them. I was provided with a quiet room for most interviews, which solved the problems of coping with the noise of the shopfloor, but which removed the opportunity for annotation by means of artefacts and demonstrations. One useful compensatory device I discovered by accident was the provision of sheets of paper, so that interviewees could make dummies to represent particular job specifications, or incorporate them into gestures demonstrating production processes. Some interviews were conducted in situ, and these proved the importance of setting, being richer in artefactual and other detail.

By the time I reached Trinity, I found that I no longer needed the list in front of me, and to some extent these interviews relaxed their structure somewhat, and their length varied as at Freedom. They were mainly conducted in production areas between runs with the relevant texts and machinery to hand, in the managers' office, or in the "quiet room" (relatively speaking) adjacent to the press consoles, and always with a networked terminal of the production control system to hand, so that people could demonstrate what they meant, using both historic and realtime production data.

There was a significant interplay between interview and observation methods of data collection. At all sites, participant observation and informal conversations on the shopfloor helped to fill the gaps created by interviewing people out of their immediate work context or when production was not occurring. Specific issues raised in interviews could then be directly related by workers or by myself to production activities or products. In some cases, interviews provided the opportunity to discuss jobs or events that I had previously witnessed on the shopfloor as examples of particular points.

With the consent of interviewees, interviews at Freedom and Weirs were recorded on audio-tape. Interviews were transcribed verbatim, including laughter, pauses, hesitations and repetitions. A

'sanitised' (Buchanan et al., 1988) transcript was supplied to all interviewees later if desired (and most did), for interest, and also with the understanding that they could add annotations or request amendments. Where recording consent was not given or where interviewees were moving about production areas demonstrating what they did, I made notes, and in one case, a transcript of these was requested. At Trinity, interviews were not taped because of background noise levels. Notes were taken at the time, and annotated afterwards.

3.3.3 Texts and visuals

Since much knowledge, particularly that relating to technology, is embodied in or mobilised by texts or images (Ferguson, 1977; Law and Whittaker, 1989; Latour, 1986), I also inspected and collected company documents, forms, and other texts, such as technical manuals for analysis, and accumulated samples of work-in-progress as artefactual evidence. This was important given the very physical (and particularly visual) nature of the print production process (Hardstone, 1991) and the end product. To gather data about the spatial dimension of organisational knowledge, I took photographs and produced layout plans of the premises. Finally, as a means of gathering visual data I shot footage of the production process at Weirs on video. This was subsequently edited to produce the videotape that accompanies the thesis (see chapter 4) as a means of describing printing more vividly than could be conveyed by words alone. Given the subject of the research and the industry that is its focus, the use of visual as well as verbal material was a necessary element, and was not primarily intended as a reaction against the 'marginalisation of the visual' perceived by Fyfe and Law (1988) in much work in the social sciences.

3.3.4. Action research

The final component of my fieldwork strategy occurred at Freedom and Weirs. It could be described as both "action research" and "consultancy", and yet it was neither. The latter could be defined as producing a report making recommendations for whose implementation or consequences the consultant bears no responsibility. This was not the case. Consultancy has been decried as a valid research method on grounds of its conflict with academic interests and its potential for encouraging unethical research practice (Buchanan et al., 1988). If it were used as the sole means of data collection, this might be a legitimate criticism, especially if the subject of research and the area of consultancy were identical. They were not, and other data and data collection methods were relied upon almost exclusively. Moreover, time spent on each project was separated from time spent gathering data by other means, which allowed this researcher to wear "different hats" explicitly. Subject to such provisos, consultancy can be a useful variant on the action research method.

Rapoport (1970) defines action research as contributing simultaneously to the practical concerns of people in an immediate problematic situation and to the goals of social science through joint collaboration within a mutually acceptable ethical framework. Whilst what I did at each site was certainly practical and aimed at helping address specific business problems, the subject of both projects (costing methods and systems design) was tangential to the thesis. Hence this method cannot be described as "action research", which carries connotations of testing out theories or hypotheses in the field, thereby deliberately altering its usual mode of operation in a manner useful to the researcher as well as to the firm.

I was not testing out hypotheses with the costing projects, nor were they intended to alter situations for the purposes of my research. It was inevitable that my presence altered people's behaviour somewhat, although I found myself "blending in" at sites

as time went on. On the other hand, I did tell people about my research in some detail, and some began to comment on how and when they were mobilising their knowledge collectively, and to observe this process themselves. In that I was consciously becoming part of their knowledge networks and applying this concept to help myself achieve the projects, this method could be seen as exhibiting some of the characteristics of "action research". Costing and estimating jobs are also part of managing production, and I thus gained an insight at each firm into their mobilisation of knowledge around this issue.

Freedom Press had been experiencing trading difficulties for some months prior to fieldwork. They had already agreed to give me access, but I also offered to do whatever they felt most useful while I was on site. The result was a request from the collective to establish a new costing system using current costs, to run on their new computer system, which I did. This may be seen as straining the bounds of "intersubjectivity" (Knorr-Cetina, 1981) somewhat, but it was worthwhile in terms of the unrestricted access to data and organisational processes it allowed me. At no time during fieldwork at Freedom (or at the other two sites) did I feel any temptation to "go native"; I always had dual-identity : ex-printworker and researcher.

In the case of Weirs, which was a completely unknown quantity at the start, access was mediated by the Regional Enterprise Board. My suggestion of a "small project" in exchange for access was agreed, and I was given preliminary information by the REB with which to construct a direct approach to the company. This resulted in the preparation of an outline proposal to assess the usefulness of adding an alternative version to their existing costing system and to assist in its implementation, in exchange for 8-10 weeks' access for fieldwork. This offer was accepted and both parts duly fulfilled, to mutual satisfaction. I do not believe that access would have been granted had this exchange not occurred. It also served to "credentialise" me, not because I was a researcher, but in my capacity as an ex-printworker. By becoming involved "on their

side", I was again given access to data that I would not otherwise have gained.

The projects were an invaluable part of fieldwork. Doing something specific and constructive provided an initial means of access for prolonged fieldwork, and an additional reason to be there once I arrived. It has been suggested that action research 'constitutes a kind of science with a different epistemology that produces a different kind of knowledge, a knowledge which is contingent on the particular situation' (Susman and Evered, 197:600). This contention was borne out by my own experience. By being involved in these projects, I became part of the firms' networks myself, like any other external carrier of knowledge drawn into mobilisation. I thus gained first-hand experience of how this process worked, which may partly compensate for not including suppliers, customers and subcontractors in my fieldwork other than from the case study firms' point of view.

Working on these projects, I had to find out where different areas of knowledge were located, both inside and outside the firm, and how to mobilise them. I too needed to access other sources of knowledge, which led me in turn to create my own networks and extend my own knowledge in order to solve their specific problems. This component of my research also provided me with an opportunity to experience first-hand the "instrumentalities" (De Solla Price, 1984) of the firms' computer systems, particularly their estimating and costing modules.

Finally, research is a two-way process, requiring give and take on both sides. Where the final outcome of a research project is unclear and remote in time, and where some participants are dubious as to the subject's usefulness or practical applicability, consultancy work may provide a more immediate practical exchange than a research report.

3.3.5. Secondary data

Data on the printing industry (chapter 4) were gathered from a wide variety of sources. Primary data were gathered in the case study firms during fieldwork, and from semi-structured interviews with BPIF directors and consultants at their London and Northern Region offices. Secondary data sources included the trade press and journals, printing equipment manuals, and BPIF and PIRA reports. Where relevant, print-related academic literature from a variety of disciplines was reviewed. Most archive research was eventually carried out at the St. Brides Printing Library in London. Although the BPIF was willing to assist with documentary data, it had recently moved to smaller premises and data which might have been relevant to the thesis had been destroyed during relocation, including a survey on the uptake and experience of computer-aided production management systems by member firms. This may be more widely indicative of the temporary nature of industrial archive materials. PIRA was not used as a source of data, as it charged researchers substantial fees for database searches of the trade press, copies of articles (£10 each), and even entry to its premises (£35 per day). Direct approaches to the trade press for copies of journals also failed when I revealed my identity as a researcher. "British Printer" and "LithoWeek" cannot be purchased, being only available on (free) subscription to selected industry personnel. I therefore gained access to these materials by subscribing in my own name through an industrial contact which was not one of the case study sites. The principal sources of statistical information on the printing industry are government departments and trade associations. Both are problematic, and their difficulties have been noted by other researchers in this area (Harvey and Greenhalgh, 1988; PIRA, 1992).

To summarise, the research adopted a qualitative method, blending ethnography with the generation of conceptual categories and their properties drawn from grounded theory. This was combined with an exploration of the applicability and modification of existing analytical frameworks to empirical data drawn from three in-depth case-studies of firms in the printing industry. A range of data collection methods was used, including participant observation, interviews and a fusion of action research with consultancy. Data were analysed using an iterative combination of comparative analysis and existing theory.

Table 3.1 : FREEDOM PRESS

Activity	general printing
Work	jobbing
Age	>10 years
Location	London inner city
No. of workers	10-20
Size (in industry terms)	medium
Legal constitution	worker cooperative
Management structure	collective
In-house facilities :	
Artwork	yes
Typesetting	no
Repro	some
Camera/platemaking	yes/yes
Press technology	large sheetfed offset litho
Presses	Heidelberg MO + KORD
Finishing	guillotine only
Computer system :	yes
Off-the-shelf/bespoke	bespoke
Designer	freelance individual
Integrated modules	no

Table 3.2 : WEIRS WEB

Activity	direct mail printing
Work	jobbing
Age of site	=/ < 5 years
Location	West Lothian greenfield
No. of workers	100-150
Size (in industry terms)	large
Legal constitution	division of limited company
Age of parent company	> 100 years
Management structure	hierarchical

On-site facilities :

Artwork	no
Typesetting	no
Camera/platemaking	no/yes
Repro	no
Press technology	heatset web offset litho
Presses	Heidelberg Web-8s
Finishing	yes

Computer system :	yes
Off-the-shelf/bespoke	off-the-shelf, customised
Designer	software company
Integrated modules	yes

Table 3.3 : TRINITY PRESS

Activity	newspaper printing
Work	contract
Age of site	=/<5 years
Location	Edinburgh city
No. of workers	100-150
Size (in industry terms)	large
Legal constitution	division of limited company
Age of parent company	>100 years
Management structure	hierarchical/crew-based teamwork

On-site facilities :

Artwork	no
Typesetting	no
Camera/platemaking	no/yes
Repro	no
Press technology	coldset web offset litho
Presses	Goss
Finishing	yes
Computer system :	yes
Off-the-shelf/bespoke	bespoke for press, customised
Designer	software company
Integrated modules	yes

CHAPTER 4 - PRINTING IN BRITAIN

It is now time to examine the activity central to this research - printing. This chapter paints a broad picture of the industry, enabling the reader to site the case study firms and the work of other print researchers in an overall context of markets, products, processes, contractual and other networks, and economic trends, all of which are relevant to the mobilisation of print knowledge. It discusses links between printworkers, firms, customers and suppliers which form an important part of production knowledge, and examines developments occurring in production and production management technologies during the decade. Technical terms and acronyms are explained in the Glossary. A videotape accompanies section 4.3. to provide a more visual description of production processes than could be achieved by text and static images.

4.1. VIEWS FROM OUTSIDE

To begin with, it is worth considering printing from the point of view of people outside the industry. In September 1991, one of the major trade journals (LithoWeek) sampled public perceptions of print, resulting in correspondence to the letters page for several subsequent issues. The survey, perhaps unsurprisingly, revealed that insofar as the industry had an image, this was negative, and outdated. Printing was viewed as beset by industrial relations problems, exemplified in respondents' minds by the dispute between News International plc and the media trade unions over Wapping. It was seen as dirty work carried out by 'sloppy, slapdash' men who 'wore awful clothes like long brown jackets' using antiquated technology, in 'a dingy litter-filled garage where a creaking machine turns out smudged handbills' (LW 17/9/91:19). One incomer to the industry, an ex-banker appointed as Chief Executive to one of the larger companies, brought his preconceptions with him, 'Printing in this country is largely a product of British Railway's

arches' (LW 22/10/91:16) The industry was perceived as nepotistic, closed to women, and secretive, 'It must employ huge numbers of people, but they keep pretty quiet about the sort of careers on offer' (LW3/9/91:29); and yet financially insignificant, 'It's certainly not a big money spinner for the economy' (front cover, LW 3/9/91). So what factors might account for these opinions, apart from the grain of truth present in all stereotypes ?

Printing technologies have been with us for so long that we no longer remark on their importance, 'It's a bit old fashioned and boring, isn't it ?' (front cover, LithoWeek 3/9/91), despite the fact that the myth of the "paperless office" has failed to materialise. We are surrounded by so much printed matter that we take its presence in our lives for granted, whilst remaining largely ignorant of how it is produced 'when you think of all the printed material we see every day you realise it must come from somewhere' (LW 3/9/92:29). Eisenstein (1979:17) suggests that 'the more printed materials accumulate, the more we are inclined to overlook them in favor of more recent, less familiar media. Articles speculating about the effects of television will thus find a larger market than conjectures about the impact of print'. In the 1990s, the Internet could be seen as analogous to Eisenstein's 1979 example of television. In addition, print performs an ancillary function : it is the use of the end product that matters, rather than the production process, 'for most customers, print is very much a background activity, something that has to happen to achieve another end, rather than an end in itself' (LW 1/10/91:16).

Printing rarely appeared on the agenda of local and regional development agencies, although in the late 1970s and early 1980s, bodies such as the Greater London Council (GLC) and the Greater London Enterprise Board (GLEB) supported print co-operatives by providing access to training in finance, decision-making and strategic planning, and to affordable loan finance for capital equipment purchases. This was more because the beneficiaries of such a strategy were worker cooperatives than because they were printers, although there was an element of support for

"alternative" printshops which provided a cheap and accessible resource for social and community groups hitherto seen as under- or mis-represented in the existing media.

Where media have been considered in more recent strategies for urban regeneration, the emphasis has been on audio-visual industries, such as film and video production; on broadcast television and radio; and where the strategy has widened to encompass "the cultural industries" this has most frequently meant the addition of popular music to the preceding list (Harvey and Greenhalgh, 1988). The fragmentation and diversity of the printing industry, the large number of small and medium-sized firms, and the difficulty in obtaining adequate statistics on which to build policy may also have contributed to its exclusion from planning initiatives.

There is a dearth of academic literature on printing, and no coherent body of work on the subject, apart from international conference proceedings of industry-specific technical research associations, whose recent concerns include colour measurement for digitisation, ink formulation and press control techniques^{2000 - 04}. Eisenstein (1979:20) remarks on the virtual absence of printing from the agenda of historians of science and technology, attributing this to the plethora of more recent, or more recently exhumed, technologies, 'As just one more item in an increasingly cluttered inventory, the printing press has also become less distinctive'. In the field of cultural studies, work on print concentrates on its content, style and publication (in the sense of press freedom, or the lack of a "working-class" press), rather than on technology or production processes, and the focus of media studies over recent years has tended to be newer audio-visual media such as television, film and video, and more recently, virtual reality and multimedia.

Cockburn's (1983) influential study of gender, skill and technological change in printing focused on the then significant issue of the transition from hot metal type composition to keyboard

typesetting within the national newspaper sector (Fleet Street). As a site for enquiry into such issues, her choice was both appropriate and illuminating, and the issues she raises about gender relations in printing are still relevant. However, this sector was and is not typical of the industry as a whole (in terms of firm size, product, process, technology, working practices, and industrial relations), comprising a tiny percentage of the total number of print firms in the country, 'Newspaper printing is usually regarded as outside the general printing industry' (BPIF, 1986:12). Nor was it typical of newspaper printing in general, as regional presses operated differently. A more recent, historical study by Reynolds (1989) examines the entry of women as compositors into the Edinburgh book printing trade in the early years of the 20th century, and the circumstances leading to their subsequent exclusion from the industry. Again, this is set against a background of technological change (from manual typesetting to Monotype machine typesetting) and a discussion of skill, trade union membership and gender relations in the workplace. Reynolds' observations on the industry as a whole also provide a useful historical comparison with its structure in the 1980s and 1990s.

Blauner's (1964) study, although now quite dated, looked at firms which could be considered more representative of printing. His research questions were concerned with the degree of alienation experienced by workers in relation to the type of production process, taking printing as an exemplar of craft production, as opposed to machine minding, assembly line work, and continuous process industries. Given the rate of technological change in the industry since this study, his prediction that 'printing may change rapidly from a craft to an automated industry', whilst not occurring immediately or universally, seems to be coming true, given the developments of the last decade.

The issue of technological change in general printing has been investigated by Goss (1988), who examines the change from letterpress to litho in terms of debates about whether new technology deskills production workers. He found that in firms

within the traditional industry, the craft status of printers and the influence of the print unions combined to prevent workers being seen as "deskilled" by litho production technologies, even though they felt that a narrower range of knowledge was actually required to operate their machines. He also found that employers in traditional print firms, apart from having antagonistic attitudes to trade unions, were broadly sympathetic to the preservation of printworkers' craft status and skill claims. Goss attributes this to the fact that most print employers and managers had worked their way up from the shopfloor and thus held those same values themselves. By contrast, Goss discovered that no such traditions held in the "instant print" sector, where managers were likely to be new entrant entrepreneurs with no previous industry experience or affinity. Their workers were only given the most basic training in the litho presses they would operate, had no craft or skilled status, earned low wages in consequence, and did not see themselves as part of the printing industry. Goss concludes that skill is socially constructed, and that many factors other than new technology itself influence whether or not workers are deskilled by its introduction.

Most recently, Driver and Gillespie (1991a; 1991b) have examined publishing and pre-press in the magazine sector of the printing industry, looking at the interrelation between technological change - mainly desktop publishing [DTP] and electronic data transmission [EDT] - and patterns of transnational consolidation of publishing company ownership, and potential consequences for the siting of production. This does not address the significance of such technical change for the printing industry. EDT was not yet an issue for print firms, since most still relied on face-to-face contact, telephone, fax and mail services to communicate with clients and suppliers (LW 29/10/91:16).

4.2. SECTORS, MARKETS AND PRODUCTS

The industry comprised various product sectors and served many different markets. Industry sectors are listed below in fig. 4.1, which locates the case study firms and the work of other researchers on the industry within this framework. General printers (Goss, 1988) such as Freedom might print any product category, except newspapers and security print.

Fig. 4.1 : PIRA classification of industry sectors by product

Newspapers	- national (Cockburn)	- dailies	(popular/tabloid) (quality/broadsheet)
		- Sundays	(popular/tabloid) (quality/broadsheet)
	- regional (Trinity)	- mornings	
		- evenings	
		- weeklies	- paid for - freesheets
Magazines (Driver and Gillespie)	- Business	- trade	
		- technical	
		- professional	
	- Consumer	- women's	- weekly - monthly
		- TV listings	
		- specialist	
		- general	
Books (Reynolds)	- Fiction		
	- Non-fiction	- consumer	
		- schools	
		- university and professional	
Packaging			
Other		- Security print (banknotes, cheques, etc.)	
		- City and financial print	
		- Catalogues and brochures	
		- Direct mail (Weirs)	
		- Diaries and organisers	
		- Calendars	
		- Greetings cards	
		- Labels	
		- Business forms	

Source : PIRA (1992)

This schema does not distinguish different print-buying markets for the same type of product. For instance, orders for printing greetings cards ^{may} be placed by charities, museums and art galleries; stationers and companies such as Boots or W.H. Smiths; individual artists or designers; as well as by retail suppliers such as Camden Graphics. All these ^{do} not necessarily turn to specialist greetings cards printers, such as British Greetings or Burgess. Galleries ^{may} use fine art printers for greetings cards as well as for posters and limited edition prints, since the quality of image reproduction and the perceived attitude of the printer towards the product ^{matter} more than the bare job specification. Similarly, customers for catalogues and brochures ^{can} be large firms, including Argos, Littlewoods, Thomson's and Lunn Poly, or smaller organisations, such as specialist travel operators, independent record labels, and charities. Again, not all orders ^{go} to BPC or Watmoughs, the major British suppliers. Many factors influence their choice, particularly when smaller customers ^{seek} a general printer - not only price, quality and turnaround (which ^{are} important), but also location, attitude, reputation, existing customer base, and production capabilities.

The market served and the identity of the customer had implications for print knowledge. In the case of printer-publishers, for example newspaper companies, the market was known, as it was internal to the organisation. For firms which had to look outside for custom, knowing the market involved anticipating customer expectations regarding job specifications, price, quality and service, and being able to predict the behaviour of known competitors in respect of these factors. Firms also needed to know how much knowledge of print prospective customers had, and thus the general approach to adopt that would be most conducive to getting the order in the first place, what terminology it was appropriate to use in conversation, and how much assistance it must provide or could rely on receiving during the job,

'It should be ascertained whether the customer is quite familiar with design and print - as in the case of an advertising agency or department, or whether he is technically unfamiliar with print.

This is important, as a rough which will convey its message to a trained print buyer is not adequate for a customer who must be presented with the complete design, plus an explanation of how it is to be reproduced'. (Brinkley, n.d.:30)

Some firms served markets in which it was believed that customers had little knowledge of print, and were content to remain that way, 'our customers do not have an in-depth knowledge of the printing process and I do not feel it necessary, as part of our job, to educate them unless they so desire' (LW 15/9/91:16). Other printers worked on principles of enlightened self-interest and attempted to teach their customers how to produce better artwork (which made their own job easier) and how to commission or design products that would fit a limited budget (thereby hopefully earning customer gratitude and the job). Giving customers a guided tour of production areas was also commonly used as a way to explain the printing process, as well as being seen as a good PR exercise. Potential problems could sometimes be discussed with knowledgeable customers before they happened, and alternative strategies mutually agreed upon in advance, so as not to disrupt production or delivery dates. Regular customers might even design jobs to suit a printer's technological capabilities.

Firms could also be distinguished by their contractual relations with customers. "Jobbing" printers took on work on an ad hoc basis from any customer who chose them on the basis of an estimate supplied. The contract was for the supply of that specific job, and did not imply any regularity or repeat ordering, although most jobbing printers had at least some regular customers and informal repeat orders. "Contract" printers undertook regular work for customers on the basis of a legal contract awarded for a set period of time (often one or three years), after an invitation to tender issued to competing firms on a shortlist, and which only became void in the event of a breach of contract. Such arrangements were most common for magazines, periodicals and books, and other regular jobs whose timing and approximate extent and quantity could be known. Most firms were a mixture of the two - contract printers took on ad hoc work to fill any gaps in production, and jobbing

printers sometimes had annual contracts with regular magazine or other customers.

4.3. PROCESSES AND TECHNOLOGIES

Print firms employed a wide variety of methods to convert material supplied by customers into the finished product. At any given time, a technological continuum existed in the industry, wherein firms might employ twenty year-old or state-of-the-art technologies. There were overall trends in print technologies towards faster set-up times and higher processing speeds, partly from mechanical equipment redesign for increased robustness (such as drive gears with greater torque resistance), and partly through increased use of automation (plate clamping systems on presses) and computerised control systems. Extra units on machines, linked by conveyors, enabled adjacent (or additional) processes to be carried out in-line without interim product handling or storage. The more processes that could be carried out on a sheet, the greater the "added-value" and profit for printers.

A number of steps were entailed in production, regardless of the technology utilised, although it depended on the customer what stage had been reached before a job went to the printer (fig.4.2). Moves by equipment manufacturers to eliminate interim processes between desk-top publishing (DTP) and printing had not yet reached a commercial market at the time of fieldwork, but were imminent. The digitisation of artwork enabled by DTP was being refined to increasingly high image resolution and connected to computer-controlled platemaking and printing equipment capable of receiving and reproducing digitised images. This would dramatically alter industry structure, occupational groupings and technologies, 'the printing industry as we know it will not exist in thirty years' time' (Keith Jackson, BPIF). It is beyond the scope of this thesis to provide a comprehensive account of all possible production permutations and technological developments, but the following

brief account of processes and technologies covers issues relevant to the case study firms.

Fig. 4.2. Stages of the printing process

ORINATION (design; text and image assembly)
proofing (content and design)
REPRO (converting artwork into reproducible form)
proofing (colour balance and image position)
PLATEMAKING (developing artwork on film onto durable plates)
PRINTING (reproduction of image from plates onto paper)
FINISHING (trimming, folding, binding, packing, etc.)

Customers supplied copy text and original images. The designer produced a rough design for the job. When this was agreed, artwork was either produced using a desk-top publishing package (DTP), or by computer typesetting, and laying out and pasting up text and images manually. The designer checked that instructions had been carried out, and customers proofed the artwork for completeness. Smaller pages might be gathered together in the correct order for printing and imposed onto larger grids of plate size (see below). Finally, trim marks were added to each image corner to show the finished size of the end product.

Mono artwork was photographed and developed onto negative film in the camera department. Any full colour artwork was passed through a scanner, which analysed the images, breaking them down into the four components from which all colours were printed : cyan, magenta, yellow and key; and translated them into patterns of dots for each colour, heavier or lighter in concentration depending on the darkness or lightness of the original. The machine then output four pieces of film per image, one for each "process" colour. These were re-combined if necessary with the mono film, a process known as film-planning, checked for positioning by superimposition over a light source, and punched with holes for register pins.

Films (see video) were developed by exposure onto similarly punched metal plates (instead of photographic paper), one for each process colour, using a printdown frame with pins to hold film and plate steady so the image registered correctly. The image was fixed on the plate by etching in a chemical bath, rinsed clean with water, and preserved with a coating of gum arabic until required for printing. Sometimes (as at Weirs), the image was baked to the plate in an oven for added durability. If the job was to run on a press with computerised press control (CPC), plates were scanned onto a cassette holding details of ink densities. This was subsequently inserted into the press console, where it programmed the ink ducts to regulate ink coverage of the paper.

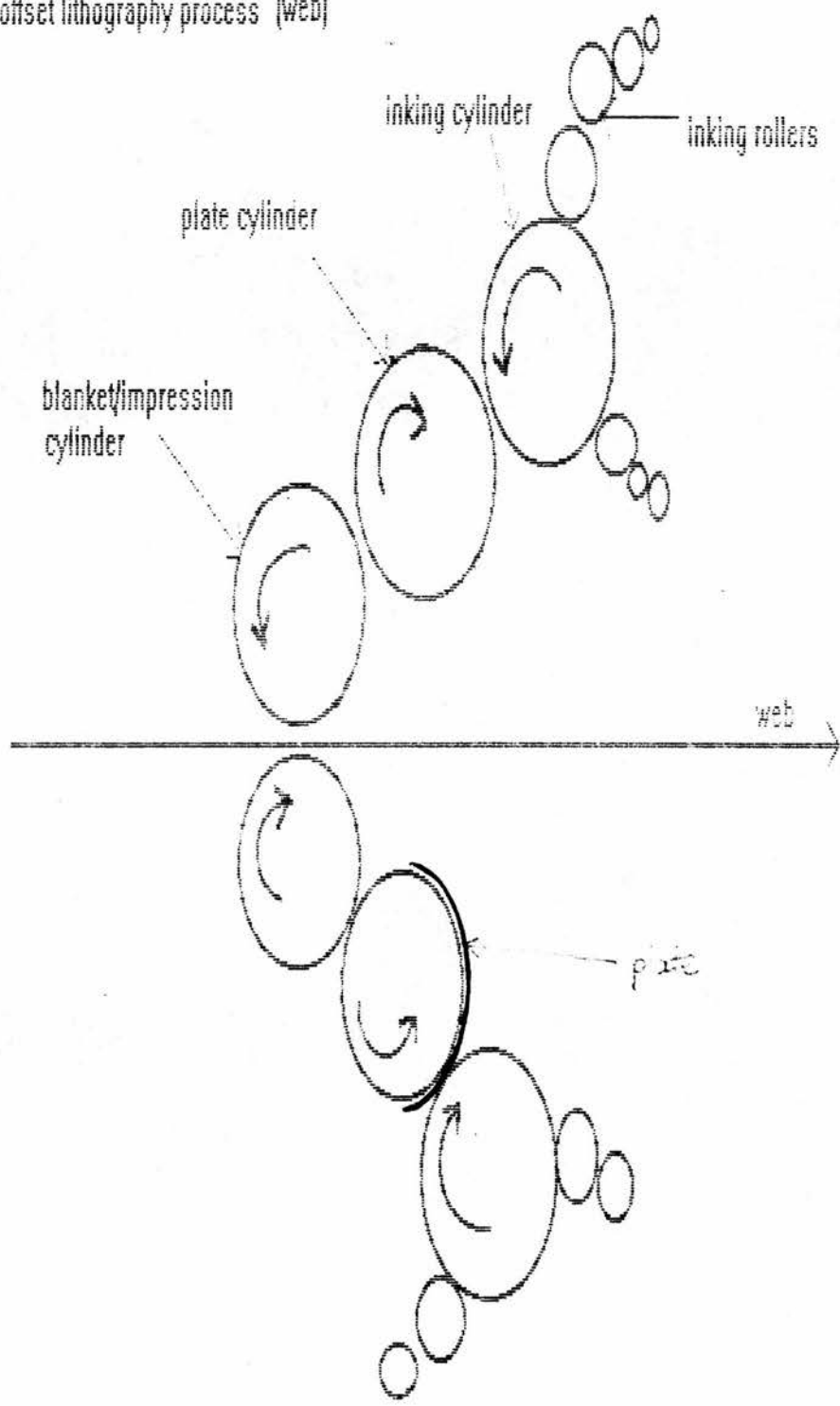
Four-colour film or plates were usually proofed to provide a definitive image of which the customer approved, and which was thereafter used as a benchmark by printers. Proofing could be done in several ways: cromalin or ozalid proofs from final film (Weirs) and machine or flat-bed proofing from plates (Freedom).

This research examined firms which used the offset lithography print process (fig. 4.3 and video),

'a process in which the printing and non-printing surface are on the same plane [the plate] and the paper makes contact with the whole surface. The printing part of the surface is treated to receive and transmit ink to the paper, usually via a blanket (thus "offset"). The non-printing surface is treated to attract water and thus rejects [oil-based] ink from the ink roller, which touches the whole surface' (BPIF, 1992:185).

This was carried out on either WEB-fed (Weirs and Trinity) or SHEET-fed (Freedom) presses, terms referring to the form in which paper was introduced into the machine : from a continuous reel or as separate sheets. Web printing could be either COLDSET (Trinity), or HEATSET (Weirs), involving the use of a drying unit such as an oven. Sheet-fed presses could be LARGE (Freedom) or SMALL offset, depending on their maximum printable sheet size. The video shows makeready and run on a heatset web offset press (Weirs).

3: The offset lithography process (web)



The press was first made ready for the job. Paper was brought to the infeed/reel end of the machine and the first load set in place; inks were mixed, the ink trays filled, and the level of process inks in their barrels checked. Plates were fixed to the plate cylinders, the CPC cassette inserted (if applicable), and the job test-run until image position on the sheet was correct and the right colour balance achieved by reference to the proof. This necessitated adjusting paper feed and press speed; web tension and position (for webs); ink flow through the ducts across the width of the sheet; and cylinder pressures to achieve an appropriate dot size.

On a CPC press, initial settings were done automatically, reading data from the cassette, and leaving printers to fine tune the press. Without CPC, or on a mechanical press, settings were made by hand, either at the control console or using dials, levers and keys on the press itself. In order to maintain consistency with the proof during the run, sheets from the delivery end of the press were periodically scrutinised, and adjustments made to settings if needed. Printed sheets were stacked on pallets to await finishing.

Prior to finishing (see video), piles of sheets were knocked up after printing, so they lay flat with flush edges. This was done either by hand, or on an automatic air table. They could then be trimmed to size using a guillotine programmed to perform a preset sequence of cuts, although sheets were still hand-turned and blades activated by the operator, for safety reasons. Other products were finished using different equipment : leaflets were folded and trimmed on a folding machine, as were individual sections of text and cover for book or magazine work. These were then collated, edge trimmed and wire-stitched at the spine using a stitching machine (not shown in the video). All machines first had to be set up and made ready, as with printing, but taking into account factors such as sheet feed and speed, and matching folds and trims to the printed image and the product mock-up. Finished products were wrapped and palletted.

Printing involved the creation of a single original and its subsequent reproduction into multiple copies, by a process of combining and standardising disparate text and image elements into a coherent whole (origination), translating this into a succession of different formats (reproduction) until a stable medium (the plate) for mass reproduction was achieved (printing). Often the image was composed of several sections, and these had then to be assembled and converted into a consistent whole (finishing). What began as a two-dimensional original became a solid three-dimensional product.

4.4. CAPITAL INVESTMENT AND SUBCONTRACTING

All firms in the industry, even "general" printers (which printed a wide variety of products using relatively all-purpose machinery), tended to specialise in some way. The high cost of equipment led firms to concentrate on a single process (such as colour scanning or book-binding), or a single market or product area (such as direct mail). Others restricted their activities to particular sections of the overall conversion process (such as design and artwork preparation, or reproduction and printing); or to what could be achieved using a certain configuration of production equipment. The capital required was a serious limitation for small firms, and there was a large market in second-hand equipment (LW 20/10/92). However, the rate of technological change in the industry, and the collapse of firms during recession which flooded the secondhand market made survivors wary of investing,

'in the early 1980s a 10-15 year old press gave little difference in terms of productivity and print quality compared with a modern used or even a new machine... Today a press without off-press controls might be cheap, but its output cannot be compared with that of more modern machines' (BP Nov 1992:31).

Nevertheless, a feature of the industry remarked on by Corrigan in his account of jobbing letterpress printers in Dublin in the 1890s still held true a century later, 'the plant was not typical of the

progress made up to the period, but few small presses then were. They were mostly equipped with type and machinery bought from the secondhand lists' (Corrigan, 1944:83).

The speed of each stage of production coloured firms' choice of specialist area, because it affected work flow between departments. Origination of finished artwork might take days or weeks, allowing for customer consultation and copy-proofing by the author, whereas the job might only take an hour to print. Hence, even if the art department worked full-time on a number of jobs, the rest of production would stand idle most of the time unless the firm took on additional camera-ready jobs from outside to fill print capacity. The same problem of relative speed occurred between printing, and finishing which was slower again.

The variety of the end product also meant that some processes (such as foil blocking or die-cutting) were only infrequently required, and it was not economical to keep the equipment in-house. If the firm opted to invest in the technology and to take in work from outside to fill machine capacity, this would amount to running a second business, requiring knowledge perhaps not present in the firm, and additional coordination. These factors affected industry structure, producing a rough division of firms into those that did artwork, repro, printing, or finishing, and those specialising in more expensive or obscure processes, 'some technology will always be the preserve of the specialist because it is too expensive, cumbersome or complicated' (LW 20/12/89), though many print companies kept pre-press equipment to meet their everyday needs.

This industry structure involved firms subcontracting jobs to other firms at various stages of production, a well-established practice dating back to the industrial revolution (Bendix, 1956) and noted by Corrigan (1944). The customer had contact with only one firm, usually that handling the design and production of artwork (origination being the stage at which customers were directly involved). For this reason, some printers retained a graphic designer in-house (comparatively cheap in terms of capital

investment), in order to reach the customer at source, rather than relying solely on industry contacts. It also made it easier for printers to control customers' initial artwork requirements, thereby ensuring that the job specification was achievable in production terms, at the price quoted. Most designers' ideas were possible, but often difficult, time-consuming and expensive to print, because they had little knowledge of print production, despite injunctions in design textbooks,

'[the designer] will be expected to know the possibilities and limitations of the process for which he may be working... It is only by knowing what happens to a design when it leaves his hands that he will realise why it is necessary to prepare a drawing in a certain way : why separation of colours is necessary, the difference between [various reproductive methods], the significance of register, etc.' (Brinkley, n.d.:19).

A further consideration in deciding which processes to keep in-house were the time and co-ordination entailed in subcontracting, together with problems of regulating the flow of internal production, and maintaining quality control over processes occurring in other firms. Some printers therefore chose to deal only with other companies within the industry, rarely seeing the customer and receiving instructions directly from the contractor. Because of this, they were known as "trade printers", although 'Every establishment was to some extent a "trade house", in that somewhere or other in its output there would be work done with somebody else's imprint on it' (Corrigan, 1944:170).

Subcontracting required a firm to have extensive knowledge of relevant areas of the industry (and to know which areas were relevant), in terms of where to obtain a service, who to contact in the firm, what plant they had and what it could do, who had spare capacity, what the going rate for the job was and potential discounts, the likely quality and punctuality of the subcontractee's work, and, perhaps, their credit control and debt-chasing efficiency. Even if a firm did not perform a particular process in-house, workers needed to know how to issue accurate instructions to subcontractors, using appropriate terminology,

'it is virtually impossible for anyone to know all the technical details involved in all the processes and finishing methods employed. An efficient order clerk nevertheless makes it part of his [sic] job to know... where these services exist, to which kind of jobs they are applicable or necessary, and to discuss or arrange for the operations to be carried out as may be required for specific orders' (BPIF, 1985:259).

In order to minimise the uncertainty of putting work out, firms maintained long-term relationships with their subcontractors, once initial trust had been created. The knowledge that firms had of subcontractors extended to detailed knowledge of each other's current production schedules, working practices, and the personalities of individuals.

Such connections worked both ways, particularly in "trade houses". Not only did the practice occur between firms offering different production processes, but also between firms which might otherwise be competitors. For instance, one printer might subcontract part of a larger order to another with more suitable equipment, or in order to get the whole package completed in a shorter time. In return, it might receive a contract for a job taken on when the second firm found its production schedule over-booked, or when problems on one job held up those running after. Many of these networks were specific to a local area or industry sector,

'The master printers of Dublin were a friendly lot, as they are in most places, and when the pressure in one office rose too high for ordinary measures to relieve it, a rival would lend a hand. He was generally willing to do so, if only on the principle "If you scratch my back I'll scratch yours". He might be in the same difficulty himself the following week and be glad of a reciprocal accommodation' (Corrigan, 1944:171).

4.5. MANAGING PRODUCTION

Managing production can briefly be defined as ensuring that jobs are produced to the correct specification and to an appropriate standard of quality, keeping to agreed budgets and customer

deadlines, whilst attempting to make best use of labour, plant and capital (Muhlemann et al., 1992). As a general job description, this cover a multitude of activities (AP, Feb, 1992) :

Fig. 4.4. Activities involved in managing print production

- Establishing job specifications
- Estimating
- Scheduling production
- Issuing works instructions
- Materials ordering / purchasing
- Instructing subcontractors
- Stock control and materials issue
- Organising staffing arrangements
- Regulating work flow
- Checking production to job specifications
- Quality control
- Progress chasing
- Troubleshooting
- Customer liaison
- Checking costs to estimates
- Scheduling equipment maintenance

These tasks called for a wide spread of knowledge : how to translate orders into job specifications and convert these into works instructions and materials requirements for each production process; the problems likely to arise at any point from job specifications or designs, and how to compensate for them; the performance of particular materials, workers and machines, and how these influenced choice of production methods and scheduling decisions, including attempts to avoid departmental bottlenecks; customers' quality requirements; knowledge about subcontractors; where and when to seek specialist outside help with problems; how to diagnose machine faults and decide on appropriate action; and the cost implications of all these factors.

Although the worker designated as "production manager" usually carried ultimate responsibility for the smooth running of operations, all these activities could not be done by one person. Nor could a single individual carry all the knowledge that might be useful. The average day of the Production Director of a large

printworks was described thus (note the amount of interaction with a variety of people) :

'two hours a day as preparation and planning time with his nine managers... the biggest chunk of his time is spent on the shopfloor sorting out problems "I've run all the presses from time to time. Also if the shopfloor people think you understand their problems, they'll approach you" [he said]... and talking to customers. This includes designing products for customers and telling them how they can get such and such an effect for a more economical price' (LW, 9/3/93:22).

The activities listed above were distributed through the organisation, even in smaller firms. Some printworks had internal and external coordinators. Others had departmental or shift supervisors. Estimating might be done by accounts staff. Materials ordering, departmental scheduling or quality control were performed by production workers. Whatever the arrangements of the individual firm, the management of production was a collective effort, as will be seen in later chapters.

Managing and administering production were often performed using manual systems, involving handwritten lists, specifications and works instructions. However, parallel with trends in production technology mentioned in 4.3, came changes in production management technologies involving computerisation and integration of these activities within modular systems. Uptake varied widely within the industry, as noted with regard to production innovations. Although by 1990, 80% of firms had some form of computer system (LW 5/9/90) for word processing and accounting, only 10% had some form of computer system addressing aspects of production management (LW 25/4/90) : mainly estimating, works instructions, job history reports (for progress-chasing), and stock control.

These systems were referred to in printing as management information systems (MIS), but actually related to managing production. Initially, systems were aimed at the industry as a whole, with consequent implementation problems. It was later acknowledged that 'what is needed is a comprehensive understanding of the working environment within which the system is to be used'

(PCM, Aug 1992:22). Subsequent developments included tailoring systems to particular industry sectors or technological configurations. By 1990, they were being sold as essential for survival, 'With 1992 approaching, the economy in a slump, and clients STILL demanding quicker turnaround, can you afford not to computerise ?' (NP, Mar 1990:51).

The degree of integration between different modules varied with the system. Whether all the facilities provided could actually be used was debatable. Conflicting statements were made about the consequences of implementation : on the one hand, this was 'more than just a mere chance to replace the old methods with a faster version' (PW 29/7/92:29), and yet the modular structure 'enables the company to digest the change piecemeal and proceed as fast as budgets allow' (LW 3/9/91:22), which discouraged such an approach.

The most successful modules were those indirectly connected with production processes, which could operate in isolation, such as estimating. Yet even these could fail to serve their purpose. Smaller firms found that their estimators could work faster manually (LW 2/9/92). Other users claimed benefits, 'any of the office staff can key in and produce an estimate without having to have any specialist knowledge' which did not bear closer inspection, 'it was obvious... that a good working knowledge of print production was very necessary as he was constantly making decisions about processes and equipment' (PCM Feb 1992:6).

The belief that systems could replace the knowledge carried by people cropped up in suppliers' advertisements, including this customer testimonial, which manages to thoroughly confuse knowledge with information.

'Nicholas Thomson felt that J Thomson needed a MIS because much of the knowledge and experience, plus the feel for the way the business was running was in his father's head. It is virtually impossible to teach this sort of information to someone else and with his father coming up for retirement, a MIS was needed which could gather the same information his father had accumulated over 20 years' (LW 2/3/93: facing 34).

In Finland, issues of knowledge, expertise and computer systems were being considered in more restrained fashion in an attempt to apply knowledge elicitation (KE) techniques to produce knowledge-based systems (KBS) for printers over a small range of limited production-related applications, with a long way to go before commercial availability, 'It was clear... that these systems would take more time to mature than most other new technologies' (Ahonen and Karttunen, 1990).

Further problems lay in linking "commercial" modules (such as estimating, costing and stock control) with the accounting systems frequently offered as part of the package. Many firms simply stuck with their existing accounting arrangements. Production scheduling resisted computerisation, 'one of the hardest nuts to crack' (BP May 1992:24). Firms often found scheduling modules unusable, and continued with manual methods. Companies implemented some modules and left others alone. The trade press ^{blamed} printers, 'the success or failure of a new installation is primarily in the hands of the user' (PCM, Aug 1992:25).

Evidence (Fleck et al., 1989; Webster, 1990) suggests that many firms implementing computer-based production management systems experienced considerable problems, and this was equally true of their application in printing (Webster, 1990; Hardstone, 1991). When the complexities of print production are considered, it was hardly surprising that firms experienced implementation difficulties. If such systems are most useful when 'demand can be forecast on a long term basis and production runs set up accordingly' (Fleck et al., 1989), then they were inappropriate to most sectors of the printing industry. This was rarely understood by industry commentators, 'By its very nature, printing is a batch process, and tying together different operations electronically can seem complex, daunting' (PW 13/5/92:32).
Another development was the application of shop floor data collection (SFDC) to production activity. This module linked the system to production equipment via keypads operated by shopfloor workers,

'It's called "closing the loop"... using electronics to feed production information in, monitor operations and take feedback on performance and productivity back out so an overall management picture is gleaned' (PW 13/5/92:32).

It was initially anticipated that there would be resistance to 'a spy on the press' (NP Mar 1990:51), but SFDC seemed to gain acceptance 'to the point where this technique is recognised as having benefits for everyone in a company' (PIRA, 1992:65), with workers claimed to be more enthusiastic than management, 'It is often this level [shopfloor] that welcomes it, or so suppliers and existing users would have you believe' (PW 13/5/92:31). One suggested benefit was a reduction in the amount of paperwork workers completed for each job. Given the recession, fears of redundancy, and the reluctance of print unions to provide guidelines for the negotiation of new technology agreements with employers (NP, Mar 1990:53), this lack of opposition was unsurprising.

The outcome of these systems in combination with integrated production technologies was expected to be computer-integrated manufacturing (CIM), although this seemed to be confused by commentators with dreams of the (virtually) workerless factory,

'The next phase of development will be the direct connection of the MIS to production machinery, initially to monitor its activity, and eventually to download machine settings - a stepping stone towards the automated printworks' (PIRA, 1992:65).

This was consistent with a move towards continuous flow production in some sectors, but looked unlikely for the majority of small firms, not least because of the cost of installing electronic sensors on presses not originally supplied with them.

Meanwhile, an alternative to achieving CIM through links between MIS and production via SFDC was being prepared and tested by major press manufacturers, although 'the final product has yet to be launched as MAN Roland believes the market is not yet ready for the concept' (PW 19/2/92:20). This was CIM, but centred on production control systems built into new designs of plant which fed data into

a management module,

'All information from the different stations run together and are, at one's wish, retrievable. Information on ... presses, material usage, accurate costs and the situation can be purposefully condensed. The whole company and all situations in production can be made visible, like under a microscope' (Schweisser and Rettberg, 1989:712).

Such developments were consonant with those taking place in production technology towards the elimination of all equipment other than DTP workstations, presses and finishing, 'the press will be the workhorse of the printshop of the future... and our aim is for it to be the centre for all data and material transfer' (Heidelberg spokesperson, BP, Mar 1992:66), particularly as the suppliers were one and the same. This type of technology was already available to the newspaper sector (see ch. 8).

Not surprisingly, this caused animosity from suppliers of conventional MIS, 'They are interested in running machines: we are interested in running the business' (MIS supplier, PW 19/2/92:18). However, only 10% of firms used some form of MIS, whilst the majority of printers had Heidelberg or MAN Roland presses; the implementation of SFDC modules in MIS relied on production equipment manufacturers' cooperation in linking the two; and conventional MIS were unsuccessful at integrating financial, commercial and production modules, so that the absence of accounting modules from the plant manufacturers' CIM systems was irrelevant. It was tempting to predict that the press manufacturers would prevail.

4.6. NETWORKING AND TRAINING

Relationships between firms in the industry were not solely contractual. Informal networks existed, which could be sectoral or geographical. Firms knew other's reputations, markets, products and technologies, and sometimes their financial circumstances. Obvious

places for managers and trade unionists in the industry to network were BPIF or YMP, and GPMU local or regional branch meetings. Not so immediately apparent were the contacts workers made at printing college, either as production apprentices or while on the growing number of BTEC, HND, undergraduate and postgraduate degree courses in print administration, which led to jobs in estimating and sales. This aspect of networking was more significant outside London, where there were fewer such institutions, and ex-students dispersed into a smaller regional industry.

Job mobility between firms was a source of knowledge exchange about working practices, tricks of the trade or specific types of equipment. This was less in evidence than previously, although still significant. Contraction in the labour market during recession slowed staff turnover in surviving firms. Conversely, it created an unwelcome form of mobility for some workers : one printer interviewed had worked for six firms in 1990-1991, all of which had either closed or contracted. Changes in the apprenticeship system towards a narrower curriculum limited occupational mobility between production areas or industry sectors. Whereas apprentices used to be trained over a period of seven years in the whole production process, this had been reduced to three years, with early specialisation in one particular area : origination, reproduction, printing or finishing. These changes had knowledge implications, in that younger workers were less likely to have formal knowledge of areas of production other than the one in which they were employed, and relied on learning about the practical aspects of other processes informally from those who had served their seven years.

During the period under review, few managers in the printing industry had formal management training, although almost all had a background in production. A City and Guilds print production management course existed for workers who had completed craft apprenticeships, but many found the combination of shiftwork, courses and growing family responsibilities too much, and dropped out (fieldwork interviews). This did not affect their career

prospects, as job advertisements for supervisors and managers rarely requested formal qualifications. This situation may alter once students from the new courses work their way through organisations. In-service training in teamwork for employees and management alike was raised in the trade press as a means of firm survival - a novel departure,

'the art of mobilising and pulling together the intellectual resources of all the employees in the service of the firm... Only by drawing on the combined brainpower of all its employees can a firm face up to the turbulence of today's environment' (Konosuke Matsushita, Chairman, Matsushita Electronic Industrial Company, quoted in LW 12/1/93:18).

Willingness to address these issues could be seen as reflecting the industry's anxiety about skills shortages because of technological change, and potential future problems arising from ^{the} ~~the~~ lack of new entrants.

Other sources of knowledge about the industry were materials and equipment suppliers' sales representatives, who discussed the use and performance of their own and their competitors' products with printworkers. They had a vested interest in being helpful, in terms of winning orders and gaining valuable customer feedback. They passed on more dubious information about other firms, and were notorious for spreading rumours about firm closures. This could be useful in pricing decisions when pitching for work against competitors, but more often its value was anecdotal. Both "the grapevine" and the trade press gave smaller firms a sense of the industry as a whole.

4.7. ECONOMICS

In order to understand the position of the case study firms during the period of this research, it is useful to examine briefly the years leading up to 1989 - 1993 in economic terms. The industry ^{is} ~~is~~ always affected by fluctuations in interest rates, because of the

levels of capital investment required in plant and equipment, mostly financed by loans. At the same time, exchange rates influenced the price of machinery, which is usually imported from Germany or Japan; together with the cost of raw materials, such as paper from Scandinavia or Canada. Demand for print is seasonal, peaking in March and September, with summer and winter lulls.

During the recession of the early 1980s, the industry contracted. Firms closed, jobs were lost and workers left the print. The recovery began late in 1986, when 'significant change was then seen in the climate for the industry. The usual seasonal upturn was more marked than normal' (BPIF, 1992). As the sterling exchange rate fell, prices of imported paper and production machinery rose. Business was booming, so this did not seem to matter. The number of new firms increased sharply, and existing firms increased the number of shifts worked or bought additional equipment to cope with rising customer demand. As the industry expanded, there were shortages of skilled labour, since 'victims of earlier redundancy were no longer available to the industry' (BPIF, 1992:217), and poaching of staff between firms became common.

Access to credit finance became easier, particularly with lease-purchase agreements. One result was 'a complacent attitude to over-indulging in debt' (Rothwell, PIRA, 1992:21), especially among smaller firms unused to being allowed to borrow so freely. They were not the only ones to invest heavily on credit. Newspaper and periodical printers also bought significant amounts of extremely expensive machinery, mainly new web presses, which at the time were becoming physically smaller, more powerful, and much cheaper. According to government statistics, annual capital expenditure in the industry almost trebled between 1983 (£273.2m) and 1989 (£1069.4m) (PIRA, 1992).

Demand for print continued rising, but it was a buyer's market, leading to price competition and narrowing profit margins. These were compensated by an increase in the volume of production. Even the Stock Market crash on Black Monday, which damaged the trade of

City printers, did not significantly affect other sectors. Throughout 1988, demand and competition remained high. Printers found it hard to raise prices, although there was plenty of work. Overcapacity was already affecting the industry. Interest rates rose, which alarmed firms which had over-committed themselves to loan repayments on equipment purchases. The rising sterling exchange rate increased material prices.

Trading conditions began to decline visibly. The rise in base interest rates to 15% in October 1989 hit printers and customers alike. Orders were placed at the last minute, or not at all. Printers' workloads became erratic, seasonal patterns were exaggerated, and competition became ever more cut-throat, with firms charging jobs at breakeven prices just to keep working. As the market contracted, print costs rose again, and margins declined still further. Firms began to go out of business. By the summer of 1990, it was finally admitted that the entire industry was in 'serious recession' (BPIF, 1992), and volumes of business were 50% lower than their 1987 peak before Black Monday (LW 17/9/91:3).

Even in 1990, despite industry revenues of approximately ?23.5bn, profit margins remained small, and were squeezed further as the recession deepened. LithoWeek's 1992 survey of larger printing companies found that their average pre-tax profit was 3.97%, down from 5.36% the previous year, 'a measly reward by any standards' (PIRA, 1992:24). A rough rule of thumb for smaller general printers was that material and outwork costs accounted for 50 - 60% of turnover, leaving a gross profit of 40-50% to cover direct labour and all indirect costs. This did not produce high profit margins.

Because of the diversity of the industry, margins and sales trends varied between sectors, and also between firms carrying on similar activities, depending on their markets. Sectors particularly affected by economic downturn were financial print and business forms, reflecting a decline in the number of commercial transactions; and catalogues and brochures, because of tour operators going under and orders for long-run mail-order catalogues

reverting to European printers, which had become relatively cheaper because of exchange rate rises.

1991 was considered to be the industry's hardest year since the Second World War (PIRA, 1992:17-24), and 11,000 jobs (more than 6% of the total workforce) were expected to be shed during that period (LW 26/11/91:4; DT 25/11/91:30). Shopfloor workers were not the only ones to suffer. Top management dismissed production managers and did the job themselves in an attempt to save costs by cutting layers of management (never very many in printing to begin with!). There was a glut of unemployed estimators, formerly one of the safest jobs in the industry (LW 10/7/91:15). Approximately 145 (4%) of the BPIF's member firms had already gone out of business, and 85% of the remaining 3,400 were working 'well below capacity' (DT 25/11/91:30). These difficulties were principally attributed to economic factors by industry commentators,

'the depth of the current recession has hit the printing industry particularly hard because of an unfortunate coincidence of demand-led and structural factors' (Rothwell, PIRA, 1992:17).

On the demand side of this argument, the printing industry as a whole appeared to reflect the general fortunes of the economy. This was not always the case. Until sectors other than newspapers or books became a significant feature,

'The cycles of expansion and contraction in the printing industry were... relatively unaffected, or only indirectly affected by larger cycles of economic activity in this period [1860-1914]. Technical and structural innovation and the changing nature of demand had relatively greater impact than economic depression' (Reynolds, 1989:9-10).

Much commercial print relates to business advertising and promotional material, and demand is thus linked to the "advertising cycle", which reaches a low point during periods of recession, but which may be one of the first areas to indicate recovery. The health of newspaper and magazine sectors is closely linked to levels of advertising and business and consumer confidence. Although 'The relationship, if any, between expanding printing

industries and the growth of capitalist enterprise during the early modern era still remains to be explored' (Eisenstein, 1979:30), it would appear that this connection existed in the late 1980s and early 1990s.

Every week, the trade press carried reports of firms of all sizes and in all sectors going under (LW, 1990-92, passim). As a result, the second-hand equipment market became saturated. The value of its stock plummeted, and levels of investment in such plant fell, as printers waited for the economic climate to improve and to see what new technologies could offer. One of the biggest and best-known suppliers of second-hand printing equipment folded. Demand in the second-hand market shifted towards "used modern" plant (less than five years old), rather than "old". Equipment manufacturers started moving into this area, buying back their older models and reconditioning them for resale. In the light of technological changes, the resale value of some plant fell dramatically, hard for an industry used to resale or part-exchange as a supplementary means of financing future capital investment. By the end of 1992, 45% of print firms had no capital investment plans for 1993 (LW, 20/10/92)

In the early 1990s, business confidence was lower than at any time in the previous decade, the rate of growth in Gross Domestic Product had slowed, and consumer expenditure had fallen. All these factors adversely affected demand for print, and the industry suffered. The hope that there would be sufficient trade for survivors to carry on as before, once enough firms had gone under (LW 5/9/90), was not fulfilled. Profit margins tightened further as printers competed for fewer customers with less money to spend. Late payment by debtors, which could be shrugged off as an unfortunate industry characteristic in the boom years, became a matter of life or death for some firms, exacerbated by the bad debts of customers going into liquidation (BPIF, 1992:217).

By the end of 1992, 83% of firms were operating below capacity, 74% had recently shed or were about to shed staff, and 73% had order books that were emptier than normal (BP, Dec 1992:5). The first

casualties of the recession had been small and medium sized enterprises, but from 1991 onwards, large printers with reserves also went into receivership or liquidation, even in more buoyant industry sectors such as direct mail.

It is in this overall context of variety, complexity, technological upheaval and financial anxiety that the three case study firms were operating when I carried out my fieldwork between 1991 and 1994. In the next chapter, their circumstances are described in greater detail.

5.1. FREEDOM PRESS

Freedom was a general jobbing printshop, employing 10 workers (all GPMU members) and generating annual turnover of £250-500,000. It was situated in Clerkenwell (fig.5.1)¹, an area of central London long associated with the printing trade, close to Fleet Street. Set up in the mid-1970s as a workers cooperative in the north of England, it originally had links with the libertarian movement. At the end of the decade, the press moved to London, first to cramped and inconvenient premises above a row of shops near Sadlers Wells, and then into a single unit (which eventually became the pressroom) in an former warehouse converted into managed workspaces for letting (fig.5.2). As turnover grew, Freedom expanded to occupy additional units as these fell vacant, until it filled all five ground floor units clustered round a central lobby, with its own street level entrance and a delivery bay in the rear courtyard. This made it possible for Freedom to take in materials and send out work-in-progress on pallets, using pallet trucks and a motorised forklift.

By 1984, it was one of the four largest printing cooperatives in London (and in the country). These grouped together to form the London Cooperative Printers Association (LCPA), in order to represent the interests of their members to the print unions (then NGA and SOGAT) and the employers' association (BPIF), and to coordinate its members' activities, particularly in terms of joint marketing initiatives and the regulation of competition between the firms involved. This led to an informal agreement to allocate what were then perceived as the major segments of the printing

. The illustrations accompanying this chapter are found at the end of the subsection to which they relate.

cooperatives' market, and Freedom was allotted the labour movement, and more specifically, trade unions (the others being the arts, education, and the music industry). Over the years, these divisions were eroded, with some acrimony, although precedent ensured their partial survival. Early in its existence, the LCPA broadened its membership to include smaller print cooperatives, and this made enforcement of such agreements more difficult.

Freedom's customer base extended beyond this remit to include charities, small publishers, national and local branches of political parties, campaigning and community groups, and local traders. Funding of community projects by the Greater London Council (until its abolition in 1986) and London's Labour-controlled local authorities swelled the cooperatives' potential market, although this source of work diminished as rate-capping and the introduction of the Poll Tax took effect. Attempts to compensate for this loss of custom were made from 1985 onwards, resulting in the appointment of a worker specifically allocated to sales and marketing. These efforts took Freedom into printing for groups involved in the areas of housing, care of the elderly and environmental issues. Other longstanding sources of work were the external political and social commitments of individual workers, most of whom had a wide network of useful contacts and potential customers.

As a general printer, Freedom produced a wide variety of products, ranging from leaflets to books, from fly-posters to art catalogues, in mono, full-colour or special inks, and in runs varying from 500 to 500,000, depending on the item. For example, 500 was an economic quantity for full-colour posters, whereas the set-up costs involved made the firm uncompetitive for an equivalent run of mono leaflets, in comparison to smaller presses (\leq A3). Similarly, 500,000 mono A5 leaflets could be produced in a matter of hours, whereas 500,000 books (apart from being a run length that no publisher could hope to sell) would have taken weeks or months. Although there were some annual contracts for regular magazine, journal and newsletter work, much work was carried out on a jobbing basis, mainly for customers

who returned regularly, if only once a year.

Most jobs were finished to some permutation of the A sizes, the most common being A4, A5 or 1/3 A4, although some publishing customers had distinctive page sizes, specified in millimetres, designed to make their products stand out on the shelf, and other less frequently requested sizes were also possible. The presses were suited to this variety of formats, being designed to deliver sheets of up to approximately A2 size prior to finishing, and adequate for most jobs other than the very small (such as business cards) or the very large (bus shelter or cinema posters). The feed and delivery units could be adapted to take any smaller intermediate size between A3 and A2. This facility was used particularly for the printing of folders or wallet files, whose finished size would accommodate A4 or A5 items such as booklets, but which needed provision for flaps and gussets for gluing or slotting.

Both presses were sheetfed, the KORD (fig.5.3) being single colour¹ with a top speed of 6,000 sheets/hour, and the MO (fig.5.4) a two-unit convertible², capable of a maximum of 8-10,000 sheets/hour. There were product areas in which Freedom was less competitive, such as long run book or long run four colour work (the former requiring A1 or larger presses, and the latter necessitating four-unit presses), but since the typical customer rarely requested such jobs, this was not a major disadvantage. Products for which this combination of presses was most suited were A4 magazines or A5 booklets with text in one or two colours and a multi- or full-colour cover. The former could be printed on the MO and the latter (simultaneously) on the KORD, in order to reduce turnaround time.

. Printing one colour per pass through the machine.

. Either printing one colour on both sides, or two colours on one side of the sheet in a single pass through the machine.

Freedom had its own graphic design department (fig.5.5), which was particularly important, given that many of its customers had little knowledge of how to prepare artwork for printing, since they were often most concerned with the editorial content of their work. One of its functions was to train customers in how to present their material, and to explain why this was necessary for production. Since customers often had a limited budget for printing, the designer, in conjunction with an estimator, would also offer advice on how to make best use of the available money, and how to achieve a desired effect or style more cheaply. This occurred for two reasons : an explicit commitment to demystifying printing and the sharing of knowledge, and a less often articulated view that being helpful to customers was good for business. Some customers, such as larger charities or trade unions, did have design knowledge, and produced camera-ready artwork. In addition, Freedom took in work for printing from external designers, although this sometimes brought production problems.

A decision had been taken not to invest in typesetting equipment, as this was not considered economical. Instead, the firm relied on other printing cooperatives with in-house typesetting, and some commercial typesetters located within walking distance. The need for proofing by designer and customer meant that copy passed to and fro several times. This incurred additional despatch costs, although as much work as possible was delivered on foot or by bicycle. In 1991, Freedom acquired DTP with their new computer system, although this was mainly used for display typesetting, rather than text.

The firm also had in-house camera (fig.5.6) and platemaking equipment (figs. 5.7. and 5.8) sufficient for its day-to-day needs, although it subcontracted four-colour repro work, because of the cost of colour scanners and its lack of internal knowledge of four-colour planning. In 1986 the employment of a plateroom worker with repro skills meant that this stage could be taken back in-house if time allowed, although scanning continued to be subcontracted. When the entire repro process was carried out elsewhere, plates were

supplied with flat-bed proofs, but after 1986, machine proofs were sometimes produced in-house.

The press department was self-sufficient, and subcontracting was only undertaken in extreme circumstances. The guillotine (fig.5.9) was used for trimming sheets to the size required by the presses prior to printing, and for finishing leaflets, postcards and posters. All other finishing was subcontracted. Since there were no finishing cooperatives, Freedom employed a number of companies depending on the process required, but sent most of its routine work to one or two finishers, with which it maintained close longterm links. These firms were used by other print cooperatives, as well as by printers serving similar markets, but with a different legal constitution. A delivery cooperative with vans and small lorries despatched work-in-progress to subcontractors and finished jobs to customers. This firm served most London print cooperatives.

Scheduling, materials ordering and stock control were managed using diaries, wallcharts (fig.5.10) and lists kept in the office (fig.5.11). In-house progress-chasing was face-to-face, while subcontractors were contacted by telephone. Estimates were done either manually with tables, price lists and an estimate request form, or from the form onto the computerised estimating module of the extremely unfinished CAPM system that came into use in the summer of 1991. This was based on one previously created by a freelance system designer sympathetic to the aims of "alternative" and cooperative working, but for another client. At Freedom, the system had always been problematic. It was eventually abandoned and the single terminal used solely for DTP. At the start of my fieldwork, relations with the system designer had broken down on both sides, although reconciliatory moves were subsequently made. Freedom already had a stand-alone computerised accounting system (since 1987).

Freedom was both a general jobbing printer with a local network of subcontractors and suppliers within the printing industry, and it

was a member of the cooperative print network. Only in London could this situation have arisen, since no other city had such a large or well-developed cooperative sector. Not only was Freedom subject to fluctuations in trade arising from general economic trends, but it served an "alternative" market which was contracting in the late 1980s and early 1990s, because of wider political changes. This had already resulted in the closure of smaller printing cooperatives.

At the time of fieldwork, in common with many small general printers, Freedom was experiencing trading difficulties during the recession. Annual turnover had fallen by a third, from a 1988 peak of £500-750K, despite attempts to move into new markets. The loan from Greater London Enterprise for the last major item of capital expenditure, the MO, had been fully paid off, and there were no other capital debts. In order to survive, it was decided in 1991 to restructure the operation : the workforce of 14 was reduced to 10 through redundancies (a dedicated estimator; one graphic designer and one planner/platemaker); and the rationalisation of the production management function, previously divided between two workers, one responsible for internal and one for external coordination, into a single post, held by one person. Only the pressroom remained on shiftwork.

My action research revised and recalculated the departmental costing system so that hourly rates (used as a basis for estimating) could be updated and more information about performance made available. In spite of these efforts, Freedom called in the receivers at the end of May 1992. The business was put up for sale as a going concern, with all its plant, at £20K. Although a buyout offer was made by some of the ex-workers, the eventual sale price of the separate items of plant at auction was higher than their bid for the business.



Fig. 5.1. Clarks Green, church
Along the road from Freedom.

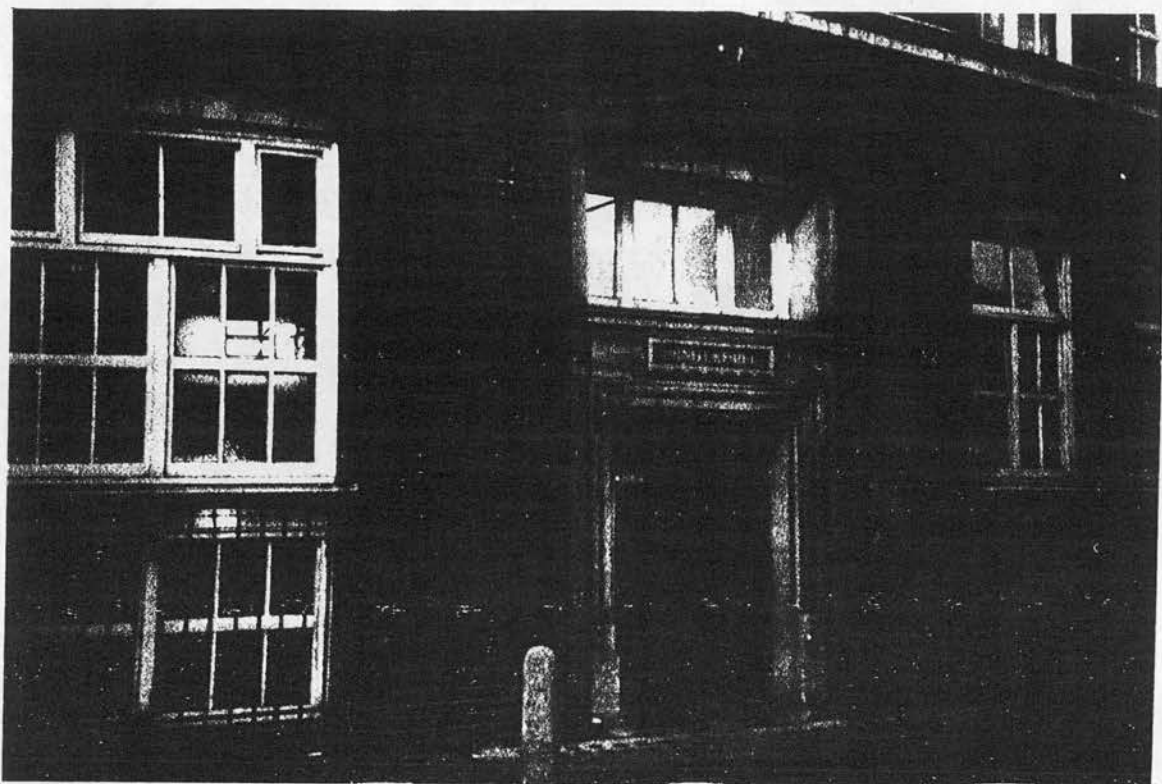


Fig. 5.2. Exterior, Freedom Press



Fig. 5.3. KORD press, Freedom

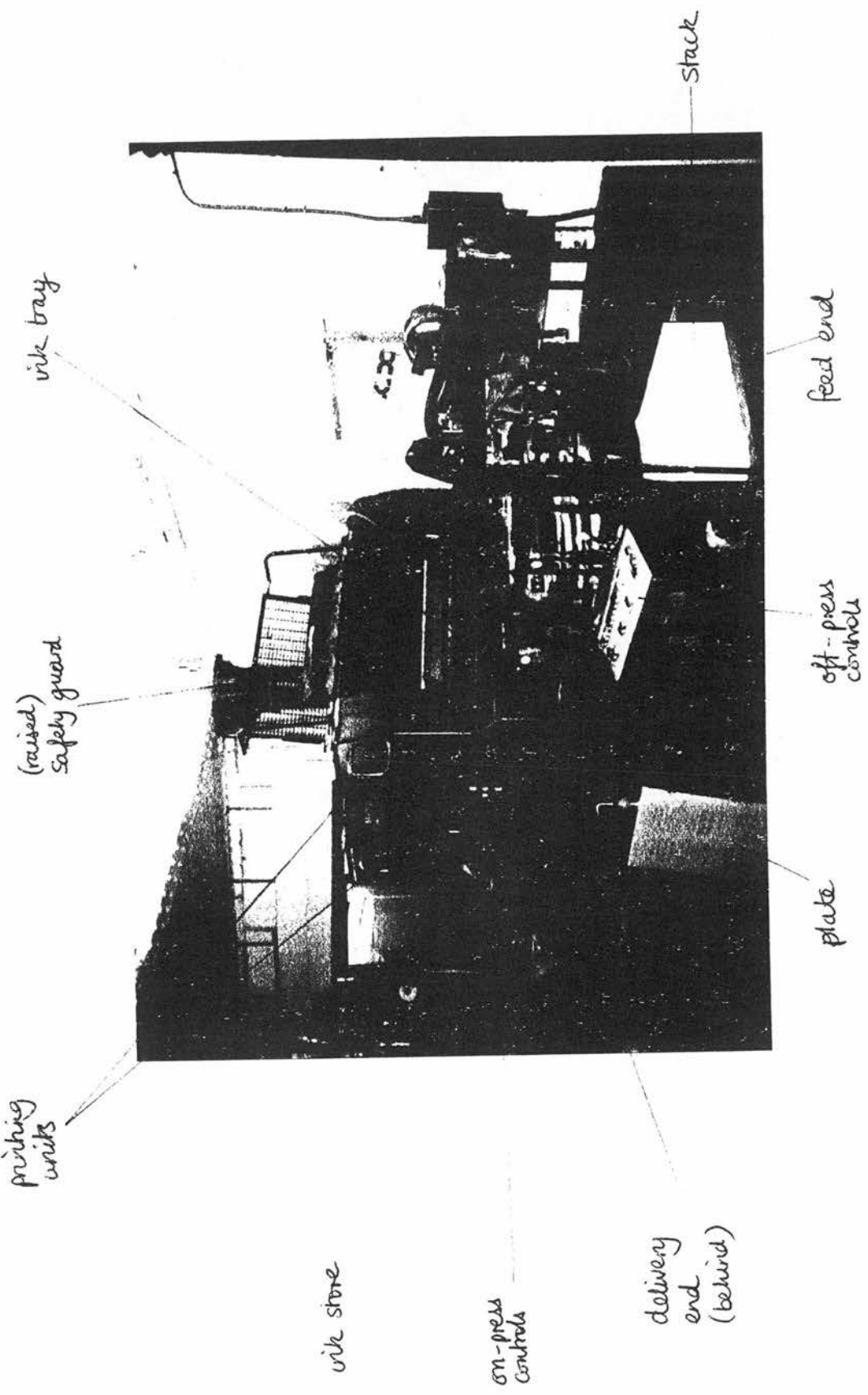
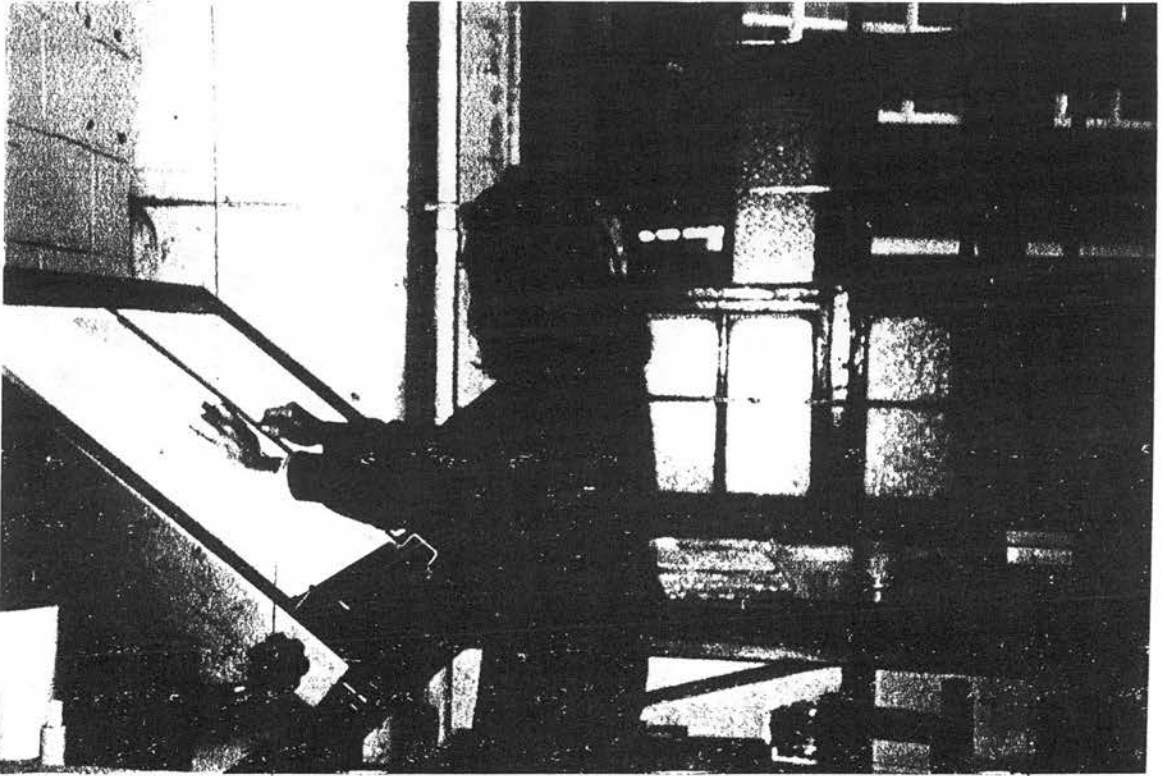


Fig. 5.4. Heidelberg MOZPS press, Freedom

gridsheet



lightbox

waxer

Fig- 5.5. Graphic design department (artroom), Freedom

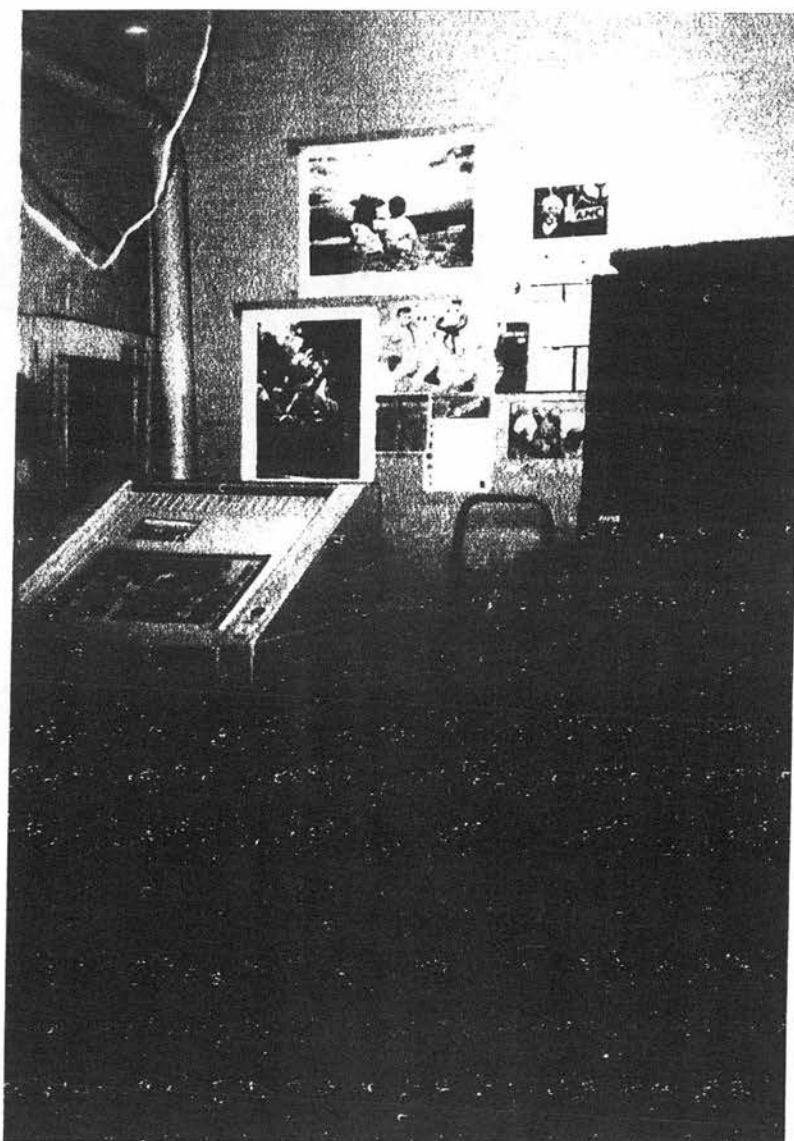


Fig. 5.6. The darkroom , Freedom

PMT processor (L)

Vertical camera (R)

lightbox



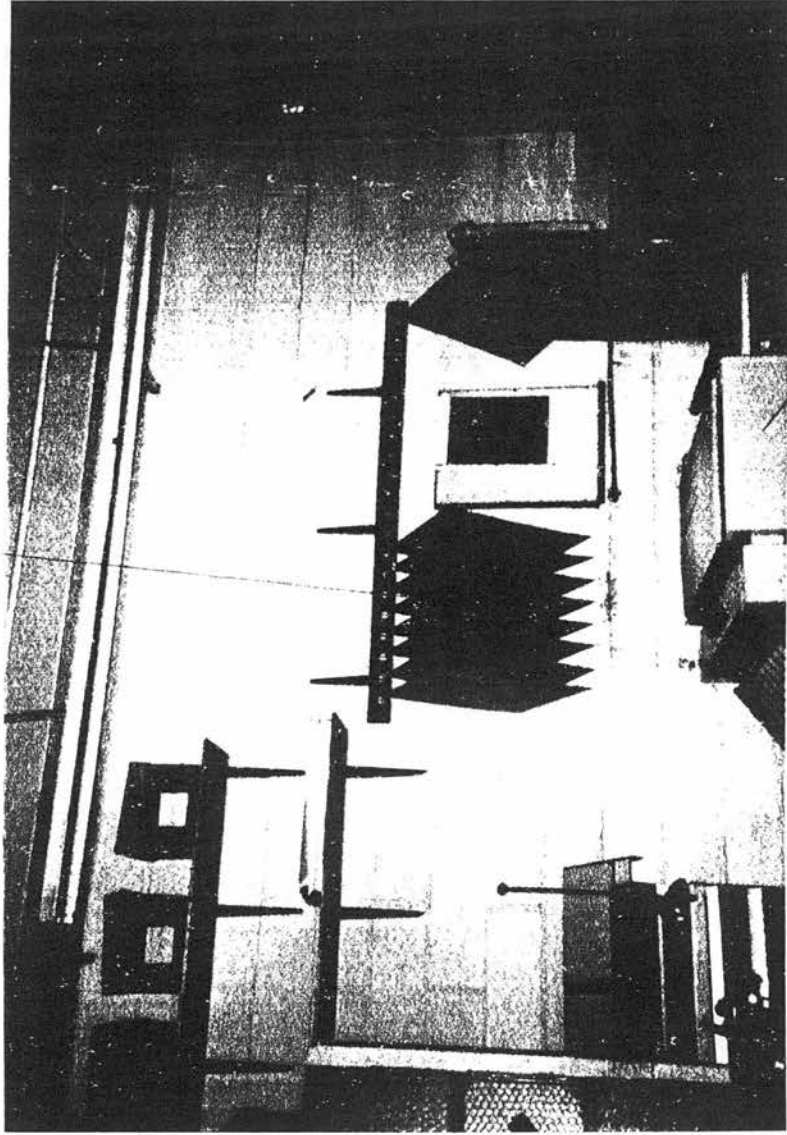
plate
printdown
frame

negative
film

red acetate
masking film

Fig. 5.7. The plate room, Freedom (I)

+ plates



boxes of
old job bags

plate
punch

sink

plate
processor

Fig. 5.8. The plateroom, Freedom (II)

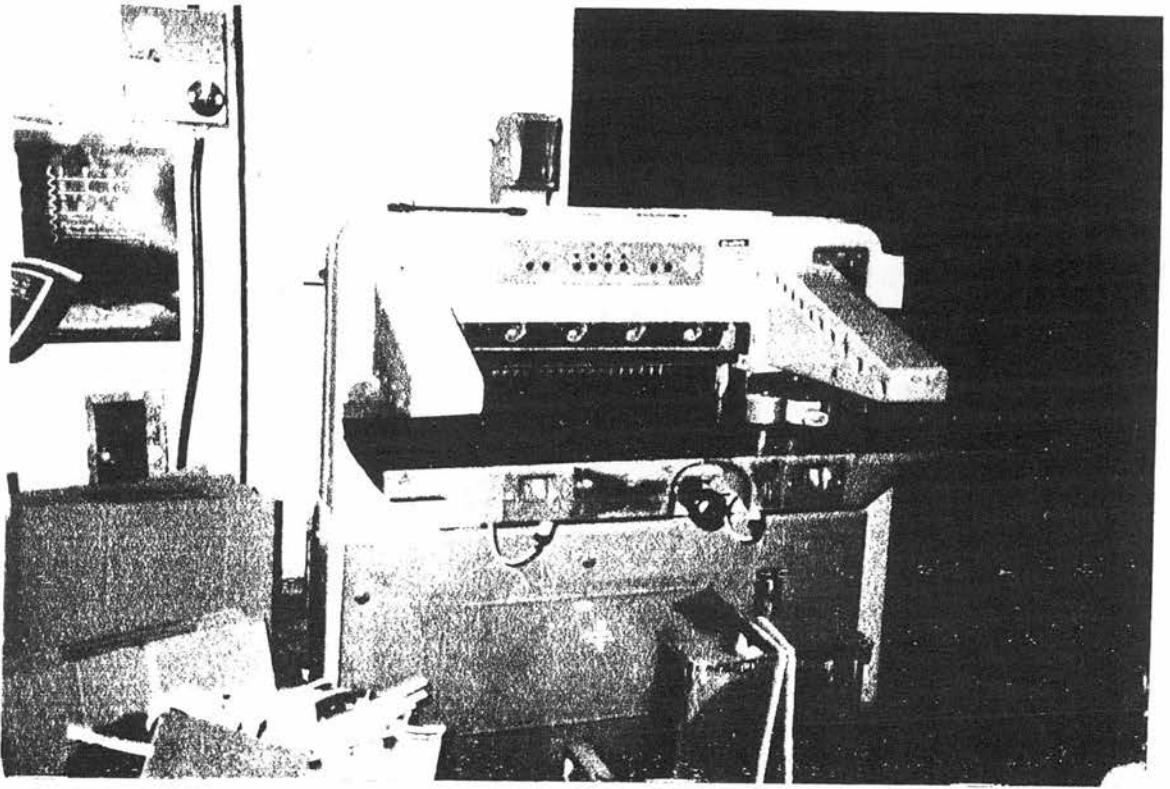


Fig. 5.9. The guillotine, Freedom

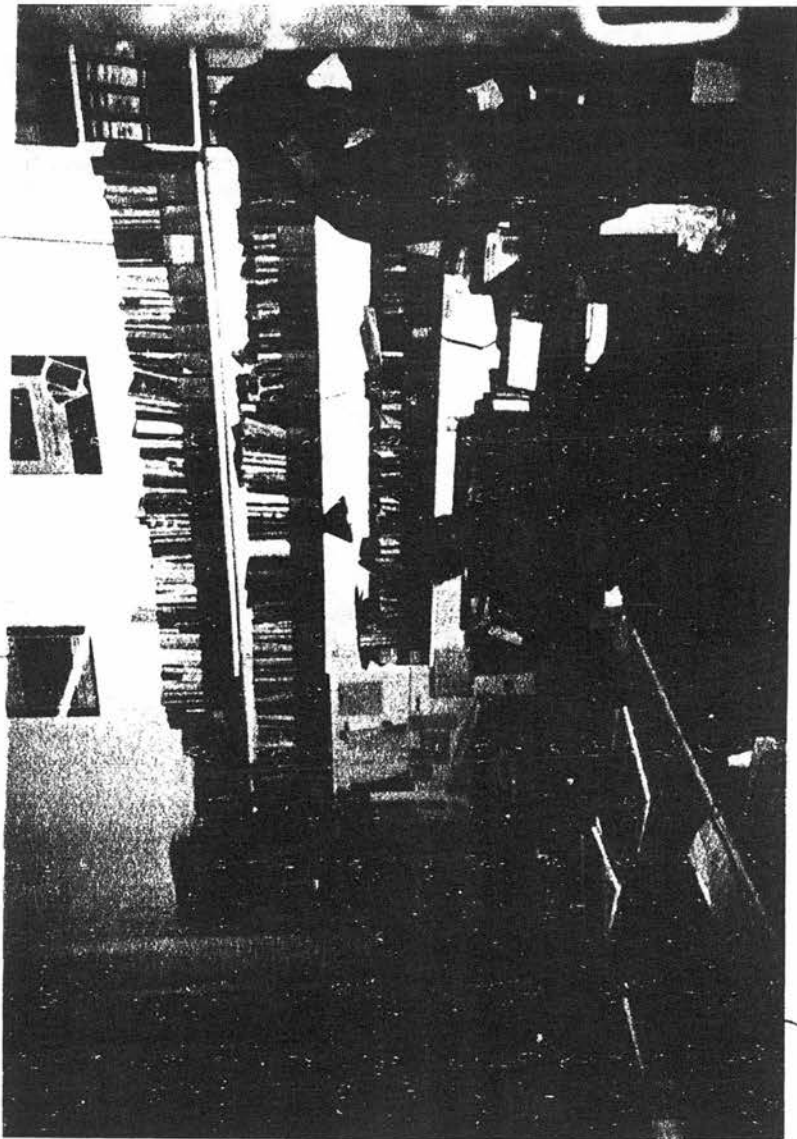
JOSE LUIS BLANCO
CARLOS DAVID

	MON	TUE	WED	THURS	FRI	SAT	SUN	MON
ARTWORK								
CAMERA								
PLATES								
MO								
KORD								
FINISH								
DELIVER								

Fig. 5.10. The schedule board, Freedom (not up-to-date)

Post-jobs

per job



files, catalogues,
price lists etc.

PC for
accounts &
word-processing

The artwork
table

Fig. 5.11. The office, Freedom

5.2. WEIRS WEB

Weirs (see video) was a large direct mail printworks sited on a greenfield industrial estate in West Lothian. The operation had been set up in 1987, by a group of 12 people, as a new venture by an established (in 1860) central Edinburgh sheetfed print firm. It grew swiftly to employ about 50 workers, and in 1991, a second press was installed, with a change to 24-hour working in all production departments. By 1992, the new plant had an annual turnover of ?5-10m and over 100 employees (all GPMU members), while the parent plant employed approximately 250 people and generated ?15-20m each year. Fieldwork was carried out at the Lothian plant, a large, purpose-built factory with land adjoining for planned future expansion, with a brief visit to the Edinburgh site for a meeting connected with the consultancy project.

Weirs had been set up to serve the expanding national market for direct mail printing, which accounted for 11% of all inland letter traffic in 1989. By 1992, it was one of the major firms operating in this area. Its customers tended to be advertising agencies handling the accounts of large manufacturers and retailers of consumer goods; mail order companies; banks; and utilities. Another significant group of customers consisted of print brokers with a similar range of clients.

Weirs' work came from all over Britain, including London and the South-east, despite the plant's geographical location. This was not seen as a disadvantage, thanks to fax machines, planes and overnight courier services, and its position provided a PR opportunity, as customers enjoyed visiting Edinburgh at the same time as passing jobs on the press at the factory. Weirs' selling points were reliability and good quality, for which their customers were prepared to pay slightly higher than average prices. Although they did not have much contract work, most jobbing customers placed repeat orders, and they were able to develop a working relationship. In this respect, Weirs was similar to Freedom.

Agencies were generally familiar with the printing process, although not always in depth, nor with consideration for ease of production after the design stage. Printbrokers were considered more of a problem in this respect. The firm took pride in being able to print and finish whatever the customer wanted, however novel or technically difficult. Jobs were usually designed and taken to final film and proofs by the agencies, who subcontracted this part of the process to repro houses, not necessarily based in the region. Weirs therefore took on jobs only at final film-planning and platemaking stages, working from separated film, and ozalid or cromalin proofs. Plates were scanned to produce a CPC cassette which was inserted into the main control console of the press, where it regulated inking levels.

The firm had two Heidelberg Web-8 presses (fig.5.12 and video) with in-line finishing units, ideal for this type of product (A4 or smaller format full-colour folded leaflets or brochures), "the production of items included in direct mailers has become a highly complex business, with extremely sophisticated in-line finishing facilities" (PIRA, 1992:50). They could be made ready in an hour, and could print up to five colours on both sides of the web in a single pass, as well as having additional units for gluing, scratch-and-sniff and perforating. Optional finishing units could then fold and spine glue the sheeted web into booklets. The cutoff size was approximately A2, no larger than the usual sheet size of Freedom's KORD and MO, but the number of operations carried out on each sheet and press capacity were far greater : 25-35000 cutoffs/hour from each press, depending on the complexity of the job, and whether or not finishing was in-line. The high cost of the presses (£1.25m each for a basic model) meant that Weirs needed a constant flow of work to justify and repay their investment.

To cope with the wide variety of folds required, since a significant aspect of direct mail design is its novelty (and hence its potential attractiveness to the consumer), Weirs had an in-house finishing department with a guillotine and several folding

machines that could be configured in a number of ways, according to the format of each job. The layout of this part of the factory was constantly changing. The firm had a collating and stitching machine for jobs stapled at the spine. Under normal conditions, Weirs was almost self-sufficient, although jobs were occasionally subcontracted out for specialist processes such as die-cutting. However, if the presses ran at full capacity, even with the in-line folders working on some jobs, the finishing department could not cope, and work had to be subcontracted, often to the parent company. Finishing equipment occupied approximately half of the shopfloor.

Turnaround was fast to meet deadlines for advertising campaigns and inserts booked for specific editions of the national press and magazines. This meant working on the basis of "film today, job tomorrow" (production manager) so it was important to keep as many processes as possible in-house once the job arrived, to save time. All production departments worked 24 hours a day, with pre-press and press on a three-shift system for 5 or 5.5 days a week, and with finishing on continental double day shifts for 6 days a week. When necessary, this was increased to 7 days a week. The adoption of a three-shift system had occurred in 1991, when it was thought that the recession was about to end. This had not happened, but it had been decided that it was possible for the firm to survive financially even if it retained this shift pattern, and that to revert to double days would be an admission of failure (and involve redundancies which they might subsequently wish to revoke).

This level of production required large premises, both for working (each press was over 28m long and 10m wide) and for storage of raw materials, particularly reels of paper. Finished goods were taken to a adjacent warehouse prior to delivery. Because of production volumes, handling facilities were mechanised, and some, like robotised pallet wrappers, were automated.

Weirs had a large and comparatively sophisticated computer-aided production management (CAPM) system (KEREN) with integration

between modules, which had been installed about 2 years previously at an approximate cost of ?20k. It was basically an off-the-shelf system but with some bespoke features, originally developed for sheet-fed printers and later adapted for web work, not altogether successfully. The suppliers had been very supportive during implementation and bespoking of the basic system, "Turnkeys are rubbish. You just cannot change your company's way of working to fit a system. The system has to fit the company" (Isys spokesperson, PCM Aug 1992:22) but had proved less enthusiastic about further customisation to Weirs' requirements, lending some support to the view that "the further away from the standard you get, the less willing suppliers are to support it" (PW 29/7/92:29). They operated a customer troubleshooting hotline, and were also linked directly to users' systems by modem in order to investigate problems promptly and without having to send engineers out.

The computer system was used for producing estimates, works instruction tickets, materials requisitions, order processing and job costing. At the time of fieldwork, the stock control module was also being implemented, replacing existing manual stock records. All seven terminals were located in the Commercial department, which dealt with these functions, and kept in close contact with the shopfloor. KEREN's other modules included production scheduling, job tracking, invoicing and SFDC, but they were not operational. These aspects of production management were carried out using an entirely manual system, which consisted of lists and forms. The official scheduling board was not used because the running order of jobs changed so often that there was no time to update it.

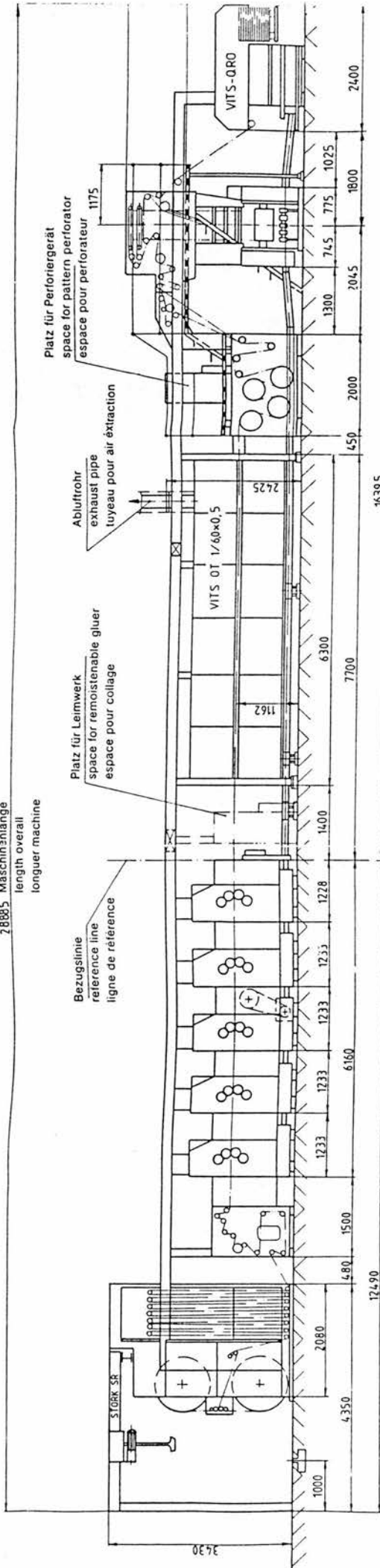
The firm also had a smaller MIS for financial matters, designed by its management accountant. This consisted of interlinked spreadsheets on a PC, which could be accessed at terminals in the main office and the MD's office. It was used to produce annual departmental costings, and to compile management reports using monthly accounting information. The MIS and KEREN were not linked, and there was some double keying of job costing data into the two

systems.

By 1992, volumes, prices and margins in the direct mail sector had also been affected by the recession, because of its connection with other advertising media, and in spite of projected long-term growth. Increasingly precise demographic targeting of material by direct mail companies also resulted in shorter print runs. Combined with the need to recoup high initial capital expenditure by constant working, this produced cutthroat competition and a breakdown of the sectoral quasi-cartel, "the increasing tendency to take on work on a contributory basis, which has exposed the industry to a precarious pricing system of its own making" (LW, 16/2/93:8). Under these circumstances, even large web printers were not immune. During fieldwork, one of Weirs' major competitors went into receivership. The object of my action research was to devise an adapted marginal job costing system which could be used as a guide to pricing work keenly but safely, and to incorporate it into the organisation and its existing MIS and CAPM system.

WEB-8

28885 Maschinlänge
length overall
longueur machine



- | | | | | | | |
|---|--|--|------------------------------|--|---------------------------------|--|
| Rollenwechsler
Splicer
Dérouleuse | Einzugwerk
Infeed unit
Débiteuse | Druckwerke
Printing units
Groupes d'impression | Trockner
Dryer
Sécheur | Kühlwalzen
Chill rollers
Groupe de refroidissement | Falzapparat
Folder
Pieuse | Planoauslage
Sheeter
Sortie à plat |
|---|--|--|------------------------------|--|---------------------------------|--|

Fig. 5.12. Cross-sectional diagram of Web-8 press, Weiss (Heidelberg UK, 1987)

5.3. TRINITY PRESS

Trinity Press was the new, purpose-built printworks of a long-established Edinburgh newspaper firm, sited on a small pocket of industrial land away from the city centre. The plant had cost £15m, including £6m for the press, and £2m for the mailroom. It printed The Scotsman, the Edinburgh Evening News, Scotland on Sunday, a variety of weekly supplements to the main titles, and local or special interest freesheets. Most of these were owned by Trinity's parent company, Thomson Regional News (TRN), part of Thomson International Group. By 1993, Trinity operated 24 hours a day and employed about 100 people : a small core of workers from the original plant augmented by personnel recruited from commercial web presses and apprenticed trades outside the industry. Trade unions were not recognised for collective bargaining purposes. Fieldwork was carried out at Trinity, with a visit to the city-centre site's editorial, advertising and pre-press and computing departments.

Trinity lacked the ornate Victorian individuality of the old premises. It was the type of industrial unit built on hundreds of industrial estates in the 1980s : a high, windowless corrugated shell, with a smaller office block on one side and ample yard access for delivery and despatch by articulated lorries, bounded by a perimeter fence. Within, production equipment set into the floor rose almost to the roof. The factory was brightly lit, with white-painted walls. Around the machinery were various mezzanine-level viewing and operation areas, surrounded by guard rails.

Layout corresponded to material flows and production processes, projecting an image of pared-down efficiency : sleek production achieved with minimum administration and hierarchy. The openness of the layout emphasised the "flatness" of the organisational structure, and hence the desired relationship between workforce and management. It facilitated an overview of how work was progressing, so that activities could be examined and assessed. This was explicitly contrasted with the previous warren-like premises, layers of management and industrial relations climate.

Trinity took on jobs from final film. Proofs of advertisements were supplied, but rarely consulted because of time constraints. Its production areas consisted of platemaking, printing with in-line finishing, and an automated mailroom. The plant was self-sufficient, and had no need for subcontractors. Once plates had been made, they were scanned and the inking details fed into the press via the MIS. The press used the coldset web offset litho process, and had been manufactured by Goss specifically for Trinity's requirements (fig.5.13). Its capacity was immense. The notional cutoff was approximately A1 - twice that of Weirs, but output was measured in finished copies per hour rather than cutoffs, and the usual running speed was 60,000 copies per hour, with maximum pagination of 48pp broadsheet (or 96pp tabloid), of which 12pp (24pp) could be full-colour, and 4pp (8pp) spot colour. Minimum pagination was 18pp, of which 8pp would be full colour. Production capacity was not the problem; the major limiting factors were the availability and positioning of colour pages. Editorial, advertising and pre-press departments sometimes failed to take this into account, resulting in unclear or impossible edition specifications.

Flexibility was achieved in several ways, to cope with variations in the run lengths and pagination of different editions and titles. The press (fig. 5.14) could be divided in two : A press and B press, which operated separately or together. Each of these was fed with paper from 3 reelstands (Weirs' Web-8 ran one reel at a time), and the number of reelstands in action could be varied as needed. On each side of the press, two reels fed up through mono inking units which printed both sides of the web. The third reel on A press fed upwards through a "colour tower" with four inking units, one for each process colour. This arrangement was similar to that of the Web-8, but the web travelled vertically, rather than horizontally. The colour tower on B press was arranged to print full-colour on one side of the web, and black plus a spot colour on the other. Paper reels came in 3 widths; mains, three-quarters, and halves. This made it possible to print products of any even

numbered pagination from 18pp to 48pp broadsheet, by a combination of reels. In order to place colour pages in positions favoured by editorial or advertising (early right hand, and the sports section), webs could be slit and turned as they ran through the press.

Once papers had been printed and folded in-line, they passed into the mailroom, individually gripped on overhead conveyors. Here, they were automatically stacked, baled and sent along a conveyor belt, straight out through hatches into the backs of delivery vans waiting in the loading bay. Titles needing collation (as with multi-sectioned Sunday papers) or direct mail inserts were first diverted onto buffer storage reels to avoid bottlenecks, because the Muller inserting system ran more slowly (25,000cph) than the press and stackers. Papers then came off the storage reels, passed through the insertors, where they were flipped open, the insert dropped in, closed again, and back onto overhead chains to the stackers. Two stitching lines, similar to but smaller than the one at Weirs, stapled and trimmed A4 products, which were taken unbaled from the stackers to be finished at the stitchers' much slower pace (25-30,000cph), and later used as inserts. Progress chasing was unnecessary, because of the continuous, automated flow of production between departments.

Production was undertaken by three crews of 13 : 1 platemaker, 7 printers, 2 mailroom and 3 maintenance engineers. Extra casual staff were employed in the mailroom during complex insertions. In addition, there were the plant, press and night managers, dayshift mailroom and despatch coordinators, and the chief engineer. For newspaper printing, this represented an unusually flat management structure, although it was standard in large commercial firms such as Weirs. Crews worked 6 days, followed by 7 nights, and then 8 days holiday. Shifts began at 9am and 9pm, lasting as long as it took to complete jobs in hand. As the number of titles expanded, the plant became operational 24 hours a day, seven days a week, except Sundays when there was no day shift.

Scheduling production was straightforward, since it was always the same. Even the time of each edition remained constant. A simple typed schedule was compiled and circulated weekly. During weekdays, the crew produced 5 editions of the local evening paper, followed by a freesheet or an insert for a later paper. On Saturday morning, they printed fewer editions of the evening paper (and no other jobs) and went home early at 1.30pm. At night, they printed 4 editions of the national daily, followed by similar miscellaneous jobs. The latter might appear at weekly, monthly or quarterly intervals. On Saturday nights they printed the Sunday paper. The daily run length for all editions of each title was approximately 100,000, with individual editions ranging between 10,000 and 60,000 copies. By 1993, the plant was running at almost full capacity.

The scale of production and the size of the machinery called for large premises. The press alone was 50m long, 15m (and 5 storeys) high, and 4m wide, with an additional 2m working space required on either side. The reel store occupied a similar area, and the mailroom was twice this size. Moving reels around the plant was largely mechanised.

The computer-aided production system was the largest and most complex of any of the sites I visited; its modules fully integrated with each other, and with platemaking, press and stacking equipment. Supplied by a company owned by the press manufacturer, it centred on the press CPC, extending from there to embrace other aspects of production management. This was in contrast to more common systems (such as KEREN), which started from the administration of production, and which were only linked to the shopfloor by an optional SFDC module. The Allen-Bradley system had become operational about 18 months after the press started running, after long deliberation and attempts at reconfiguration. Not everyone was satisfied with the result. Plant managers were "very disappointed", feeling that there had been a breakdown in communication with the suppliers. The project had run out of money, and some modules remained unimplemented.

Many of the system's functions were production-related, giving upcoming jobs an identity, specifying the required press activities, and pre-setting the CPC at a rough starting point for the job. Once jobs began, the system tracked progress in realtime, ensuring that all advance information (such as inking levels) was conveyed to the correct part of the press. The system logged all events occurring on the press, from which production reports could be compiled, produced press maintenance schedules, and pinpointed the location of malfunctioning parts. Reel stock control was manual, using lists and materials usage forms. Shift and job scheduling modules were unnecessary because of the fixed crewing arrangements and repetitive job mix. All financial matters were dealt with on separate computer systems at the parent plant, so there were no costing or estimating modules. Total costs were calculated monthly and divided by total pagination to give an average cost per page. Trinity worked to performance targets without being able to assess their financial implications.

During the 1980s, overall newspaper readership and sales declined. This was very marked in the case of regional evening papers and weeklies, although there was growth in freesheets. Newspaper ownership became concentrated in fewer hands, until 20 companies (including Thomson) controlled over 80% of regional production. With the recession, revenue from advertisements for jobs, houses and cars, on which regional publishers largely depended, fell steeply. In 1990, regional papers generated almost 80% of their revenue from advertising, and 20% from cover sales. For the national press, proportions were roughly 50:50. Competing titles closed, and larger players concentrated their holdings geographically in "strategic realignment" (PIRA, 1992:32). Other cost-saving moves included direct text input by journalists, reductions in editorial staff, and rationalisation of print plants with lower manning levels, all of which had occurred at Trinity.

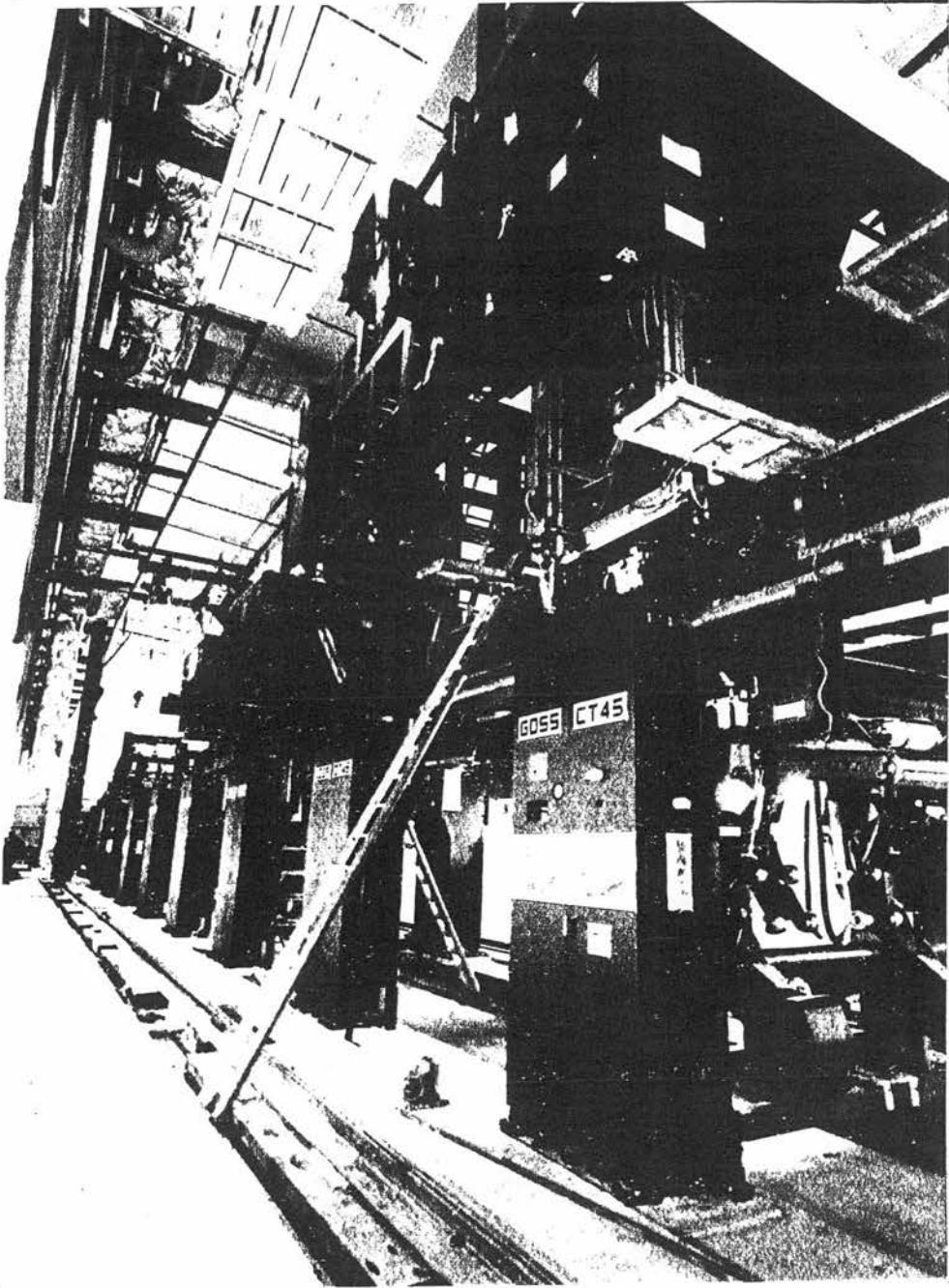


Fig. 5.13. Building the press at Trinity
Photo: J. Fisher, Chief Engineer

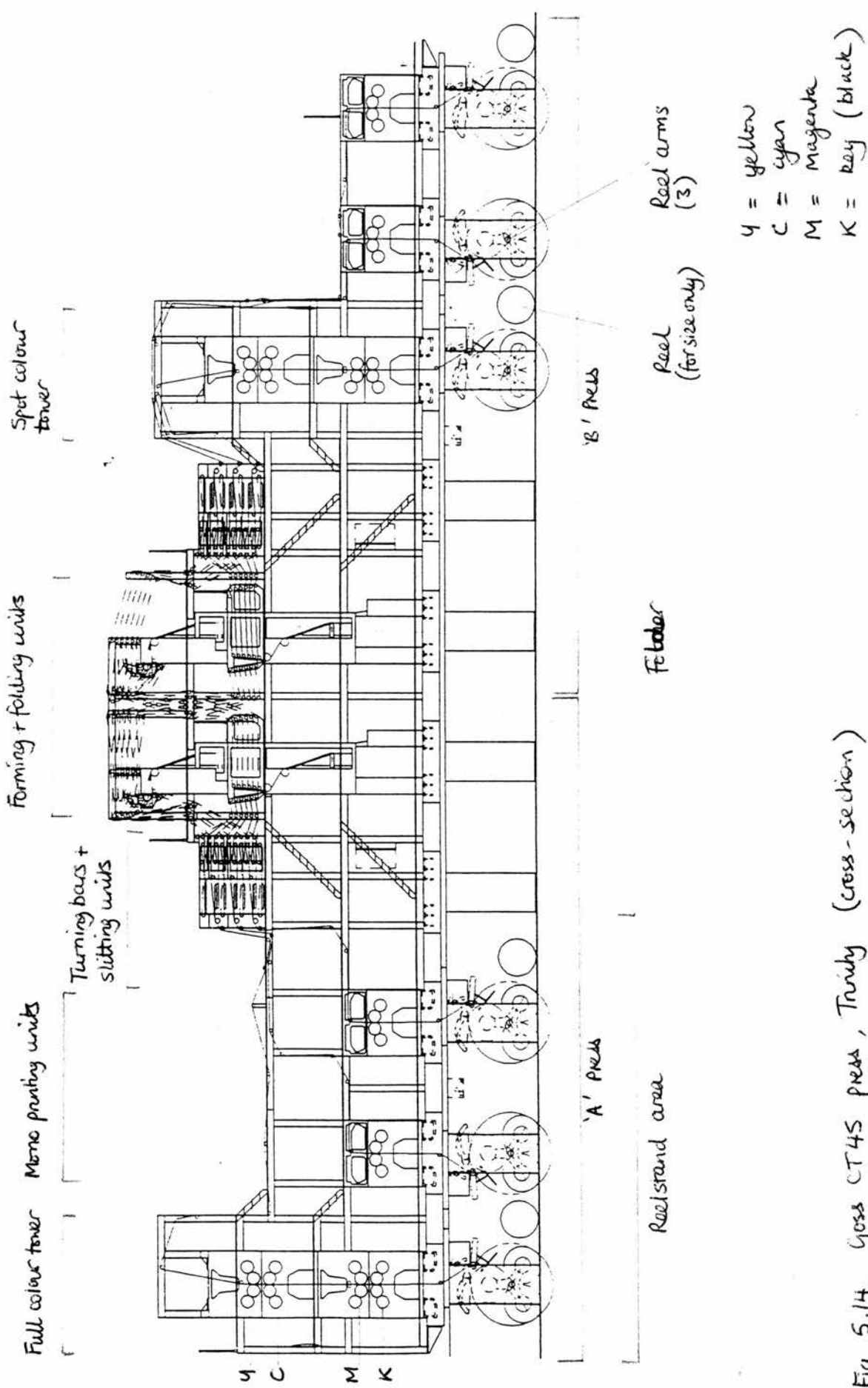


Fig. 5.14. Gross CT45 press, Trinity (cross-section)
 (Gross Training Manual n.d.)

CHAPTER 6 - FREEDOM PRESS

This chapter examines the substantive and cognitive content of everyday print knowledge at Freedom Press, its distribution amongst cooperative workers, and its everyday mobilisation prior to production. It shows the importance of shared technical and other knowledge for deciding and defining which work to undertake and how to produce it. Product and process visualisation, site-specific rules of thumb, and meta-knowledge about the firm and the industry figure prominently. The account of the everyday practice of that knowledge prior to production highlights the role of a wide range of material objects, and the significance of Freedom's internal and external industrial, social and political networks. These are mobilised to access a variety of personal knowledge, which can be evaluated and contextualised in the light of common print knowledge. Collectivity and the formal and informal sharing of knowledge for problem-solving are much in evidence, perhaps unsurprisingly, given the firm's cooperative ethos. But in the "horror stories" which circulate, functioning as a vehicle for reinforcing printworkers' identity, remembering specific jobs and exchanging knowledge within the print community, customers are characterised as "outsiders" who lack that knowledge, despite educating them about print.

Situations in which collectivity or common knowledge were important occurred when the following questions were being addressed by workers, and each is considered in turn below as a means of presenting the empirical material :

ACTIVITY	QUESTION	SITUATION
Obtaining work	Do we want this job ?	Definition
Job specification	What is this job ?	Definition
Planning the job	How do we produce it ?	Problem-solution
Planning production	Where does it fit ?	Problem-solution

6.1. OBTAINING WORK : DEFINING FEASIBILITY AND DESIRABILITY

As a general jobbing print cooperative catering to a specific market, Freedom produced a wide range of products bespoke to individual customer requirements. When customers phoned to discuss potential jobs, workers had to consider whether or not to take the enquiry further. Knowledge about products, processes and the printing industry played an important role in this, as did knowledge about prospective customers' activities, their knowledge of printing and their financial conduct. These gave workers the ability to develop technical, economic and political criteria by which to define jobs, evaluating their feasibility and desirability. Creating and using networks of contacts fostered these abilities. What kind of technological knowledge did workers have, and how much was "common knowledge" ?

6.1.1. Job feasibility

Deciding whether or not a job was feasible required wide-ranging knowledge about printing technologies and products. This involved knowing what jobs Freedom could produce on its own equipment, and what other print and print-related firms could do. Such knowledge was necessary because although most enquiries related to jobs that Freedom could produce, almost all would entail some form of subcontracting. In the case of jobs that could not be produced with or without putting-out, workers liked to offer callers alternative contacts, thereby attempting to gain a reputation for being helpful and straightforward.

To begin with, it was important for workers to identify categories of job which were definitely not feasible. Some could not be produced by the offset litho process : carrier bags, balloons and T-shirts. Others, although litho printed, were ruled out because they required in-line work, such as the application of remoistenable glue (as at Weirs), which could neither be done in-

house nor subcontracted as a separate process. Workers needed to know which products were typically produced by other printing methods, which firms used them, and whether they were competent and could thus be subcontracted to or recommended to callers with reasonable confidence. At the same time, it was useful to know the nearest substitutes Freedom could provide, in case it was possible to persuade potential customers to change their minds. Enquirers about short-run tabloid newsprint jobs might be asked if they would prefer to print on bank or bond, which were feasible. This type of knowledge was acquired either secondhand through general print and print cooperative networks, or firsthand from Freedom's own previous experience of their work.

The combination of general purpose equipment and subcontracting made almost any other job technically feasible. But just because Freedom could produce a job did not mean that it could compete with other firms tendering for the work. Technical criteria interacted with non-technical considerations, such as knowledge about customers, suppliers or collaborator-competitors, the state of the market, and current and future production schedules. In other words, jobs also had to be desirable.

These other factors were particularly significant when workers at Freedom were deciding about technically borderline jobs. These included small products such as badges, postcards and stickers which were only possible in large quantity, or very short run work which might be undertaken for regular customers but not for others. In addition, Freedom often quoted for composite orders, such as campaign packs, which included items which it could not produce. Workers needed to know whether it was worthwhile preparing an estimate for the whole, subcontracting production of entire components, rather than the more usual putting-out of specific processes, such as typesetting or finishing.

Because of the varied nature of Freedom's work and the greater flexibility of sheetfed presses, rules of thumb for feasibility were more complex than at Weirs, but consisted similarly of sets of

interconnected parameters within which Freedom's production equipment would function best in technical terms, and within which it had been designed to operate most competitively. Details of quantity, finished size and paper type were not enough, although they might eliminate some jobs at the ends of these ranges which were technically impossible for Freedom to print. Pagination and the number of colours used were equally significant, although these in themselves did not make a job impossible. Being able to tell whether a job was feasible from these five characteristics was a form of knowledge whose predominant cognitive component varied according to the experience of its carriers.

Experienced workers rarely articulated their reasoning about job feasibility, other than through such comments as "it's obvious", or "you just know", and their knowledge could be described as largely tacit. However, it was not inarticulable, since it had once been based on "informal" knowledge - the underlying rules of thumb which were used at first by new workers less familiar with Freedom's activities, until they too acquired a tacit sense of what was feasible and what was not, '*getting to know the limits of the work we can do easily and competitively*' [sales worker]. These rules could have been expressed (although they remained unwritten) using the job specification and strings of terms such as "if... [greater / less than] ... and (not)... [larger / smaller than]... but (not)..., then this job is... (in)feasible / possible, but I need more information". Since they related specifically to Freedom's production capabilities, these rules (tacit or otherwise) embodied contingent knowledge, and would not have been usable in another print firm without modification.

This logic was underpinned by formal knowledge. All the rules of thumb (except paper type) related to the number of impressions a job would take to print, which could be calculated mathematically - the total sheets needed for the run, multiplied by the number of times each sheet would pass through the press. In theory it would have been possible to compute a single numerical parameter [minimum and maximum number of impressions] within which jobs were feasible.

In practice where feasibility was concerned it was the interplay between the various characteristics of the job specification that mattered. Creating simplified "super-parameters" for deciding feasibility would have ignored the variety of products and processes.

Office workers usually made decisions about feasibility, because they had the most direct and constant exposure to all these factors, and dealt most frequently with customers, suppliers and subcontractors. In the course of their daily work, they acquired and pooled relevant information. Before the recession, there had been consensus as to the smallest feasible print job and hence which enquiries were worth estimating. This was a form of "common knowledge" which did not require collective mobilisation except in the case of new workers who were advised to check their decisions with those more experienced before progressing customer enquiries. However, as work became scarcer these certainties had been eroded, and individuals disagreed about which jobs were feasible. The rules of thumb were increasingly bent in desperation.

The type of work undertaken by Freedom ("what we do"; "what we're good at") formed part of the organisational meta-knowledge (Fleck, 1988) ("why we're here") carried by workers and external actors who dealt regularly with the firm. As the definition of feasible jobs became less clear-cut, this aspect of the firm's identity also blurred. Office workers talked about winning orders mainly in terms of undercutting other firms' prices. Previously there had been a collectively agreed and explicitly stated strategy that Freedom did not and could not compete on price, but on reliability and service. This had been forgotten, and newer workers were attempting to reinvent it, *'For the first time since I started, there are good people in every production department. We shouldn't compete on price now - we could offer good quality and service'* [printer].

In the struggle for survival, estimating lost its previous function as a screening device in terms of job feasibility,

'to establish whether we can produce a job at a price that suits us and the customer. They won't send you stuff if they think you're wildly expensive. A few would be suspicious if it was too cheap. Most will go for something as cheap as possible. Equally you have get sufficient out of it for it to be worth doing. So estimating should enable you to establish whether it's a job you want to do or not' [finance worker].

6.1.2. Customer desirability

The identity of the customer was essential for determining job desirability. Freedom had basic categories of customers it would not take on and material it would not print, connected with certain political affiliations and specific forms of prejudice and discrimination. At the time of fieldwork, all workers were aware of these general criteria, which constituted part of common knowledge. These values (meta-knowledge) were intrinsic to the organisation's reasons for existence, made explicit to every applicant during recruitment and induction.

The majority of new customers came to Freedom on the basis of recommendation by existing customers and subcontractors, or through reputational networks operating among politically left-wing, "alternative", local community and single-issue campaign groups, 'We've got the sympathy of charities, campaign groups and trade unions' [sales worker]. A limited amount of advertising was undertaken, in 'the sort of magazine that we hope people who would come to us would read - Spare Rib, Marxism Today, Gay Business Association News, Square Peg, Living Marxism, New Socialist' [sales worker], which served to signal Freedom's continued existence, rather than as a means of attracting new customers. The legal obligation for a printer's imprint to appear on all its products (other than those exempt) helped publicity. Most day-to-day enquiries came from self-selecting customers aware of Freedom's cooperative status and political sympathies.

It was useful for workers to know of customers either from previous experience or by reputation. Over time, the accumulation of such

knowledge enabled them to situate customers within an overall framework of the social and political activities occurring in London. This provided them with a mental map of their customer base. Parts of this overlapped with and could be cross-checked to workers' external political and social commitments and experience. However, everybody's frameworks and experiences differed, although there were common elements.

Information about customers and their activities was pooled at collective meetings and during the working day. This did not happen in a regular or systematic way, but was typically triggered by questions such as "has anybody heard about X recently ?" in response to specific circumstances such as requests for estimates. Such information was passed on informally through casual conversation. And as well as percolating into the organisation, information flowed out again. Almost none of this was written down, with the exception of organisations' names, phone numbers, addresses and contact names. These were kept in a common cardfile (sometimes out of date), but individual workers kept their own lists, and the current information appeared on estimates and job bags when required for immediate use.

Personal and organisational contacts, whether direct (A and B know each other), mutual (A and B both know C), or reputational (A knows of B from C) were important ways of reassuring customers that they would be treated in a way that showed knowledge of and sympathy for their aims. This was what made Freedom and the other London print cooperatives different from any other print firm in the eyes of their customers, and it brought them most of their work. Being part of these networks enabled workers to predict existing customers' printing needs, and to check out and approach new customers in advance,

'knowing about wider policy outside that might affect the voluntary sector, you know there are certain types of work that are more likely. Keeping an eye on the public sector, which I know, because I've worked inside that sector' [sales worker],

Other factors taken into account when vetting jobs were the number

and frequency of customers' orders, their profitability, and the typical invoice value of their work. At the same time, workers used personal knowledge of customers to prioritise their efforts,

'if I'm in the middle of [an estimate] and one of my customers rings up, who I know, and when I know that if I do [an estimate] quickly and at a good price then we'll get the job, then I'll probably stop what I'm doing and do their quote' [sales worker].

This information gathering and exchange produced a shared basic awareness among workers about which customers were most and least desirable. Office-based staff, with the most frequent customer contact, had particularly detailed knowledge. The office was open-plan and contained most of the cooperative's written and other visual records, so it was possible for workers to find out what was happening by asking for information directly or by asking where it could be found. These questions could be addressed to specific individuals, or to the occupants of the office in general : "does anyone know...?"

The definition of jobs was largely undertaken by workers acting on their own in response to customer enquiries. This process assumed the existence of two bodies of "common knowledge" shared by some if not all workers, and actively pooled : one related to technical factors, and the other to non-technical criteria, particularly customer identity. Both were created, extended and maintained through reputational networks of internal and external contacts that were industrial, political and social : knowledge fostered by collective and personal experience.

These knowledges were also embodied in objects. They were revealed to all by past and present jobs : posters displayed on the walls; finished books, booklets and leaflets on shelves, neatly boxed in customer alphabetical order; and open cabinets for storing job bags, artwork and platebags. They were concealed from public view in files holding details of estimates and invoices; in workers' personal files containing information about customers, suppliers and subcontractors; and in the filing cabinet that was reputed to

hold the entire history of Freedom Press.

The existence of a significant and explicit body of non-technical knowledge about customers was not surprising, given the firm's cooperative constitution and political stance, although it was unusual for a print firm to use such knowledge as a basis for accepting or rejecting work. However, there was not and probably never had been complete consensus about what constituted a feasible or desirable job, although an adequate framework existed for solo decision-making in most cases.

This section reveals the importance of meta-knowledge. It illustrates that meta-knowledge in the organisation was not fixed or of indefinite duration. It could be forgotten or reinvented. Not only did Freedom define itself by its customers and the jobs it produced, but these in turn defined the cooperative : meta-knowledge was a continuing process. At Freedom, meta-knowledge related not only to printing, but also to political and social values : two domains of common knowledge were drawn upon to define jobs : print and politics.

6.2. JOB SPECIFICATION : DEFINING PRODUCT AND PROCESS

Workers then had to elicit a full specification to prepare estimates, and works instructions if the job became a firm order. What kinds of knowledge did they need to do this ? Knowledge about products, processes and materials was essential (as at Weirs), but what else ?

Although everyone at Freedom was familiar with job specifications and used a common language to describe printing processes and products, this knowledge was not sufficient in itself for

comprehensive elicitation¹ of job details from customers. This was partly because the language of a specification did not encompass all that could be said about a job. It was biased towards description of the product in terms of printing and finishing, whereas much of the firm's activity consisted of design and pre-press work. Obtaining a conventional specification was only half the story. Workers then used it to elicit details of design and reprographic work required, using their experience of what such products were likely to entail combined with picking up cues from what customers said. A two-colour booklet might have photographic illustrations, and these could be reproduced as duotones using the two colours. Knowing about customers' previous print jobs helped : if they had wanted duotones before, they might again.

Although customer enquiries were usually dealt with by office-based staff, production workers occasionally dealt with telephone enquiries. They tended to produce incomplete information, and the customer would have to be contacted again by an office worker, *'you quite often have to phone back the customer to find out important things like quantity, because someone will forget to ask how many, or if it's really as simple or difficult as it sounds'*

[coordinator]. It could be suggested that the division of labour within the cooperative contributed to a division of knowledge. Knowing what questions to ask was a skill developed by office workers through frequent and repeated experience, which production workers did not gain because they were mainly engaged in production activities. As such, this knowledge was "common" to all office workers, but not to all collective members. Practice was essential for extending and maintaining it, as I discovered for myself during fieldwork.

Throughout the case study chapters, for brevity, I use the term "elicitation" to refer to the process of obtaining technical and non-technical job details and information from customers through questioning. This is not intended to imply "knowledge elicitation" as practised by expert systems designers, as the intentions, methods and outcomes of the two processes differ considerably.

To begin with, elicitation involved trial and error. Office workers learnt from their own and others' mistakes because of the lack of division of labour between elicitation and estimating. If they had forgotten to ask something or had only incomplete information, they would find out when they tried to produce an estimate,

'you realise that you've only got about half the details you need. You ring them up and you get all those, and then you suddenly realise that there are three more things that you don't know. And then you think "Do I ring them again, or do I guess?"' [finance worker]

Workers needed to remember to ask enough questions to obtain a job specification sufficiently accurate to estimate from. They were helped in this by pre-printed "estimate request forms", created by mobilising knowledge collectively.

'We designed it. We went through lots of jobs and decided what things we did need. This is mark II, because we did one, and used it for a few months, and decided what needed changing... If you're taking quotes down over the phone, it's very easy to forget to ask something, and it's very annoying to the customer if you keep ringing them to ask things, so if you've got that in front of you...' [sales worker]

Some workers found the forms confusing because they covered so many eventualities, *'the forms are so multi-columned - there are so many things to check'* [coordinator], and it was easy to make mistakes. There was not enough space to enter all the job details, particularly with large handwriting, although it had other benefits,

'I quite like the fact that you've got the form, you can go through it, it and if you're even half-awake you can make sure you've got it all done, check that you haven't done anything too stupid, and that it all adds up' [finance worker].

Workers needed print knowledge to determine the level of customer knowledge about printing. This influenced how they went about obtaining details of the job required. New workers were encouraged to assess the extent of customer knowledge throughout the elicitation process, *'the number of pages is always the number of sides, in printing. You might get a customer who doesn't know. If*

you don't know that they know, then check' [induction of new sales worker]. Customer knowledge was known to vary greatly, from *'complete incomprehension about anything at all about printing'* to *'just bits and bobs that they're not sure about'* [sales worker]. Workers were prepared to cope with the full range, and it was not seen as a problem, *'you just have to take account of that... as long as you get the information out of them, it doesn't really matter... you can sort of coax them a bit, like'* [sales worker]. Customers' lack of knowledge took a variety of forms. Some did not know what range of work printing firms could be expected to undertake, and assumed that Freedom would write their original copy as well as printing it. Others did not understand the litho process or printing terminology :

'I had a customer last week, and he showed me the colour that he wanted. But he showed me a paper sample as a colour. That's a perfectly reasonable thing to think, "we'll have it this colour". But that wasn't an ink colour, so I had to show him the pantone book and say "well, you actually choose the colour from here"... You have people who think, if you're printing a white out, that it's white printed on blue. If you don't understand how litho printing works, it's a perfectly understandable assumption. If blue is the background colour and white is the text, who's to say it's not printed in white ?' [sales worker].

By speaking to customers on the phone, workers quickly picked up what printing knowledge they had, *'if they sound a bit hesitant'* or *'by what details they give you'* or if they *'said something that was obviously completely wrong'* [sales worker]. Then they would go through the job step by step, using everyday examples or analogies where needed,

'so you've got to go through it slowly. "Do you know what size it's going to be ?" "Not really". "Well, you know an A4 sheet of paper..." - nearly everybody knows A4 - "... is it the same as that ? twice as big ? four times as big ?"' [sales worker].

Although everyone at Freedom was familiar with the language and terminology of printing, they were able to talk to customers in layperson's terms and to translate the resulting information afterwards if necessary,

'although I don't have the practical knowledge, having never actually run a press, the terminology was familiar to me, particularly vis-a-vis the clients we've got. I've done very similar jobs to the jobs they're doing, and I can interpret what they need, without being too technical. I think that kind of knowledge is very important, although it's not very practical' [sales worker].

There was a collective commitment to demystifying the production process, *'I wrote a leaflet about design to help customers with that side of it'* [sales worker] and providing informal education and advice for customers about printing,

'I like advising customers. I do quite a lot of that. A customer will ring up, and they'll want a quote, but they won't know exactly what they want. So you can give them a bit of advice on what sort of paper would be good for their job, or suggest a different format, or tell them how they could do it more cheaply. That's quite a good part of the job' [sales worker].

Some workers remarked that there had been changes in the general level of customer knowledge about printing,

'I think people in the voluntary sector as a whole don't have that much printing expertise, but they are more knowledgeable than they used to be. It's because they're getting more print done, but also because print technology's become a bit simpler. People are doing DTP now, so typesetting's not such a mystery to them as it used to be' [sales worker]

Workers at Freedom were sometimes able to make production easier for themselves in a way that Weirs could not, because it did not have the same control over design and specification (7.2.1.). Knowledge gave Freedom the power to define some customers' jobs for them, *'If they start veering towards something you know is going to be expensive, then you warn them before you've even costed it'* [sales worker].

Many customers, particularly regulars, did know how to specify jobs, and they expected workers to speak the same language. Demonstration of production knowledge by office workers reassured potential customers that Freedom knew what it was doing, especially if they associated worker cooperatives with enthusiastic amateurism. As the firm moved beyond its traditional customer base

in an attempt to survive, this became even more important. Being seen as 'so professional' [customer comment] could win orders. However, the demonstration of expertise had to be carried through into production,

'if somebody comes into the office, they see everybody here.... and their job is the final proof. If they give us the job, that's fine, but if the job goes through the factory and it's rubbish, they're not going to come back to us' [sales worker]

The ability to visualise artwork in 2-D from a verbal description, and finished products in 3-D from the specification was important during elicitation, particularly when the process was conducted by telephone. Elicitation also took place face-to-face. A sales worker visited customers at their premises, taking the firm's portfolio of past work to which the current job [as artwork, roughs or an idea] could be related. This was similar to what occurred at Weirs, and entailed a similar kind of knowledge mobilisation.

Customers frequently visited to discuss their printing requirements, bringing with them artwork, design roughs and ideas about what they wanted the product to look like. On such occasions, one or more office workers and perhaps the graphic designer and other production workers might be involved. Office workers brought their elicitation skills and ability to imagine a finished product through all the different stages of production; the designer helped customers visualise and articulate what they wanted in terms of artwork and the overall "look" of the job; and production workers offered advice on the production implications of the design and possible alternatives.

At Freedom's premises, they had access to a wide range of objects and tools which could assist the visualisation process and make it tangible : the "official" portfolio; finished samples of almost every job Freedom had ever produced; typeface alphabets; paper samples to see and touch; pantone books; samples of specialist processes distributed by subcontractors; steel rules to measure artwork or individual images; scrap paper for making up dummies;

linen testers to assess the customer's artwork for reproducibility; any relevant work-in-progress; and production machinery.

All these participants, human and non-human, became involved in an elicitation process whereby a wide range of technological knowledge was mobilised collectively around what was known as "the artwork table", in the centre of the office, in order to produce a precise job specification and pre-press details. At the same time, someone might prepare an estimate, so that modifications could be proposed immediately if the price rose beyond budget. This mobilisation of resources was impressive. It demonstrated Freedom's commitment. It drew in customers. And made it difficult for them to take the job elsewhere.

6.3. PLANNING THE JOB : PROBLEM-SOLVING NETWORKS

Once a specification had been obtained, workers planned how the job would be produced, estimated its cost, and decided what price to quote. This formed a first draft of the works instructions, *'working out the cost is only part of the use of an estimate, because once it becomes an order, I need to know the information that's in there to turn it into a job'* [coordinator]. A wide range of technological knowledge distributed among a variety of carriers was mobilised during these stages.

6.3.1 Internal Networks

The office workers did not share a common background of formal training or previous work experience. Some had gained their knowledge of printing processes, products and materials from formal courses, such as the HND in Printing Administration. Others had entered the industry from parallel jobs in publishing, and thus had second-hand familiarity with the printing industry combined with functional experience, in for example accounting or marketing. In

theory, all new workers underwent induction into the cooperative, including time spent in each production department. The amount varied according to need and the urgency with which the extra pair of hands was required. During induction, they learnt about printing and how Freedom operated,

'I spent days being trained in each department. It answered a lot of questions about things I didn't know. I had some idea about the processes before, but every printer's got its own way of doing a job. I'd like to see more jobs going through, but I haven't got time' [sales worker].

However, whether the technical details of production were perceived by them as relevant depended on their initial job description,

'I spent a day in the plateroom and a day in the printroom as people do when they first start. I didn't get as far as the camera. But even if I'd done it then, I would probably have forgotten a lot, whereas in fact now it might be more use. But I never make the time because of pressure of work.' [finance worker]

After induction, office workers acquired knowledge about printing "on the job". Over time, they built up production knowledge, based on their own and others' past experiences, combined with external contributions from suppliers, subcontractors and the trade press, *'Everything adds to your knowledge, but you need to constantly update it, or you develop a fixed idea about things that it is actually possible to do'* [sales worker]. This knowledge was actively shared. It was also embodied in samples of past jobs and their associated documentation. To this extent, office workers were carriers of "common knowledge" about production. However, they all did different jobs, albeit with elements of overlap. Hence they did not carry a totally homogeneous body of print knowledge between them. Nor was their information centralised, being spread among many shared and personal files, although it was accessible through questioning, *'At the moment our information is not in a very accessible form. It's a bit haphazard. We're doing it from manual records and from memory'* [sales worker]. With time and experience each developed their own specialist areas. Allied to the varied and bespoke nature of products, the buying-in of particular materials for specific jobs, and the need to subcontract parts of the

production process, this made the office a focal site for the collective mobilisation of knowledge.

Workers had to decide from the specification which parts of a job to produce in-house and which to subcontract. Sometimes they faced "make or buy" decisions, taking into account factors such as the difficulty of the task, the skills of production workers, the likely turnaround time of the whole job, the amount of time the process would take in-house relative to that needed for other jobs, and the cost and convenience of putting-out. Production workers' job satisfaction might also be considered. Given the variety of issues at stake, it was likely that nobody would take such a decision in isolation.

Workers would mentally follow a job step by step through to completion, figuring out how it was to be done. The ability to visualise jobs in 3-D with or without sight of artwork was important, in terms of product and process,

'It's normally the printing. I think of which way they're going to turn it, like if you realise something's got to be done work and tumble. I sometimes visualise it if I'm checking how many passes it is... like something that's black plus two on both sides. I would think how I'm going to do it [finance worker]

Making dummies of products was common practice, recommended to new workers by those more experienced as a vital problem-solving tool,

'if you ever get confused, always get bits of paper and play around with them, because it makes so much difference to do it visually. You can get (A2) paper off the stockpile or scrap, or (A4) bits. It's very, very useful to make up dummies' [induction of new sales worker by existing sales worker].

Occasionally it was the form of the finished job that was difficult to imagine, but most often it was the imposition of multi-section or odd-sized work, and the position of colour pages and tints. The cognitive components of their knowledge altered with experience and "indwelling". Over time, workers' informal rules of thumb and visualisation skills for estimating and planning more standard products became tacit, though never entirely,

'I quite often draw the A2 sheet and divide it up if I'm doing things like working out how many sections something is and how many up on a sheet. There are some I can do in my head, but quite a lot of things I think it's simplest to do a drawing because then you can look at it logically step by step' [finance worker]

Dummies had other uses too, particularly if customers did not know how design related to printing costs,

'If there are going to be tints, you need to work out where they fall. And the best way to do that is to make a dummy and see whether they're all on the same spread. Then you can give advice with it. If they haven't got much money and they've got loads of tints, you can say "if you confine those tints to just two spreads" or "if you confine the extra colour to just the centre pages". You can tell them how to do it a cheaper way' [sales worker]

In many cases, a dummy was constructed and placed in the job bag if the order came in, and would accompany the job through production, sometimes travelling outside the firm to subcontractors. The dummy was a proportionate scale model with page numbers or other identification (eg. "back"/"front" for leaflets), composed of sections representing A2 sheets folded down to finished size but not trimmed. Hence it could be deconstructed at any point to reveal the imposition and content of its pages and the production processes required for each sheet. It could then be just as easily reconstructed for its next user. Without this tangible reminder of how the job should be done and what it ought to look like, mistakes could and did occur at any stage of production. Verbal warnings from the production coordinator, such as "watch out for this one, it's tricky because..." were not enough.

Hands-on knowledge of production processes was not essential for planning production of a job. Vicarious knowledge was often sufficient, *'through having worked with typesetters and printers for years, you build up a picture of how systems work. You've got common, but not specific knowledge. You can apply that'* [sales worker], as long as workers knew who else to consult if they did not carry this knowledge themselves or wanted a second opinion based on practical experience,

'if I'm not sure how we'd do something, whether we'd do it A3 or A2, or sheetwork or work and turn, then I'd ask [the coordinator] or one of the printers, because either I know it's something I'm not certain about, or it's one of these kind of judgment things. Sometimes it's a close decision, and I might ask both' [finance worker].

Most office-based workers had some practical experience, which helped them to work out how a job would be produced at each stage, what materials would be used, and how long processes would take. This might be derived from previous employment, or the practical part of their formal training,

'Design is one problem area, although I have experience of doing design on my own. So is platemaking. Again I've had experience, so I can sort of judge it' [coordinator]

'You know there might be a problem with thin paper, which wouldn't occur to you if you'd never actually tried to feed a thin paper through a press' [sales worker]

or less formally,

'I've been involved in political activism one way and another for many years now, and I used to spend quite a lot of time cutting things out and doing paste-up... putting together leaflets when DTP was just coming in. Having been on the construction end, it helps me to be more sympathetic to customers who give you rubbish and expect you to turn it into a beautiful leaflet' [finance worker].

Freedom's financial problems meant that they could not always afford to call in engineers to fix faulty machinery, so office workers had to know what state the equipment was in, and the production implications, which affected the way jobs were planned and quoted. It was considered better practice to work around difficulties at an early stage than to ignore them,

'Quite a lot of stuff needs fixing. The main thing at the moment seems to be the side lay. And a separate problem on register. It's alright but if you're turning something over and you've got black plus 2 on both sides you can have problems. If there are problems with the press then it's best to go and ask "how do we do this?" to try and make sure that it is quoted in a way that is manageable rather than gives them hell in there.' [finance worker]

To spend time in the Freedom office was to be subject to a

constant, audible flow of questions and answers between workers, and to be surrounded by movement as files, job samples and other items were retrieved to supply information about how to produce work, *'there's a lot of liaising and discussion in the office that's very important. It may not seem that productive, but it is'* [sales worker]. "Listening in" was a way of finding out about estimates or jobs with which workers were not personally involved. Office workers came and went between production departments for similar reasons. This was not only a collective mobilisation of knowledge, it was also its collective creation and redistribution.

6.3.2. External Networks

As well as asking questions internally, workers drew on external networks to mobilise knowledge about the production of jobs. These contacts included a wide range of suppliers and subcontractors in print and print-related industries. They were usually made by telephone, and formed part of the general office background noise of enquiries.

If the choice of materials was unspecified or imprecisely defined by the customer, a decision was made by workers taking the job's specified characteristics and their associated production processes into account (as well as cost),

'Black and red solid... What sort of paper do you want it on ? Right... You want it to be fairly substantial looking. Is cheapness the prime thing ? You could have 100gsm matt coated cartridge. Below that it'd probably start to look a bit tatty. By the sound of it' [finance worker to customer].

This required knowledge about materials performance and usage, and the quantities and form/size in which they could be purchased. When customers requested a specific brand or type of material, there might be unforeseen implications for other aspects of production. Information from external sources based on technical knowledge or past experience of using materials rarely or never encountered by Freedom could be invaluable.

One request for a booklet with a cover made from board containing "real silk" [customer] resulted in several phone calls to paper suppliers to name and locate it. However, it was not until an outwork price for binding was requested (which entailed specifying paper type) that the finishers confided that going by their previous experience this paper marked badly as it ran through the folding machine unless its surface had been sealed by varnishing or lamination beforehand. They advised using a substitute if possible. The customer insisted on that one. Ink suppliers were then contacted to advise on the best type of varnish for the material, and on how it should be used.

Technical advice from outside the firm was useful when workers had to contact subcontractors for prices on processes of which they had little knowledge. This occurred in the course of the job details being elicited from Freedom. Subcontractors might use other terminology for specification, whose components implied production concerns which were not those of printers, but which would have implications for the way Freedom presented work-in-progress. Through such experiences, workers gained knowledge about other types of print-related production.

In general, relations with technical and sales staff of suppliers and subcontractors involved the mutually useful exchange of knowledge, in factual and anecdotal form,

'One thing I like about the printing industry is that people will tell you things. It's not a load of trade secrets. If I want to know about a finishing process that I don't know much about, then I can talk to the finishers and they'll explain. It's nice hearing people's stories as well' [sales worker]

Firms exchanged "horror stories" about products, processes, materials and customers. Networking involved the anticipation of mutually useful exchanges of goods or services for money, *'They think if they're helpful then it's more likely to turn into a job for them.'* [finance worker] or reciprocal subcontract work.

Financial problems made it more likely that Freedom would flit from one firm to another on account of not yet having settled previous bills, or from experience of their debt-chasing procedures, '*it might be politic if you found a new ink supplier. X are a bit handy with their legal department*' [finance worker to printer]. However, they still maintained close long-term links with three firms : its principal typesetting and finishing subcontractors, and the supplier of its most important material - paper. In terms of the mobilisation of knowledge through questioning, these were treated like additional production departments,

'It's often easier than rooting around. If somebody wants a certain type of paper and I don't know straight off, then I'll ask in the office. But sometimes I'll just ring [the supplier]. You can ask, "can you get this particular type of paper in a particular weight?" even though it's not on their price list' [finance worker].

As well as technical assistance, suppliers and subcontractors provided information by phone about products, processes and prices not found in their official catalogues. Suppliers often had '*odd things*' in stock on an irregular basis which might be useful for quoting unusual specifications. Subcontractors offered similar process and price benefits,

'I ring [the finisher] because they often give different prices for trimming and folding¹ from their list. And if it's folding, collating and hand inserting², because they don't have a standard price for that, and it's expensive. I quite often ring them about folders³, [finance worker].

The external networks of knowledge about customers referred to in section 6.1.2. played a role at this stage of a job. Knowledge about customers was useful because it enabled planning and estimating to be done more precisely, '*if you know the designer,*

A standard process.

A non-standard process requiring additional casual labour.

A non-standard process and product involving construction of a unique job-specific platen (pattern for cutting and creasing), followed by hand assembly, requiring extra casual labour.

you usually know what state the artwork's going to be in' [sales worker]. Accuracy was considered important by office workers. They did not like giving customers "a rough idea" : this was seen as shoddy work and gave the customer unrealistic expectations of cost,

'if somebody says "I want 1000 A2 posters", you can't do it. "1000 A2 posters in one colour" - you still can't do it. You really do need the information. Well you can, but the less you have, the more hit and miss it is going to be. If someone wants a workable price, you really have to go through all this' [coordinator].

Estimating was seen by most office workers as a craft like any other area of print production, with its own period of apprenticeship, *'I made a policy of not trying to do it too quickly because it was obvious that it was quite complex if you were going to get it right'* [finance worker]. Most people, not just new workers, double-checked their own estimates and asked others to recheck them. There was disapproval of the 'broad brush' approach, and of those who thought an estimate was workable *'as long as it's got the right number of noughts on the end'* [finance worker].

Customer knowledge influenced job pricing, *'we add it all up and then we think about it. If they're poor you might knock a bit off, if they're rich you might add a bit on'* [sales worker]. Customers' lack of knowledge about printing could become a liability, causing production and other problems. This was especially true of those who supplied their own, poor quality artwork, *'because you're compensating for that lack all the way through production'* [finance worker]. In-house jokes about particular customers were one way of coping with these pressures, and they were a means of demonstrating and passing on that kind of knowledge, in much the same way as the "horror stories" that circulated about specific jobs.

Knowing the signs of a troublesome job enabled workers to build nuisance premiums or additional work into estimates to ensure that if the contract materialised, they would at least be financially compensated, *'if there's somebody we know we've had problems with before, we'll add a bit extra for that'* [sales worker], although this was difficult to predict for some production processes,

'Sometimes two quite similar-looking jobs which have the same spec (say, two-colour A4 leaflets) can have totally different amounts of time needed in platemaking' [coordinator].

Knowledge about the financial status and behaviour of prospective customers was important in the recession, and as their institutional sources of funding dried up. External networks were useful for gathering information about customers' funding, creditworthiness, promptness in settling bills, and propensity to quibble over invoices. These networks included other print cooperatives, who warned each other about slow or bad payers, and financial "horror stories" circulated about particularly bad past experiences. Information was exchanged about who was currently printing certain large regular jobs, so it was possible to find out whether a fresh enquiry represented a customer trying to avoid paying its previous printer and taking work elsewhere. Past experience of financial dealings with regular customers was an important source of knowledge. This was often not articulated, and could thus be described as tacit. However, it could be made explicit if workers asked each other to account for pricing or credit decisions, or interrupted each other to make suggestions.

From the above, it is clear that the collective mobilisation of knowledge during the planning of jobs extended beyond the formal boundaries of the organisation to encompass a wide and varied network of industrial contacts. Such links were both possible and necessary for a number of reasons including the variety of product specifications and the structure of the general jobbing sector of the printing industry. As a print cooperative servicing what could be termed "the libertarian Left", Freedom relied on its knowledge and membership of associated social and political networks for planning and pricing jobs.

6.4. PLANNING PRODUCTION : COLLECTIVE PROBLEM-SOLVING

Putting a job into work and fitting it into the production schedule required coordination and cooperation between customers, office and production workers, suppliers and subcontractors. They all verified its specification (however conceived) in order to determine when and how it was to be produced. Jobs became a common focus for the mobilisation of a variety of technological knowledge.

Customers placing orders spoke directly to the production coordinator, or one of the other office workers, giving finalised details of the job, its date of arrival and ideal turnaround,

'when we're busy on production, all staff get involved with customers about jobs that are in at the moment. The production coordinator needs backup, because he can't even go out of the room without there being some enquiry coming through' [sales worker].

In the "booking-in book", each job was allocated a sequential number by which it could be traced thereafter through Freedom's administrative and financial systems. It was also given a name, which was more often used by workers to refer to the job, *'you want to give it a title because it's easier to remember things by words than by number'* [sales worker during induction of new sales worker]. Its specification and expected dates of arrival and completion were tabulated, and the reference number of the relevant estimate inserted. The division of office labour was flexible. Anyone could make this entry, as long as they informed the coordinator that new work had been ordered.

Turnaround was usually worked out and confirmed (if not previously agreed) by the coordinator using rough mental rules of thumb, *'information which I say is to hand, but it's actually more at the back of your mind... what job is suitable for which machine, how long things are going to take in different departments'* [coordinator]. These related to the various processes carried out in each department, *'you know at what speed the machine will run,*

because you'll at some stage have been told that' [coordinator]. To do this he thought the job through production, using the estimate for reference, and taking into account the current loading of the schedule as pencilled into the scheduling book, or as updated in his memory. The job in hand would then be added to these versions of the overall work schedule.

If time was tight, either because the required turnaround was swift or because the schedule was already crowded, the coordinator asked production workers how fast the work could be done, or where the best place was to slot the new job in. Their replies involved consideration of the machine most suitable or available for running the job, and where it would fit into the existing order in terms of the specifications of adjacent work and ease of changeover (cleaning and resetting production equipment), *'what's the job involve ?... only I was thinking of washup - is there colour on it ?... that'd be done on the KORD ?* [printer to coordinator].

Turnaround varied for each job depending on its specification and urgency, and on the identity of the customer, *'how long is piece of string ?'* [coordinator]. The knowledge mobilised by the coordinator to produce an expected date and time of completion was largely tacit although it could be articulated heuristically for individual jobs, *'it's easy to be very specific and say "well, if you bring it in to us tomorrow afternoon, you can have it back in two days"'* [coordinator].

A provisional timescale calculated on a similar basis might already have been given to the customer by whoever had prepared the estimate. However, this could not take into account the particular week's schedule if the customer had been vague about when the work could be expected. Office workers knew how long a job would take in the abstract, but not in terms of the specific context in which it finally arrived. Their heuristics were based on the assumption of an uninterrupted run through each department, which was often not the case.

Scheduling was complex, requiring the mobilisation of a variety of knowledge. It was largely carried out by the coordinator, with input from other workers, customers, subcontractors and suppliers. Rules of thumb governed how long each stage of the process would take for a specific job in theory. Contingent knowledge suggested how long processes were likely to take in practice based on comparisons with previous experience of similar jobs and the performance of particular workers, materials, machines or subcontractors, and in the light of the concurrent job mix. Over time, this knowledge was internalised by the coordinator and became largely tacit.

The uncertainty of jobbing work made planning difficult. Customers delayed placing orders until the last minute, and might be late bringing jobs in,

'The problem is that you're right at the end of the line. If someone rings, you have to respond. You can't wait or plan, or do something the way you might want to do it. I'm not used to being on that end of it. The publisher gets a lot more freedom than I'd realised ! Often we are the last port of call for something that's already running late' [sales worker, ex-publishing]

At any time, the overall schedule could change in response to external events or in-house production problems, and its most up-to-date version was almost always in the coordinator's head, *'It's crisis work, and the things that you should be doing, like writing up the board and tightening up the schedule for next week will be left, because they're not essential now'* [coordinator]. This was seen as a problem, as it was then not collectively accessible, unlike the schedule book which lay open on a desk in the office, and the (unused) whiteboard on the wall. This mattered because production workers partly relied on it to do their own departmental scheduling and materials ordering, although they consulted workers in adjacent production departments as well as the coordinator in order to plan their workflow.

The coordinator prepared a job bag for each job, showing all the details from the "booking-in book", the works instructions and

expected time in each in-house department. He noted any subcontracting needed, deciding who was to do it, and added the works instructions to be issued to each firm, and materials to be used from stock or specially purchased. The latter were entered in the "paper book", which was used for ordering, confirming deliveries and stock checking. Works instructions were based on job specifications and estimates, and the coordinator might ask other office workers for clarification, particularly if assumptions had been made based on contingent knowledge that was not commonly held or had not been explicitly written down.

All these rewritings of the job specification into various record books appeared wasteful of workers' time and energy, providing scope for mis-inscription and misunderstanding. However, like the constant barrage of questions and answers in the office, they performed a useful function, *'I like making lists. And I don't mind rewriting the job specs because it reminds me about jobs in general, and it gives me time to think through what each job involves'* [coordinator].

Each time the specification was rewritten, the person doing it was thinking the job through production; checking the accuracy of the preceding version, and verifying the job's feasibility. In this way, the job imprinted itself in office workers' minds. By the time it was delivered and invoiced to the customer, almost every worker had experienced the job vicariously or at first hand. Hence jobs became objects of common knowledge through the process of (re)specification from a multiplicity of perspectives. This provided a basis for the collective mobilisation of diverse bodies of knowledge for problem-solving at any stage of production, *'Everybody is involved. Whilst "one-person management" may be more EFFICIENT for coordinating, often two heads are better than one'* [coordinator, in minutes of monthly collective meeting].

What happened when the job came in depended on whether or not it was accompanied by the customer or designer. If it was, there would be a demonstration of the collective mobilisation of knowledge

similar to that described in section 6.1. This ceremony concluded (provided someone remembered) with the signing of the job bag by the customer, indicating their acceptance of the job specification as described thereon and their agreement to the work being carried out as contained in the works instructions at the estimated cost¹.

If the customer did not bring in the job, the process was more low-key, involving [usually] the coordinator alone at the artwork table surrounded by artefacts enabling him to mobilise knowledge in order to organise production. These included the job bag giving the specification and works instructions, the schedule book, estimate, steel rule, pantone book, linen tester, and whatever artwork or copy and original images the customer had provided. From time to time, other workers might be consulted singly about particular aspects of the job. The arrival of unaccompanied artwork was not a social occasion. Material objects on their own do not appear to spark off the collective mobilisation of knowledge.

The first step was to compare the artwork to the specification and estimate, and to recalculate its cost and price if there was a discrepancy,

'the customer books it in and says "there's 10 pmts". But when it comes in you need to do 20. So I need to be aware of what's gone into the estimate, so I can say "well, hang on, that's another £100 worth of photography in there"' [coordinator]

This did not always happen, which could lead to inaccurate works instructions, or customers refusing to pay more than the estimated price when additional work had been undertaken. Some jobs came in without an estimate. This was most likely to occur with regular customers' work, *'if they say "can we have a price, but can you start work anyway", and I know that they'll roughly be spending £1000'* [coordinator]. In such cases this was when the job was estimated and its precise specification established (see 6.1).

In other words, many customers did not understand the details to which they were signing agreement.

Works instructions were checked to the artwork to ensure completeness. Final details of design, typesetting, repro and platemaking could be established at this stage and production requirements predicted with greater certainty than before, in the face of visible and tangible evidence. If ambiguity remained, the customer could be contacted, *'I'll give you a call once I've seen it, and check that everything's understood'* [coordinator to customer], or production workers called in to advise. This was Freedom's last chance to verify the job as a whole before production began, *'It's important to get it right. Rather than regret it later when we're in the middle of printing and you find out that's not how they want it'* [sales worker].

Subcontractors were instructed in person or by telephone. Repro was handled face-to-face with a representative from the repro house, the artwork, original images, a dummy of the finished product, linen testers and steel rules. These meetings took place at Freedom's artwork table. Personal contact was necessary because it was difficult to explain requirements without the image and the artwork (its context) being present with both parties when its reproduction and manipulation were discussed. It was preferred by workers because not every job needed external repro, hence they did not build up close relationships with these subcontractors, or a sufficient range of mutual examples of past jobs. They were therefore unable to employ the shorthand method of instruction used with typesetters or finishers : "rather like that job we sent you...". In addition, work needing repro was likely to be technically challenging in other respects : full-(four)colour, or A2 duotone images for posters. This made mutual comprehension even more important.

The provision of final film, plates and proofs by repro houses was vital for checking that instructions had been correctly issued and interpreted. It gave customers an opportunity to confirm that they would be getting what they wanted, assuming the final job resembled the proof. Attempting to cut costs by doing without proofs could

backfire, even if the job itself was well printed,

'we were doing this job, and the scan came back. We got what we asked for, and Graham printed it. But the customer didn't see it first. We should have done them a proof. They decided they didn't like that particular green. So we had the scan redone. That put us back a day. The printer was in a dejected state - he'd had enough of running it - but it's a really exceptional piece of work. It was a technical challenge, and I know the platemaker likes doing that sort of work. It's something nice to show customers, to have on the wall and say "we did that"' [coordinator].

Finishing was subcontracted by telephone, since its specification was more straightforward. When the job went out as work-in-progress, it was accompanied by written instructions and a dummy made from printed sheets, rather than a blank paper scale model. More complicated jobs such as folders had already been discussed, preliminary dummies exchanged at the estimating stage, and final ones once the artwork had come to Freedom. Despite the frequency and matiness of phone contact between Freedom and its principal finisher - varying between several times a week to several times a day depending on the volume of work - noone at either firm at the time of fieldwork had ever met in person. Yet each knew the other's schedule, how production was progressing overall and for specific jobs, and what business was like in general.

Every Wednesday lunchtime, all workers met in the office to discuss cooperative matters. Production was always the first item on the agenda. The coordinator ran through the current state of the overall schedule, so that production workers would know what to expect the following week in terms of specific jobs and general workload. Potential bottlenecks could be spotted in advance, and workers decided whether to rearrange the schedule, organise overtime or undertake additional subcontracting. When the volume of work had been greater and shifts operated, there had been a daily 9am meeting at which workers planned the next 24 hours' production.

The production requirements of particularly fussy customers or high-value, long run or complex jobs were discussed in an attempt to pre-empt problems through the pooling of technological knowledge

and past experience. To make a point, workers might use objects that lay to hand around the office, such as examples of past jobs, estimates, job bags, and diagnostic instruments, in order to call similar situations to mind. Because representatives from each department were present, the implications of doing jobs in certain ways could be followed through the entire production process : "if you do it like this, then I'll have to..."

Current production problems were dealt with as they arose. At meetings, collective "post-mortems" were held on completed jobs which had been especially troublesome, or if there were recurring difficulties in a department. These made everyone aware of what had happened (if they did not already know from informal conversations) and enabled all workers to share their knowledge and suggestions for solving the problem. This made inter-departmental and cross-functional solutions easier to reach.

Planning production created a network of relationships along which technological knowledge would be mobilised during production. For this to happen, the job specification and works instructions had to attain a state of temporary stability. This was achieved through repetition until consensus was reached about how, where and when production would occur. Each successive repetition was active. For each party, it entailed thinking the job through production in the context of a projected schedule, as well as visualisation of the finished product. The repetition process involved reproduction and transmission of the specification and instructions through a variety of media, accompanied by the original image or a representation thereof as tangible and visible statement of intent. By sending out information about the job in a form which could be questioned and modified, or confirmed and acted upon by recipients in the light of their existing knowledge, networks of new knowledge were collectively created, leading to production.

From this case study, patterns in the ways everyday print knowledge was mobilised begin to emerge. When printworkers undertook tasks such as obtaining work or establishing job specifications, they drew upon domain knowledge carried in common with other practitioners within the firm or shared by members of their "technological community", at sector-level or in terms of occupational groups. Such knowledge was expressed in and structured by domain-specific language. This shared knowledge was interpreted in the light of personal experience. Freedom's workers were part of political and social communities and networks, knowledge of which was equally significant to their production-related activities, because of the cooperative's customer base and markets. Such mobilisations of common knowledge involved a single printworker making use of a variety of domain-related objects embodying knowledge, with or without information provided by "outsiders" (in this case, customers), with the aim of defining product and process for future production. A second kind of mobilisation process occurred during estimating, issuing work instructions and production planning. Temporary problem-solving networks were created between several printworkers, into which subcontractors and materials suppliers might be drawn, again making extensive use of domain-related objects. These situations could consist of informal, almost casual, conversations (sometimes by telephone), or more formal gatherings and meetings, in which questioning played an important part. Participants exchanged individual, hitherto unshared experience, sometimes in the form of "horror stories". This could then be interpreted by others within the framework of their common domain knowledge, and used to arrive at a collective solution.

CHAPTER 7 - WEIRS WEB

This chapter examines the content, distribution and mobilisation of production-related knowledge at Weirs, including two ways in which such technological knowledge can be considered collective. Firstly, it explores the shared content and distribution of "common knowledge" by looking at the establishment of job definitions and production standards. Knowledge about products and processes, their description in domain-specific language, and visualisation are all of importance. Secondly, it shows that mobilisation of print knowledge for problem-solving prior to and during production is a collective process, involving a range of participants internal and external to the firm, who make significant use of material objects. As in the preceding case study, this is shown to occur in the course of informal, apparently casual, exchanges, the telling of "horror stories", and in more formal settings, such as meetings. The material demonstrates that a shared framework of formal and heuristic knowledge is essential for making sense of personal, context-specific, contingent knowledge during problem-solving, and that not all printworkers at Weirs carry this. Again, customers are positioned as "outsiders" to the world of print. Finally, this case study reveals the interaction between printing and engineering domains of knowledge during problem-solution, the role of dual-identity "translators", and the occasions when external engineers appropriate that process and redefine problems. Knowledge-mobilising activities in which collectivity or common knowledge were important occurred in situations where the following questions were being addressed by printworkers, and each is presented in turn below, illustrated by case study material :

ACTIVITY	QUESTION	SITUATION
Obtaining work	What is this job ?	Definition
Planning work	How do we produce it ?	Problem-solution
Routine operation	Are we doing it right ?	Definition
Trouble-shooting	What if it goes wrong ?	Problem-solution

7.1. OBTAINING WORK : DEFINING A JOB

7.1.1. Feasibility

Weirs produced products bespoken to customer requirements. An initial definition of every potential job had to be established in order to decide whether customer needs matched what the firm could provide, and on that basis to turn away the enquiry or take it further¹. Knowledge about products, processes and the printing industry played an important role in this, and workers developed technical and economic criteria by which to define jobs and evaluate their feasibility.

The first step was to elicit information from the customer firm about the job. This involved people at various levels of the respective organisations' hierarchies. Within Weirs, the General Manager, Sales Director, sales reps, account executives and estimators might all discuss job specifications with customers. This implied that they all carried knowledge about how to do this. What was this "common knowledge", and what did it enable them to do ?

Everyone at Weirs used a common language to describe printing activities and objects, which established their identity as printworkers. It was not simply a specialised vocabulary (as amply evidenced by the glossary). Syntax governed what it was possible to say about jobs, delimiting their characteristics insofar as these were relevant to production, and arranging them in order of importance. The structured nature of job specifications was one of the most important manifestations of this common language. At this stage of a job, it reminded people what information was required from customers, and hence which questions to ask. Weirs had pre-

The Commercial department produced about 250 estimates a week, of which 10% and 30% became jobs.

printed customer enquiry forms which were filled in during the information gathering process, and whose design served as an aide-memoire.

Very little detail from the customer was in fact needed to establish initial technical viability, '*quantity, size, paper, repro.. delivery... very rough and ready, ball park figures*' [rep]. Although this list was incomplete, the first three attributes were most significant. What mattered was whether they suited Weirs' technical capabilities. Everyone in the firm knew what production technology it had, and the type of jobs this equipped Weirs to produce : high quality direct mail printed on web presses, with complex and varied finishing. However, the cognitive components of this knowledge varied between carriers. So did the level of detail and their awareness of the implications for deciding whether individual jobs were feasible, and not everyone at Weirs would have been able to decide which jobs to take on.

People dealing with customer enquiries had rules of thumb for matching job specifications to Weirs' production technologies : for each job characteristic (run length, size, extent, paper) they had a set of rough parameters within which the existing equipment would function best¹. These guidelines interlinked with each other, and became tacit with experience. Knowledge about printing was seen as crucial to developing a sense of what was appropriate, both generally and specifically in terms of what Weirs could produce, '*technical knowledge... a good grounding in flat sheet or web. You know the product. You know what you can do. To have sold computers or something else - it just doesn't work*' [rep]. Without this, a sales rep would not last long, '*the ones that didn't have a good*

For example, minimum economic run length = about an hour's run time (25,000 A2 cutoffs) multiplied by the number of finished items off each cutoff : hence 25,000 8pp A4 spine-glued booklets, or 75,000 6pp 1/3A4 booklets, trim and fold. Minimum paper weight = 70gsm; maximum = 150gsm. Maximum flat size = A2. Minimum finished size A5 or 1/3A4. Maximum extent = 2 sections self-cover or 2 sections + cover [subcontracted], fold, stitch and trim (= 24pp A4 or 16pp A4 + 4pp or 48pp A5 or 32pp A5 + 4pp).

general knowledge of printing have gone' [rep]. This knowledge did not have to derive from hands-on production experience, as long as the person obtaining the specification knew when, what and who to ask about unusual technical details or borderline cases.

Complete agreement over these technical parameters did not exist, since everyone used different knowledge based on their own formal training and work experience. Although some potential jobs were obviously impossible, others were only marginally so. When economic considerations were taken into account, discrepancies between various people's opinions of job feasibility widened further, increasing scope for conflict. For example, the sales director knew which jobs were most suitable for production, but progressed other enquiries if the work seemed sufficiently profitable. Achieving consensus about potential jobs was seen as important for creating harmonious external and internal working relationships, even though it did not always occur and no attempt was made to systematise the process,

'There's no point in taking away an enquiry which is totally unsuitable. The customer thinks "what are they doing taking an enquiry if they're going to knock it back in a week's time". Plus you upset Commercial because you keep hitting them with [estimate requests for] spine-glued 16pp A4, or 186pp catalogues, or [jobs] on 45gsm - things we just cannot do. They soon lose their temper with you' [rep].

Demonstration of production knowledge, as evidenced by bringing only suitable enquiries into the firm reassured people at Weirs that their co-workers knew what they were doing, and gave customers confidence that Weirs' output would be reliable and of good quality. This was important given the non-standard and uncertain nature of products and the competitive nature of the web print market. However, if this arrangement failed, and the enquiry went to Weirs' estimating department without enough detail even to confirm feasibility, the situation could not be rectified without casting doubt on individual and firm competence, *'if you start asking basic questions, of course, it makes the rep look like a right idiot. It doesn't really do your profile a lot of good,*

because they must think "what are we dealing with here ?"
[commercial manager].

Production knowledge had other uses when defining jobs : to assess the level of customer knowledge about printing, because this impinged on the elicitation process. Some customers did not know how to describe what they wanted, *'they'll say they want it in blue and grey. Well fine, but there's 30 or 40 blues and 20-odd greys. It's not their fault, they've never been used to it. They expect you to have four or five colours that you pick and print'* [account manager]. Others did not know about printing terminology, and needed to *'have their hands held'* [sales director] as they were talked step by step through the job details, *'a customer will phone and just say they want a such-and-such. And sometimes you've got to draw it out of them, "how many colours do you want it printed in ?"* [estimator]. Others were *'very professional'* [sales director], and could provide a complete and accurate job specification without prompting.

Customer knowledge about printing processes varied, even in a specialised sector like direct mail, so representatives of the firm needed to be able to explain what type of work Weirs could do. Many customers did not have much knowledge about web printing,

'all agencies "buy print". Maybe only one in twenty buy web print, regular. One in ten buy maybe one or two jobs a year. And there's an awful lot never buy web... They might have work that's big enough, but a lot of them believe that if it's not a million catalogues, it's not web. So you have to convince somebody that you can do 50K 8pp A4 or 100K A4 leaflets competitively and of good quality... If you don't know what you're selling, you'll just agree with them and say "oh yes, of course, it's not web"' [rep].

Knowledge about recent technological developments enabled Weirs to break down customer prejudice, *'a lot of agencies think that if you're buying web, you'll get a cheap, inferior job - "newsprint" - something one millimetre out on register'* [rep]. They saw these barriers as created by customers' lack of knowledge about the industry and its technologies, *'You need to think it through. They might have bought web ten years ago, and the quality was appalling.*

No wonder they think it's the same now. It's just ignorance' [rep].

Customers' lack of knowledge could complicate the elicitation process in other ways, *'the customer will say "give me a price for a million booklets". You give him a price and he says, "is that how much they are ? Our budget's only a quarter that, give me a price for a quarter million". Then it's 200K, then it's 50K' [rep],* believing that a reduction in run length would reduce price proportionately, but ignoring set-up costs. Such changes could significantly alter a job's suitability. In these situations, customer behaviour could be interpreted in the light of their knowledge about print, and appropriate questions asked (such as "how many do you REALLY need") to obtain a more realistic specification from which a decision could be made. Most customers felt they ought to know about print, and this sometimes caused difficulties in establishing an accurate specification, *'Most of them think they know about printing. Some of them do. Some don't and are totally obnoxious and full of themselves... If they don't know, they'll very rarely say. They'll hedge' [rep].*

Elicitation was not a collective mobilisation of knowledge, even though more than one person was involved. The whole process, including the use of domain-specific language, constructed customers as "outsiders" who supplied information, and printworkers as those with the knowledge to extract, manipulate and return it in the form of a finished price. This prefigured what would happen during production, when the job passed out of the hands of the customer or their agent until returned to them as the final product.

7.1.2. Technical Specification

Once job feasibility had been established, knowledge about products, processes and materials enabled people at Weirs to ask questions resulting in a technical specification that precisely defined the job. This was used to produce a price, and to plan

production. Previous estimating experience helped, because they would know what details were necessary. Not everyone involved in elicitation had this practical knowledge. Estimators sometimes had to telephone customers for more information because the job spec they had to quote on did not make sense or was incomplete, rendering it impossible to tell whether it was feasible, or to do an estimate.

Incomplete specification could also indicate failure to visualise products in 3-D, a form of tacit knowledge particularly important in view of the complex and varied finishing that Weirs provided. People from Weirs visiting customers carried a portfolio of samples of the firm's past work, to which the job in hand could be related ("we want it to look something like this"). However, the two parties mainly worked from the designer's (2-D) roughs or artwork. This was often an ambiguous guide to the form of the final product, although better than nothing. There could be problems interpreting designers' requirements, and it helped if people from Weirs had knowledge or experience of this area themselves, *'you can see what designers are trying to get at. Because if you've not done that, they're not exactly the clearest of people with their instructions and what they want... They tend to be a bit vague'* [account manager]. If artwork was unfinished or as yet non-existent, or if a job specification was being discussed by telephone, no tangible version of the product (even in 2-D) was present to assist them. These problems were recognised, *'If a job's got special folding, cutting and creasing, there can be a problem making sure the thing'll fit, that we can do it'* [rep]. Producing visual 3-D dummies of jobs at this stage made things easier, since apparently minor finishing details could make a substantial difference to the price of a job, and to how production departments would set up their machines.

Finally, knowing about materials, processes and acceptable substitutes could be the factor that clinched negotiations. Again, this knowledge was not evenly distributed, arising as it did from certain types of previous work experience, and an awareness of what

was happening in other departments of Weirs,

'we did a quote for 200K. We got a requote for 500K, and they want us to drop the price. It's on 115gsm. I know we've got 110gsm, because I remember us buying it, so I've suggested we quote it on that to shave the price a wee bit. Now somebody else who hadn't bought paper or knew as much probably wouldn't know that and would have said "well, there's not much we can do about it". But I'll probably get the order' [rep].

Such demonstrations of knowledge and attention to technical detail reassured customers that Weirs cared enough about getting the job to take pains over a specification that met cost constraints as well as producing a product that looked right. The ability to separate an estimate into its component costs, rather than the total price produced by the KEREN system served a similar function, *'they needed the price today and they wanted it all broken down, so that took a long time. But if you don't do that for them, it won't come in because they'll say "they couldn't be bothered"' [estimator].*

In the Commercial department where estimates were prepared, a further screening process weeded out unsuitable jobs, *'I vet all the enquiries before they become estimates, to see if they're worth doing. We get a lot of stuff in that isn't really for us' [assistant commercial manager].* That this was necessary was attributed to some people's lack of opportunity to acquire additional working knowledge of technical matters from their daily experience,

'a lot of the sales reps don't really know that much about [printing], because they're not working in it every day. Folk who've been in estimating would know, but folk who went from college into sales still don't really have much more of an idea. They can go out and sell and talk to people, but how the job's going to be made is much more difficult for them to pick up' [estimator].

Various factors governed whether the Commercial department considered an enquiry worth pursuing. Some related to Weirs' own production capabilities, others to those of competitor firms. If possible, they liked to find out who they were quoting against.

Information was kept on file about other printers' equipment, and interpreted in the light of knowledge about what this could do best. Knowledge about other firms' performance came from more personal sources : friends and contacts in the trade, particularly suppliers' sales reps; customer comments; and from people at Weirs who had previously worked for other companies, *'you see people moving around the trade. Because you get to know people. It's not that big really, especially in Scotland.'* [assistant commercial manager]. Knowledge gained from these industry networks was circulated on "the grapevine". The general state of the print market and the specifics of Weirs' forward loading entered the equation. This information was fed back from daily production meetings. All this produced more guidelines with which most of the commercial workers were familiar,

'There's not really any hard and fast rules. There's obvious things that we cannot physically produce. And other ones that you know your equipment is not really economical for. You know that if the enquiry's gone to a printer with different kit, they're going to hammer you for price. So you get rid of that. If you're quiet, you tend to quote for things you wouldn't normally quote for. But if you're busy and somebody's wanting some product that doesn't suit, and at a time that doesn't suit, there's not much point wasting time going for it. But it's very rare that we will not quote something because we don't think we can turn it round' [assistant commercial manager].

Even once it had been decided to quote for the job, vetting continued to prioritise estimators' work, *'if something comes along that suits us down to the ground, and there's twenty borderline enquiries in before it, it would be crazy to do the dodgy ones first and leave that one till last'* [assistant commercial manager]. Individual, unshared knowledge of customer behaviour unofficially influenced the process of defining which jobs were possible, even to the point of filtering out those otherwise technically feasible,

'you start to get a feel about the customers that bring their work here and the customers that are wasting your time and just want a price to put in with other prices (on a tender list). So if it's a customer that I know, I'll do a lot of work for it' [estimator].

All these aspects of discriminatory knowledge accumulated over time

and became tacit, *'I think you build up the experience after a while. You recognise things that come up time and time again. You build up a bit of knowledge, and you can just tell'* [assistant commercial manager].

The whole process described above of defining jobs and deciding on their feasibility relied on a body of "common knowledge", and the use of a common language. However, the sequential nature of job screening suggested that it was based on unarticulated assumptions that such common knowledge could not be trusted to exist. This was hardly surprising, given that so much of the knowledge mobilised derived from such a wide variety of personal experience. However, the diversity of people involved in discussing potential jobs with customers carried a wide range of technological knowledge between them, with substantial areas of overlap sufficient for broad consensus to develop. This had produced uncodified rules of thumb allowing for the exercise of individual discretion. Moreover, consensus about which jobs were feasible was continually shifting in response to changes in the internal and external environment. Any mobilisation of knowledge during elicitation typically occurred between one representative of Weirs and the customer, with perhaps a 2-D representation of the product and samples of jobs and materials to assist. There was thus little opportunity for people at Weirs to pool their knowledge during the preliminary stage of a job. All this changed once production planning began.

7.2. PLANNING WORK : PRE-PRODUCTION PROBLEM-SOLVING

7.2.1. Planning the Job

Even before an enquiry became a firm order, its production plan was being sketched out by estimators in the Commercial department. Their aim was *'to work out the best way of doing it, to keep the cost down so that you're doing it as economically as you can, to make money and at the same time, hopefully, beat other people'*

[estimator]. Working from a precise job specification, together with outwork and materials prices obtained by the commercial manager or his assistant and passed on to them, the estimators collectively mobilised a range of technological knowledge to work out how production was to occur, *'you've got to find out how everything works to cost the job. You find out about everything within the company'* [estimator].

Almost everyone in the department¹ had done a three-year HND in Printing Administration and Management. This gave them *'an overview of all aspects of printing - all the different kinds of products, all the different stages'* [estimator]. It combined theory with practice, *'the basics and history of printing. All the different processes and how they've evolved. We were actually using the machines and printing stuff ourselves.. making plates, doing photocomposition'* [estimator], albeit not to the same extent as a production apprenticeship, *'but enough to give us a good idea of how they worked, rather than just the theory'* [estimator]. With time, some of their technical knowledge needed updating, and estimators did not get access to the trade press to read about recent developments. Trade magazines remained in managers' offices, *'I wish I knew more about repro. That side of the industry's moving faster than anything else... what they can and what they can't do. What we were doing at college was four or five years ago now'* [estimator].

This common formal training and collective exercise of knowledge provided the relatively recently formed Commercial Department with a sense of cohesion, which was reinforced by the physical proximity in which they worked. However, even the HND's mix of theoretical instruction and hands-on experience of production technology was considered insufficient preparation in itself for the work they now did, both by those who had done the course and those who had not,

Except the manager, who had served a stationers apprenticeship in the 0s, and one of the estimators, originally a bookbinding apprentice.

'College just gives you the fundamentals, it gives you a basic knowledge. Then you start work, and you start learning. It's probably like learning to drive - you pass your test, but it's not until you start driving on your own you really learn things.'
[estimator]

'I worked as a dogsbody in my first print place, in sheetfed. We had two weeks working shifts in the factory. I felt I learned more doing that than I had - it put everything that you'd learned at college into perspective. It put things together' [account manager].

'Nowadays they all come from college, so very few of them have done the groundwork that we had to do then - you worked in all the departments on the office side of it, with day release at college... five years apprenticeship. When you got to your fourth year, you went to work on what they called a "book", looking after one or two reps doing all their internal stuff. But times change, and I don't suppose it's any better or worse now' [Commercial Manager]

Knowledge of materials performance under working conditions was one example, 'at college you get [taught about] materials, but you don't know about prices, or about how they actually work on the machine... what paper weight is going to be better' [estimator].

From seeing how past jobs had run, they learnt rules of thumb, 'heavier paper usually causes more problems - you have to slow the press down. And on the folding, if it's really heavy, it needs to be scored first. And a light paper can also cause problems'

[estimator]. Although college provided a valuable grounding in specific basic principles, 'I had never done estimating for web work before. Without the estimating at college, I wouldn't have had a clue about the job' [estimator], work was seen as the most useful source of knowledge, including the opportunity to learn from one's own and others' mistakes, 'experience in jobs - things you've seen happening, things you've seen going wrong, can help you a lot'
[estimator].

Most people involved in estimating had previously worked in smaller, sheetfed firms doing a wider range of tasks, 'I've never really been solely an estimator. I've done jobs where I've done bits of this and that' [Assistant Commercial Manager]. This had given them experience of other aspects of managing production, even

though these were not their responsibility at Weirs because of the division of labour,

'the last place I worked was a lot smaller than this. We [estimators] did the quote, got the paper and repro prices and any outwork we needed. If we won the job, we would put it into production and plan it - when it was going to go to typesetting... when it was going to get finished. We had to follow the jobs round the factory. You had to do two or three jobs, but here we're just estimating' [estimator].

This provided them with broader estimating knowledge, an awareness of how what they did fitted into the management of production as a whole, and experience of dealing with customers. When they became account managers whose function was to liaise between the customer and the factory, these became directly relevant,

'you're looking after the whole job from start to finish, making sure everything comes in, making sure deliveries go out. Being an account manager, you see every other department, and you develop a good working relationship with them. You know more about what's going on in the company, the way things work. It does open your eyes' [account manager]

At Weirs estimators acquired knowledge of a different industry sector and its technologies,

'The large scale of things I found difficult to grasp. X was a tiny, tiny printer. A job worth £1000 was high excitement, whereas here you're talking tens of thousand, sometimes hundreds of thousands. It took me a wee while to grasp that sort of thing - the volume and the speed going through the machine and the value at the end of it. It's scary' [estimator].

This mix of technical knowledge and past experience enabled estimators to decide how jobs were to be produced. This included which machine to run, at what speed, and what set-up time to allow. Where solutions were not clear-cut they asked each other for an opinion, trading their past experiences at Weirs and other firms :
"has anyone done one like this before ?"¹. For more obscure,

Although Weirs' Commercial department was quieter and more sedate than Edom's office (7.2.1), the same collective mobilisation of knowledge was occurring.

infrequent, or complex problems, they asked the account managers, the assistant commercial manager, or the commercial manager, who had all done estimating in the past, and had more years of industry experience to draw upon.

Estimators could look up records of past jobs in the common files held in their department to find similar examples, *'I see how complex the job is, and do I know of some other job that's been done in the past. You can check how the job was quoted and how it went and why, and decide between those two how you're now going to quote'* [estimator]. As well as written information held in common, workers compiled their own files, *'you tend to pick it up over the years, and you keep hold of it. I think everyone's got files and drawers full of stuff'* [assistant commercial manager]. The content varied, but could include *'things like daft sizes that you come up against, and samples of things that you think "that's unusual"'* [commercial manager]. Although these were personal and sometimes idiosyncratically arranged, they could be accessed by others through asking for assistance with specific problems.

Over time, estimators built up shared knowledge of what jobs the firm could produce, and how these would be achieved, *'We've got an idea now of what we can and can't do, but [sometimes] we ask the supervisors, or somebody in the machine room, because they're going to be doing the job'* [estimator]. When a solution could not be reached within the Commercial department because of product novelty, or if they wanted a decision confirmed, they extended their search to production departments, either by phone, *'sometimes I just phone up the Production Manager, and say "this is the job : what'll I run it at ?"'* [estimator], or in person, *'you're always better coming up here physically and letting them have a look at it'* [estimator].

Knowing about production processes enabled estimators to imagine each stage, thereby ensuring that they did not miss out any production costs from the estimate,

'whenever I'm doing a quote, I like to think how it's actually going to be getting printed... how it's going to go through the press and get cut, and what way it's going to go through the folding machine. Once you know how all the machines work, then you can envisage how it's going to be done, so it helps you. Getting to look at the machines when I first started here was good, [especially] in the bindery, which was the hardest part to get a grip of' [estimator].

The ability to visualise progress of a job in three dimensions from a job specification without sight of artwork was a particularly important form of estimating knowledge. It could be facilitated and developed by making tangible dummies of the product. As their visualisation skills increased with practice and became a form of tacit knowledge, the need to create mock-ups of more standard products diminished. Some jobs resisted this process, *'I still can't visualise certain things being folded, and I have to ask'* [account manager], and dummies remained an important problem-solving tool¹,

'unless you can imagine it, probably the best thing to do is get a bit of paper. If it's got to be folded up in certain ways or certain numbers up, I'll draw it out on a bit of paper and fold it, so I know myself how it's going to be done' [estimator].

This was helpful to production workers who became involved in working out how to produce complex jobs prior to actual production. At this stage, some jobs were test run to check their feasibility, to decide in advance on the best method if alternatives existed, and to see if any "tricks of the trade" could be applied to make the run easier : collective resolution of problems between departments,

'a few times, I've had a really complicated one. It's usually the folding. So I've come up here with a diagram or a dummy, and said "this is how it's to be folded, can we actually do it ?" It usually means that the machine has to be slowed right down, or it's going to take them four hours to set up. One time I had three of the guys from the bindery arguing whether we could do it or not, and in the end they tried it on the machine, and we could do it' [estimator].

During fieldwork, interviewees frequently used their question sheets as dummies to demonstrate a technical point.

But their scope for manoeuvre was limited. Weirs had no input into the original design of jobs, and therefore no ultimate control over the product. They dealt with agencies who subcontracted design and repro to unrelated firms before the job came for printing,

'here all our stuff comes in made up how the customer wants it. So I can't say "it would be better folded this way". We don't seem to get that opportunity. The designers never say "look, can that be done?" We had this really difficult folding job. If they had made the short fold longer, we'd probably have got away with doing it normally, but...' [finishing supervisor]

This was a source of pride - "we can do anything the customer wants" - but at a price. It contributed to the perceived reluctance of the sales and commercial workers to intervene and effectively involve production departments in the initial definition of jobs,

'One of the salesmen said "we could have designed that to suit". But they never come and say, "by the way, IS this the best way to do it?" They ask us, "can we do that?", and we'll say "well yes, but it's a problem". The [commercial] are continually asking if we can do a particular product and what speed we can run it. I say 5000 an hour, and they always estimate for 6000. And [when we do the job] we get 5000. It's difficult' [finishing supervisor].

Once details of production methods had been established, estimators calculated a price using KEREN's estimating module. This took them step by step through the job, as they entered product specifications, works instructions and costs of materials and outwork onto a series of standardised screens. Although the system was easy to use, *'once you get used to it, it's just like second nature'* [estimator], the degree of guidance it offered could be a disadvantage,

'in a way there's not as much thinking to do, because a lot of it's already in the computer, and you just have to punch in things, and it gives you the prices at the end. But it's easier to make mistakes that way, whereas if you're doing it manually, you're checking everything' [estimator]

Mathematical knowledge, such as formulae for calculating ink usage, was part of the estimating program, and thereby rendered the estimators' knowledge of such things partly irrelevant. Informal knowledge in the form of rules of thumb for machine running speeds

had been incorporated into its databases. These too were known by the estimators, *'there are standard speeds for the average thing. If it's got remoist glue on it, we usually run at about 22K an hour. If it's a huge big job without glue, we'll probably run at 30K or 31k'* [estimator]. However, KEREN did not take into consideration certain aspects of jobs, such as the need to tweak machine speeds in response to the selection of specific materials, nor did it remind or ask users whether such action was appropriate. Forgetting to make such local adjustments in the light of contingent knowledge was a common source of estimating errors,

'if there's something particular about a job, like the weight of paper, it doesn't take that into account. Usually the computer works machine speeds out directly, but if there's something that the computer doesn't know about then I've got to add it myself' [estimator].

These alterations were important, because the design of the computer system meant that information entered for estimating purposes was used to generate the basic works instruction ticket that accompanied a job through the factory.

7.2.2. Planning Production

Whenever a job was "put into work", account managers followed a checklist of standard procedures to ensure that live information was circulated to production managers and supervisors so they could begin to plan ahead. A record of the job as it stood at that point was then filed in the commercial department's common system where it could easily be found.

If Weirs subcontracted repro work locally for a job, prior to in-house production, it became a customer for other firms' services, and had to explain to external specialists what work was required. A number of different people might take part in a face-to-face meeting with a representative from the repro house, each bringing a particular area of expertise to the proceedings, especially if the task was complex or its outcome not obvious. The production

director had many years' experience of specifying repro work using its terminology; the production manager could supply a printer's viewpoint, explaining what the implications of doing repro a certain way would be when the job was put on the press; the sales rep knew the customer's wishes about design effects and the price they would be prepared to pay; and the account manager needed to keep the customer informed about progress without necessarily being familiar with technicalities,

'So that I would know what was going on and what the job was, and what they were talking about, because bits were having to be rescanned and that sort of stuff. I sat in on it with (the production manager) and (the repro guy) and went over it. Really big, complicated jobs are like that' [account manager]

Other participants in the process were the job specification, estimate, works instructions ticket, and the designer's artwork including photographic transparencies. Everyone involved in such a meeting was able to "read" the instructions implicit in a piece of artwork - able to imagine the finished full-colour 2-D image from a combination of layers of laid-out text, loose negative transparencies, written directions and arrows. Sometimes not all the Weirs people were available for a meeting, and without detailed repro knowledge, they would have to explain as clearly as possible the end result they wanted without being able to suggest ways of achieving it. Such meetings were a collective mobilisation of different areas and kinds of knowledge among a disparate assembly in order to achieve a common purpose centred on one object : the image.

Planning where individual jobs fitted into the overall scheme of production was difficult. Specifications often changed between the placing of an order and the arrival of film, without notification. When the production manager received his copy of the work ticket to check works instructions and create a job bag, he sometimes found that despite successive screening for feasibility, an impossible job had slipped through,

'then the job comes to me. Are we doing the job properly ? How do

we do it ? Sometimes that will change. We've maybe quoted the job wrong, or we've taken a job on and can we really do it ? Sometimes the bottom line's "no", and then we've got to farm it out'
[production manager]

Sometimes missing information failed to arrive, and production began without it in order to meet deadlines. Customers might send the wrong jobs for printing,

'We were here one night and a courier arrived with some film they were going to use to print immediately. I just happened to go into the office, and there was a message in the fax saying "please phone us". We phoned them and they said "we've sent you through some film, but it's completely wrong. So can we have it back". They were just very badly organised, and every job we do for them, they're always the same' [account manager]

The uncertain nature of jobbing print work meant that prediction for more than a day ahead seemed almost pointless, *'they will tell you you're getting film on Monday, and they want the job Friday. They won't give you the film until Wednesday, but they still want the job out Friday. And you've got to make things happen'*
[production manager]. The general fall in demand for print caused by the recession, and the reluctance of customers to commit themselves to production until the last minute had worsened this situation. Everyone in the firm knew that constant changes could be expected, although not everyone accepted them or understood why they were likely. Nevertheless, the production and web managers continued to compile an overall forward loading schedule for the coming week, and a daily [24hr] production plan for the presses, knowing these would not remain accurate for long, *'you've planned a programme, which can last all of ten minutes. If I wrote a programme out, by the time I got to the bottom, I would have to rewrite it because something's changed'* [production manager].

There was a division of labour between overall and departmental scheduling, *'[The production manager] should be [scheduling], although it's my job to move the jobs about the factory, as long as I get the right timing and get them on the best machines at any given time'* [finishing supervisor]. Finishing schedules were only prepared for the coming 12hr shift, *'but that can change within an*

hour or two. It's just the nature of the work' [finishing supervisor], since being at the very end of the production process, they were subject to the accumulated delays of everything that had gone before. The futility of the exercise was viewed stoically, *'all your plans are in the bucket and you've got to start again. It's no good crying about it, you've just got to get on with it'* [production manager]. Fortunately, fast turnaround meant there were usually fewer than twenty jobs in the system at any time, which made it easier to keep track of the schedule.

However, once every twenty four hours, chaos was converted to relative order when management and supervisors from all departments including sales, commercial and administration met for the daily 10am production meeting, if they were in the plant. This was a formalised collective mobilisation of knowledge about all aspects of every job. Everyone brought to the meeting the previous day's list of jobs, arranged in descending order of closeness to completion, with a brief description of each, identified by title, specification, and state of readiness. Participants brought whatever objects they needed. For example, the commercial manager brought his paper buying file and delivery schedule, and the production manager and supervisors brought their daily schedules, freshly prepared, and sometimes proofs, printed sheets or finished copies. Film, dummies, samples of previous jobs or work-in-progress might also be brought. Whoever chaired the meeting called out the name of the job, and anyone with information to share about their department's part in it was invited to speak up. Other people could then ask for clarification or more information, or supplied it to answer implicit queries. Most attention was given to jobs about to come in, or which were causing severe production problems. Business was conducted at high speed, particularly for jobs almost done whose outcome was more certain, and the meeting was sometimes over within ten minutes. Afterwards an updated job list was drawn up and circulated. This was used as the starting point for next morning's meeting.

Opinion about the usefulness of meetings varied, although it was

mainly enthusiastic. Functional managers found them a practical and satisfactory way of keeping in touch with what was going on in other departments. This was particularly the case for those who needed an overview of how business was going and a more detailed, current picture of specific jobs because their tasks involved coordination and

'gleaning bits of information. You've really got to keep your finger on the pulse. But you've got to have information flowing between all the different departments, and some people will hoard it rather than be free with it' [commercial manager].

In that people were put on the spot, there was an element of compulsion which could only be avoided by non-attendance. Most managers could not adopt this method. Some felt that physically gathering together to share knowledge helped them cohere better as a team,

'I think they're very productive, because then everybody knows what's happening. I don't know what other people think of them - unfortunately the same people are always having to give you answers, the production guys. They're the ones who have got to produce the goods, so they might not agree.' [commercial manager]

'when I first was a manager here, we didn't meet at all. It was all by word of mouth, and it was an individual thing. But since [meetings started] we have met at 10 o'clock every morning, regardless. It keeps everybody informed. Everybody should know. It makes things an awful lot easier.' [production manager].

Line managers (the finishing supervisors) were more doubtful about the usefulness of production meetings for themselves. This was partly practical, since they were largely concerned with the internal workings of their own departments, and only present for one week in four because of shift patterns, which limited the possibility of them gaining the same sense of continuity as those who worked a five-day week. It could also be because as providers of information rather than active questioners, they were being constructed as "outsiders" to the management process¹ and put under a certain compulsion to accept the version of production being

compare the situation of Weirs' customers during elicitation (7.1.1).

presented¹,

'you find out a wee bit about stuff that's coming in, but it doesn't really deal with our part of the business. It's mainly about film. Occasionally they'll ask me if a job's going to be finished on time. But nine times out of ten, I don't need to be at that meeting' [finishing supervisor]

Meetings were the most formal and concrete expression of collective purpose within the firm, and the atmosphere was one of intense concentration on the common goal of getting production to happen. In this respect they were similar to informal problem-solving routines occurring in the factory in response to production crises (7.4). In some cases, meetings became a form of pre-emptive problem-solving, which included the visual aids of job bag, film, proofs and dummy.

Afterwards, information was fed back to each department on an ad hoc basis. Where this happened, it created a reassuring feeling of security, *'when jobs come in here, it's quite organised, everybody knows what they're doing. At my last place, everything was just thrown on a table and left for weeks on end'* [account manager], tempered by knowledge of what could happen in the next twenty-four hours,

'I always check how it's getting on. I keep a note in my diary to find out if the film's come in. About halfway through, I phone production to see how it's running, and make sure we're still going to make the delivery date. In an ideal world I wouldn't have to do that, but..' [account manager].

The activities necessary to answer the question "how do we do the job?" involved the passing of information which then enabled collective mobilisation of printing knowledge to occur. This could be within a single department, such as Commercial, drawing on a relatively homogeneous body of common knowledge to solve minor queries. In more complicated cases, a greater diversity of knowledge was mobilised between departments, as when production

Compare the situation of Freedom's visiting customers (6.1.2)

workers were drawn in to plan jobs. It united different levels of the firm's hierarchy in a search for solutions, again within or between functional areas. Technical knowledge was again vital at this stage, as was the ability to visualise products and processes. However, whereas vicarious production knowledge based on informal rules of thumb was largely sufficient to define a job and decide on its feasibility, the planning of jobs required more input from hands-on experience, and the importance of both tacit and contingent knowledge about printing and finishing at Weirs increased.

7.3. ROUTINE OPERATION : ESTABLISHING PRODUCTION STANDARDS

Once jobs went into production, how could Weirs be sure they were being produced to the correct specification and quality ? This aspect of production was performed by press and finishing crews and managers, using printing machinery, printed images, diagnostic instruments and job bags. They mobilised different kinds of knowledge about production, technology and the distribution of knowledge within the firm. Achieving basic production standards relied heavily on assumptions that bodies of common print knowledge and firm values existed. Although there was much passing of information, collective mobilisation of knowledge was less in evidence, although still present, partly because of shopfloor organisation into crews. The difference between this mode of "normal", relatively self-contained operation, and the all-out inter-departmental, cross-hierarchical collective mobilisation of knowledge during production problem-solving strongly parallels differences between the situations discussed in 7.1 and those in 7.2. What is described in this section (7.3) and the next (7.4) should be seen as a continuum of responses to technical difficulties, rather than a clear-cut separation between "unproblematic" or "problem" circumstances.

7.3.1. Web crews, presses and common knowledge

Given the physical length and running speed of the press, and the spatial location of essential functions that had to be carried out, the division of labour across crews was broadly similar, with an assistant at each end, and the two printers either at the main control console, or elsewhere around the press. Working relations within crews varied and their different tasks required a variety of knowledge.

There was consensus among printers over status within the crew,

'the number two on the machine, he's more or less number one anyway. The only difference is he doesn't make the decisions at the end of the day, but if he sees anything wrong, whatsoever, he'll maybe pick things up that I miss', [No.1 printer].

Both had undergone apprenticeship, and thus assumed that they had in common a similar mix of knowledge gained at college, combined with hands-on experience of production at work during their training period and after. This enabled them to make statements like *'he's obviously a fully competent printer'* [No.1 printer] about each other.

These assumptions were not based solely on time-served status. Printers (and managers) had knowledge of other printing firms, either by industry reputation or first-hand experience of having worked there themselves, and particularly of other firms in the same geographical region (Edinburgh and the Lothians) or industry sector (heatset web offset). They also knew the employment history of their workmates. Putting the two together, they worked out what site and sector-specific knowledge others were likely to have, as well as what particular models or sizes of press they would be familiar with. A constant and informal "checking-out" of workmates' (and managers') knowledge, as reflected in their actions, occurred, *'I would want to make sure, obviously, over a number of months or years'* [No.2 printer].

Internal arrangements for dividing up work between printers varied by physical location, partly because of press size, and partly because of the CPC's identical twin consoles, *'one each for the top and bottom sides of the web. Therefore, two operators can simultaneously do the settings of ink zones, ink duct roller and circumferential and lateral registers'* (Heidelberg UK, 1987),

'We've been working together for quite a while now, so... we'll take a side each; I'll set the colour, he'll set the colour, and he'll say "are you quite happy with that ?", and I'll say "yes", and he'll just sign it without hardly even looking at it. Because he trusts me, and so that works fine' [No.2 printer].

Arrangements varied according to the timing and sequence of operations,

'certain crews work differently, but we don't have set jobs... "that's your job", or "that's my job". We just work together. if he's there first, he'll do it, and if I get there first, I'll do it. So we just share the workload' [No.1 printer].

Perceived differences between printers and assistants were attributed by printers to innate ability and training,

'they're quite separate things, assistants and printers. And there's very seldom any cross between the two. I suppose it must be the case that there are assistants who would be capable of printing, but not all.... [selection] criteria are not as strict for assistants' [No.2 printer],

Assistants were expected to learn on the job, whereas printers underwent apprenticeship in

'The whole process, photography and platemaking, and you even got aspects of letterpress, although we were litho apprentices... we got a bit of bindery, basic skills in that, and an English class and a general knowledge class. They had a couple of machines there that you could practice making plates and putting the plates on and printing the job from start to finish' [No.1 printer].

Some crews did not include assistants in the process of judging quality, because *'I'm not down on them, but they've not got a critical enough eye on the products'* [No.2 printer]. However, other crews saw assistants' involvement in these activities as essential for achieving quality:

'I speak for our crew, but I try to make them responsible. I mean I can't see everything, so if ...they see something that looks a bit suspicious, they'll point that out to me... I'll then decide whether it is OK, or it isn't OK. I've maybe already seen it, but I might not have seen it. So we help each other in that respect'
[No.1 printer].

This was seen as helping to create a congenial working atmosphere (at least from the crew leader's point of view!), *'we do work as a team... the assistants know that .. if anything goes wrong it's going to come back to me, but ... I try to make them feel that we don't want anything to come back to us, so I think they do their bit'* [No.1 printer].

From the assistants' point of view, things were sometimes not quite as cosy. Some suggested that training on the job was much more "practical" than going to college (*'a waste of time'* [assistant]), and that they learnt all they needed from their work. However, some saw their lack of theoretical and practical knowledge of printing as a handicap in performing quality control where this was required of them, other than the most obvious things : cutoff between sheets in the right place; sheets inked over all the image area. If they did not know what they were looking for beyond these criteria, how could they be expected to find it ?

Assistants were interchangeable between both ends of the press. Operating the reel stand required no knowledge of the printing process itself, but splicing the old to the new reels required considerable dexterity and tacit knowledge, and the consequence of getting it wrong was automatic shutdown of production and having to unravel the web, resplice, and rethread the festoon before restarting, which could take between 1/2 to 1 1/2 hours. At the delivery end of the press, assistants inspected print quality by removing sheets at intervals as these came off the press onto the delivery pile (they had to know when to grab) and spotting problems at a glance (which required an eye for the whole as well as for detail), inserting wedges into the pile to keep it flat, and removing full stacks of printed sheets from the press.

Assistants acquired knowledge about printing by being around the press, albeit in an unsystematic way that rendered the knowledge local, contingent, and thus not portable. It was common to find once the run had started that the reel end assistant left his post while waiting for splicing, and came up to the main console to look at and learn about the job with the printers. Assumptions about common knowledge could therefore more appropriately be ascribed to each web crew as a unit, rather than to the individuals within them.

The major object of the crews' attentions, present throughout printing, production management and problem-solving processes was the press¹. Its most immediately remarkable characteristics were size and speed. Paper was fed into the press from a reel, passing through a unit which unrolled and aired a buffer length of paper, and began to adjust it to the appropriate tension and position. The following unit completed this process. Next, the web passed through five successive printing units, each printing one colour on both sides of the web simultaneously - almost always the four "process" colours plus one other. These were supplied by a pump system from 200kg barrels at the reel end of the press. The ink was dried by floating the web through a hot-air oven at high temperature, from which it emerged with much of its moisture content removed. It was then chilled down, coated with a rehydrating mixture of silicon and water, retensioned and repositioned. Finally the web was cut into sheets of uniform size, emerging onto the delivery platform. Once paper had gone through the press, it could not pass through again, so everything had to happen on the one journey. Other units could perforate, fold, trim and spine-glue sheets to produce certain types of finished product directly from the press.

Most press functions could be set up or adjusted from the central control consoles :

ee "Printing" section of video.

'lateral and circumferential register of the plate cylinders, ink keys, ink duct rollers, water pan rollers, plate inkers and dampers, damping transfer rollers, ink ductors, dryer, web edge guides, cutoff register and all other commands necessary for operating the press' (Heidelberg UK, 1987).

Instruments for achieving this included "magic eyes" and web edge guides after each tensioning area to monitor and control web position and tension. Sensors in the ink ducts measured ink levels, opening and closing duct tongues to control the flow of ink from the barrels. An infrared camera after the oven monitored paper temperature, which was adjusted automatically by moving the hot air nozzles nearer or further from the web. Photo-cells on the sheeter picked up alignment marks on the image area and corrected web position. Once the press had been set up, it was to a certain extent self-regulating because of such devices, although from a reading of the manual, it might have been assumed that no further intervention was necessary. Needless to say, this was not the case.

When making ready to run, two groups were involved : those always based in the press area - presses, printers, assistants, process inks and diagnostic instruments; and those assembled there for the purposes of a particular job - paper, plates, special inks, the supervisor and the job bag contents. To begin with, either the supervisor or the printers collected the plates and job bag from the pre-press area, brought them to the control console and ran through the job with the crew, alerting them to potential problems, *'"watch this, mind that"'* [supervisor]. The crew read the plates, the job bag and its contents.

The job bag was important for several reasons. It carried the job specification, from which they could deduce how to set up the press and what raw materials were needed,

'it gives me instructions as to ... whether it's through the sheeter, or folded on the press... perforated or glued... [or] trimmed on the edges. Whether it's four process colours, or special colours, or five colours, and what the paper should be' [No.1 printer].

It also carried works and despatch instructions, indicating operations to be performed by each department, and how long these should take - a source of contention. For the press, these were usually only detailed as "makeready" or "run", and the printers deduced the rest from the specification, although the production manager might add extra instructions, not always complete, which were supplemented by the printers' own experience,

'[he] writes on the back "Trim both edges", and it'll maybe not have "rotary perf" on it. And you'll think "well... it was rotary perf last time"... you'll say to him "is that not rotary perf?". And he'll say "oh yes, I forgot to put that down". But you only know that because you've done it before' [No.1 printer].

A dummy of the finished job might be enclosed in the bag, as a means of conveying instructions in tangible form,

'we do get folds in here which baffle people [laughs] - "what's that fold???"'. It's very difficult to write down exactly and understand exactly what they mean by it. So usually it's quite helpful to have a photocopy or whatever, which has been trimmed and folded to size' [No.2 printer].

Another visual 2-D cue contained in the job bag was proofs. These showed the colour balance of the image as passed by the customer,

'they're quite important, otherwise we'd just have to use our own decision to what the colours should be - which can be quite different from what the customer wants, so cromalins are important, or proofs of some sort, so we know what we're running to' [No.2 printer].

The final item in the job bag was the CPC cassette, which had been produced in pre-press using the plate image reader CPC. This scanned plates for ink coverage and density and stored the results on a cassette which was inserted into the press console to set inking and damping systems automatically.

The printers then prepared the press. They set up the units required¹; checked that the warehouse had brought down the correct

The design of the press made it possible to bypass unutilised units

number of reels of paper, and that these were the right width and weight; "webbed up" by threading the web through the press; bent the plates and attached them to the plate cylinders; and inserted the CPC cassette into the console. If small quantities (<10kg) of pantone inks were needed, these were mixed from stock using computer-controlled ink scales, and put straight into the ink ducts. Special customer mixings were stocked, and were brought to the press in a mobile pump system (a 20kg version of the barrels) and hooked up to the fifth printing unit, as were larger quantities of pantones bought ready-mixed. The job was then test run.

During testing, crews removed sheets from the delivery end, scrutinised them on a lighted lectern at the console and compared them to the proofs. For this, they used diagnostic instruments : the naked eye, linen testers and a densitometer. By examining the printed image on the sheets, printers could work out which parts of the press needed adjusting before the run. After a while

'you get to a point where you think "that's commercially acceptable", and you put them in as such - we just say "put them in"... That doesn't mean that they're A1, but they're good enough not to go in the bucket. Then... depending on how big the run is, you maybe run another half an hour before ...in your own mind, that's the best you can get on that particular job. Then you say "right, that's set", and you'll take pass sheets and customer copies, and the rest of the job you keep up to that' [No.1 printer].

Passing sheets was done by the web manager, or the No.1 printer on night shift. In practice, the supervisor sometimes left the printer to pass sheets, *'he'll maybe pass the job, although he puts his trust in us, and most times we'll pass it ourselves. But if he feels that he wants to, he'll pass it'* [No.1 printer]. Printers knew from experience what quality of print they could achieve, given the machine, the job, and the time allotted. After "putting them in", the cluster of workers and objects consisted of the press, the crew, the printed image on the pass sheet and the job bag. This comparative autonomy, apart from being founded on the trust generated by proven common knowledge, was a reminder of the plant's early days when there had been no middle management, and

top managers had been printers as well,

'They've built up quite a way of working on their own in here, which I've not come across that often before. Probably because in the early days... there was nobody there to chase them up and tell them how to do things, so they tended to carry on working like that' [No.2 printer].

7.3.2. Finishers, machinery and lack of common knowledge

Assumptions about the distribution of a body of common production knowledge could not be made about the finishing department. The four shift supervisors shared the common background of a bookbinding apprenticeship covering all aspects of the production process, *'printing as well as print finishing, and platemaking, composing, everything, just to get the basic instinct of the trade'* [finishing operator, ex-bookbinding apprentice], followed by ten to twenty years experience in a variety of firms, including previous supervisory work. They saw themselves as bringing to the firm a combination of knowledge, *'somebody that's got a good general background knowledge of finishing and practical experience, and somebody that's mechanically minded, that tends to understand the workings of machinery'* [finishing supervisor]. This made them able to trust each others' decisions about production methods and quality standards, which were particularly important when shifts changed in the middle of jobs. The main proviso to this was the length of time they had each been at Weirs, since none had worked in direct mail before and all considered that it took some getting used to. They were developing a corpus of sector- and site-specific, contingent common knowledge about Weirs' products, processes and machinery. Some had brought with them specific expertise which had been incorporated into Weirs as standard practice - an example of "knowledge leakage",

'I have quite an in-depth knowledge of folding and layouts. I even developed new folds to suit particular jobs. Here they used a lot of my ideas because they never had anybody who had done all these things before. And it's now standard for a lot of the types of folds we do' [finishing supervisor].

However, most finishing operators had been recruited from a variety of backgrounds, not necessarily printing. A few had done bookbinding or finishing apprenticeships. The rest had been trained on the job, a process that was still continuing, *'we're trying to work on them all and get them a bit of training and experience. It's between us [supervisor and worker], or we'll maybe put a poor operator on with a good operator, and move them around as much as we can'* [finishing supervisor]. Operators varied in competence, *'you have different operators who keep it running better than others. But if a slower man's following a good man, he can sometimes keep it going'* [finishing supervisor], and it was left to the supervisors to assess their skills and take these into account when allocating work,

'if you work with someone 12 hours a day, you find out what they can do. Or if something goes wrong, those that will push themselves forward and take the difficult jobs, and those who could do better but are quite happy to sit back and get the easy jobs' [finishing supervisor].

The division between printers and assistants was replicated in the finishing department, with the addition of gender as an extra factor. All operators were male, and all but one of their assistants female. Some women saw no reason why they should not receive training to become operators themselves, particularly as they were more likely to have previous experience of the printing industry, and had been watching operators closely for years, if not actually deputising for them,

'at my old place, the boss comes in one day and says "there's a job wanted, set the folding machine up for it". And I'd watched and I'd seen, but he must have thought we knew how to do it. And you know you haven't got a clue, but you say "yes". We figured it out ourselves, and we got it eventually. It was great' [finishing assistant]

Finishing operators and assistants lacked a common period of formal training and were consequently unable to imagine that a body of common finishing knowledge could exist and be shared beyond the boundaries of their own daily experience at Weirs. This had implications for their ability to establish production standards

unaided. It led to distrust of other operators' abilities, unless they had actually been seen working and contingent knowledge about each others' performance had developed. Most finishers appeared to have little meta-knowledge (Fleck, 1988) about the industry, and what they did know about printing could probably not have been articulated or generalised sufficiently to become portable into other workplaces,

'these shifts are all the same. They all think the other shifts can't do the job, it's only theirs that can. I've never experienced it quite as much as I have since I came here. It's mainly tradesmen¹ that I've worked with, and these are people who've been driving vans or down the pit, or have worked in paper mills. They come here, and suddenly they've become print finishers. That's the reason, because if you've served an apprenticeship, you pick up an awful lot of things unconsciously that you don't even realise you're picking up' [finishing supervisor]

This made finishing supervisors' jobs much more hands-on than the web manager's. They were almost like a roving No.1 printer, having to

'see if every machine's running OK, and pass all the jobs before they start running, check whether the job's going to make its required trim size and nothing's going to get cut off, that the quality's up to standard, and that we're running at speed. You give the operators a hand when they're having difficulties in set-ups, or with difficult jobs' [finishing supervisor]

They had to ensure that basic activities like reading and interpreting works instructions had been carried out,

'you can say to a machine operator "do this job and read the instructions on the work bag", but you've got to go back and check, because they only read half - "oh, it's a 6pp leaflet" - and they forget there's maybe a glued hem' [finishing supervisor]

The finishers' problems gaining knowledge that was other than contingent and based on work experience were compounded by the flexible nature of the machinery. Their knowledge was not embodied in the layout of their department. Unlike the presses, which always

Printworkers "with a trade", in other words, who had undergone apprenticeship.

occupied the same position, and always had the same parts (whether or not these were being used), the folding machines were composed of major basic units with a wide variety of attachments which could be assembled to suit the demands of individual jobs. This involved moving equipment around the factory floor to wherever there was enough space, so they did not even enjoy continuity of layout. Nevertheless, supervisors, operators and assistants all gained tacit knowledge about certain types of job, and the basic units' performance, albeit at differing levels of detail. This could be contingent,

'You get to know the machines if you run them regularly. This morning I was standing outside with my coffee and a fag, and some of the other lassies were leaving, and I said "well, did you have a nice quiet night, girls ? " "No we didn't. The T66 is running alright, but the T79 is a pain in the butt". We ask, because we're curious to see what we're going into' [finishing assistant]

It could also be device-specific, and less immediately context-dependent,

'The 66s only run particular jobs well. The 78s are far superior, they seem to fold better. They're the same make, but we have less problems with them. So you put the best running jobs on the 66s. If you really want to make sure that the job's going to be out of here, you make sure you put it on one of the 78s' [finishing supervisor]

Some operators had done apprenticeships, or were "mechanically-minded", *'I've always taken to machinery. I was good at it at school. I like using my hands' [finishing operator]*. They were engaged in informally accumulating knowledge about how the equipment worked and its component parts, sometimes taking the manuals home, and sometimes hanging around asking questions,

'I still learn new things about the Muller. I found out about the double detectors about a year ago off the engineers, and I've already seen two of the foremen here, and they know nothing about that. It's bits and bobs that you pick up' [finishing operator].

They then passed on their knowledge to other finishers during

production, on an informal ad hoc basis, *'you always learn off other folk and they learn off you. We teach each other. Watching each other. Talking about what you're doing when you're setting a machine'* [finishing operator].

Folding and stitching machines were set up and made ready prior to running, like the presses. The same two groups were involved : those always based in the finishing area - machines, operators, assistants and diagnostic instruments (rulers); and those assembled for the particular job - flat printed sheets, the finishing supervisor, web manager, and job bag contents.

To begin with, the web manager ran through the job with the finishers, pointing out things about the printing that would affect their part of the process. The finishers then read the job bag and its contents. By now, these included a newly printed sheet folded to size, as well as the original 3-D dummy and 2-D proof. Folding these was an art in itself, only entrusted to supervisors, and occasionally to an ex-bookbinder familiar with precision hand-finishing. This provided the workers with a sample of the real thing, although it was not necessarily reliable for setting up equipment for the whole of the run, since there would have been fluctuations in image positioning and cut-off during printing,

'you have a small shake in the web when it's running. If the web runs off to the left, the machine operator sees it, so their first reaction is to go away and start altering plate positions to bring the image back on again. Now within two or three minutes, the job's away out the other way. The only way you can overcome that is to let it run for a couple of minutes and see if it is going to come back itself' [finishing supervisor]

These 3-D representations were important as a guide to what was required. For finishers still unfamiliar with printing terminology, and unable to visualise a job from its specification, they functioned as a substitute for the written word, *'Knowing what you're heading for when you finish a product. Most folk, if you go up to somebody and say "gatefold, cut three edges", they wouldn't know, but it's seeing it in your head, what it's going to look*

like' [finishing operator]. For others they served as essential compensation for the inadequacy of language, written or spoken, to describe some of the *'weird and wonderful folds'* [finishing supervisor] they had to produce, without leaving too much scope for misinterpretation. Visualisation of product and process was significant for finishing too.

The finishers (supervisor, operators and assistants) prepared the equipment, attaching the extras onto the basic unit to build up a machine unique to the job in hand. Pallets of flat sheets were brought to the area, knocked up at a table¹, and placed in the folder. The job was then test run until it was passed by the supervisor. During this period as well as the run proper, assistants carried out quality control, sometimes to the annoyance of operators who saw it as solely their responsibility,

'sometimes when the boy's setting up the machine, but it's still not running too smoothly, I'll give him a shout "now look, Thomas, would YOU give this to a customer ? Because I wouldn't ! Get it fixed". I get slagged for it. But it's only too right. People are paying for a decent job, so you should only give them the best' [finishing assistant]

Once the run started, very little could go wrong that did not cause production to halt and problem-solving to begin. This was partly because the finishing machines were less automated than the presses, so they did not have diagnostic programs to indicate the source of faults, and partly because the kind of problems that arose could not be corrected on the run,

'many times it's a case of going back to basics and resetting all your roller pressures and then you eventually get it running, but usually they just try and push it to get it going again, and invariably it doesn't work. You've got to go back and start all over again' [finishing supervisor].

Answering the question "are we doing it right ?" relied on a common body of production knowledge gained during a formal period of

See "Finishing" section of video.

apprenticeship, on the basis of which workers could trust each other's decisions. For printers this was necessary because of the physical size of the press, which created a spatial distance between individuals. Finishing supervisors needed to rely on each other across shift changes (temporal distance) during runs, because few operators or assistants shared their knowledge. Although web crews changed shift during runs, this was not such a problem for them, because once the press was set, minor adjustments could be made without stopping and completely resetting the machine. Collective mobilisation of diverse knowledge was not as notable a feature of setting up jobs and establishing production standards as individual or crew mobilisation of common knowledge.

The acquisition of production knowledge by informal means within the workplace was a slow and partial process, resulting in a fragmented body of knowledge composed largely of informal, tacit and contingent elements. Web assistants, non-apprenticed operators and finishing assistants lacked a framework of formal and meta-knowledge into which other cognitive components could have fitted to create an understanding of the principles underlying the isolated examples they had experienced. This would have enabled them to extrapolate in new situations.

7.4. TROUBLE-SHOOTING : PRODUCTION PROBLEM-SOLVING

When production problems occurred, machines would stop or be stopped. A range of knowledge was then collectively mobilised by a variety of people and objects whose diversity increased with the uncertainty of the solution. Problems could arise for various reasons : the nature of jobs, production processes and machines, or a combination thereof.

7.4.1. The benefits of collaboration

Crews had to decide whether to tackle the problem among themselves, or to call for more assistance. Finishers in particular had difficulties making these decisions, and supervisors tended to do it for them, keeping an eye open for problems by walking round the factory,

'here they don't want to come to you at all. They want to soldier on. They want to solve the problems themselves, which is a good thing in a sense, but you can't always afford the time. Whereas when I worked at other places and they had a problem, they were geared up to come and say, so you know. You can go over and either decide to leave them to get on with it themselves, or you give them a hand, or send someone else, or an engineer' [finishing supervisor].

Web crews tended to initiate their own action. Differences between the initial strategies adopted by printers and finishers could be attributed to their respective knowledge. Apprenticeship training included the mechanical aspects of equipment and how these could interact with production. Time-served workers were thus in a better position to diagnose the likely cause of faults than those who had learnt "on the job", and whose training had not been systematic, *'you can teach somebody a machine, and show them how to operate it, but when they're left on their own and a problem comes up, they don't know what the problem-solving part is'* [finishing supervisor]. Finishers had to cope with a much wider variety of processes and products, *'the problem is that you could run one job on a machine and run it really well. An identical folding job coming at the back of it on a different paper, and it won't run'* [finishing supervisor]. They also contended with materials variations introduced by the presses, such as fluctuating image position and cut-off, static electricity, brittle paper and curled edges, all compounded by seasonal temperature and humidity variations in the factory. Sometimes advance collaboration between production departments could help minimise these problems, *'they've said to us "if you do this, that'll make it easier for us and make the product look better", and it doesn't make it any harder for us, so we'll do it'* [No.1 printer]. The machinery itself made a

difference to the problem-solving process. With the more automated presses, *'things are more straightforward and there's sometimes really only one way to do it'* [No.2 printer], whereas finishing machines allowed for a far greater variety of manual and ad hoc local adjustments to be made¹.

Finishers tended, through struggling on, *'to look for something more difficult than it is. Sometimes it's quite obviously staring them in the face, but they can't see it because they've been at it too long'*, so outside intervention provided a means of stepping back to think more clearly, *'It's amazing what you can do going over to see a problem fresh, and calmly'* [finishing supervisor]. This was one reason for involving a range of participants in problem-solving. Another was that the period of apprenticeship and the job mobility it subsequently allowed brought benefits denied to those who learnt "on the job" : the opportunity to meet people from other firms and swap knowledge and experience, which could be used for in-house problem-solving,

'none of these guys got to go to college. I know that I thought college didn't really teach me very much apart from my job, but it obviously helped. I remember talking to guys who were coming from other firms, and if you had a problem at your work, you'd talk to them about it, and they'd say "ah yes, when we get that problem, we do this". Plus I worked in quite a few firms, and that was quite common when I first became a journeyman. Going from one shop to another, you do pick up a lot of experience because every shop has slightly different ways of doing things, and you always pick up a slightly better way of doing something' [finishing supervisor].

The blend of a framework of formal and meta-knowledge within which accumulated work experience could be interpreted was a powerful means of problem-solving when mobilised collectively. It enabled individual print production knowledge gained from experience inside

These included the insertion of scraps of paper to adjust roller
sures (see video), and the replacement of missing parts by devices
led together from whatever came to hand, an example of "bricolage". In
instance, an extra device to rake printed sections into position had
rigged up on the stitching machine using a length of wire, a bent
) of a used plate, sticky tape and a piece of shoe sole.

or outside Weirs to be brought into discussion. The contributions of older workers and managers were particularly useful, since they had the confidence to deal with anything that came up, based on similarities to what they had seen before,

'as time goes on, the knowledge comes to you without you probably realising it. I've worked in numerous factories over a long period now, so I've come across most problems in one form or other. I suppose that's what you'd call experience' [platemaker]

It was possible to distinguish between breadth and depth of working experience, which were seen as complementary,

'you could work in ten different factories inside five years, but I don't necessarily say you'd gain experience. You'd gain an insight into different forms of printing. If you worked in Weirs for 32 years, you'd be experienced in what's being produced in here, but if you're taken out and put in another factory, you might find it difficult. It's a combination' [platemaker]

Older production workers and managers at Weirs typically had one or both of these types of knowledge. Those who had been at Weirs all their working lives had experienced the wide variety of sheetfed and small web processes and products undertaken by the parent firm before Weirs Web was set up. In addition, managers had visited other print companies, *'It's always interesting to go and see how other people perform, how they operate. Sometimes it's quite exciting, when you see how other people print, or just jobs. How they produce goods'* [production manager].

Another aspect of experience was the ability to remember specific past jobs and problems, either individually or collectively. Not everybody could remember jobs in the abstract, because over the years they had done so many. The web manager claimed that the ability to forget about jobs afterwards by putting them to the back of one's mind in a mental filing cabinet was an essential survival mechanism. It took a specific reason to recall them, like being in a problem-solving situation, when workers would ask each other memory-jogging questions like, "Do you remember that job we did for X last year?", or "there was that blue job, wasn't there?" which related to work of which they had common experience, albeit from

different perspectives, *'I'm quite good at remembering how things went. A lot of times the job's come on and I can speak to [the web manager] if there's something he can do about it, and say "remember we did this the last time ?" [finishing supervisor]. Any aspect of job specification or works instructions could be invoked to trigger memory, either singly or in combination, as long as they were sufficient to distinguish the job from others, however similar. By combining the viewpoints of all those who had been involved, and thereby collectively remembering at several levels of detail what had occurred, solutions could be reached by comparing and contrasting past and present in terms of significant variables. This entailed participants being able to visualise the job from talking about it. One problem with mobilising knowledge about reprints on this basis was shiftwork, since there was no guarantee that those who had printed a relevant job were present,*

'we should have a problem slip that goes in the bag the next time that job comes on. We should be able to say "we had this problem last time, and that's how they solved it", so at least you've got a head start. You can maybe save a whole shift' [finishing supervisor].

Certain factors influenced the ease with which jobs could be recalled. Visual appearance was one : either the nature of the flat image (which was often all that printers saw of a job), or the 3-D form of the finished product, *'a sheet of paper with print on it has to be exceptional to stand out in your mind, but an actual finished product is a different kettle of fish' [No.2 printer]. This made it easier for finishers to remember jobs than printers. It meant that memory could be assisted through the visual recognition triggered by samples of past jobs, and that reprints were easier the second time round, particularly if the job bag contained a copy of the finished product 'I can't always remember the name of a job, but I can remember when I see it again. It sort of clicks' [finishing supervisor].*

Another important characteristic was the textual content and meaning of the job. The fact that Weirs printed direct mail was mentioned by many interviewees with some regret. Because they did

not read what they produced, jobs were intrinsically less memorable,

'although jobs go through, there aren't that many will stick in your mind, because it is, in inverted commas, "junk mail". Unless there was a major catastrophe with it. Whereas in previous jobs, I can remember a lot of them, because of the subject' [platemaker].

Lastly, jobs were more likely to be recalled if they had been problematic,

I was sitting on the steps of the pressroom with my head in my hands, wondering if we were ever going to get it any better' [No.1 printer].

'You learn by your mistakes. You always think of what you can do in the future to avoid that. I've got a drawerful [of examples] up the stairs. It's like the Hammer House of Horror' [production Manager]

The collective mobilisation of knowledge during production problem-solving relied initially on a common body of printing knowledge. This enabled preliminary diagnoses to be made, and decisions about who and what to involve. It provided a framework within which individual and collective experience could be harnessed and taken on trust, when this was not necessarily founded on common knowledge. It enabled the contributions of those without formal print training to be set in context and to become useful. And by providing an alternative structure in which everybody's knowledge counted, it cut across the firm's hierarchy to draw in assistants, operators, tradesmen and managers alike. Shared visual knowledge played a significant part in this mobilisation process, as did shared knowledge of printing language.

7.4.2. Mobilisation routines

Informal routines for mobilising knowledge had developed for various types of production problems. These governed which workers and objects became involved, and which domain of knowledge they represented. In certain situations, print knowledge was judged insufficient, and the search for solutions was extended to other

domains, primarily engineering. What was the effect on collective problem-solving ?

Running unusual jobs could cause problems, particularly when nothing similar had previously been attempted, and this could lead to ad hoc - and very unautomated - solutions, such as a web crew member holding a piece of paper like a funnel to compensate for the shortcomings of the die-stamping unit's trimmings removal mechanism,

'they had a job on there the other week which was unusual - the first time I'd seen it done - it was circles for different sizes of rings - and they were having a problem ...they were punching it out OK, but they couldn't get the circles to come out.. they were trying to suck out what they could suck out, and they had to have paper so what was falling down would fall, not on the web but on the floor. It was the only way they could get round it' [No.1 printer].

In such situations, the crew, the other web crew (if they were on downtime or a smooth run), and the supervisor gathered round and offered suggestions based on combined past experience and diverse knowledge. By looking at samples of the printed image, printers could often tell which part of the press needed alteration. This enabled them to restrict the scope of their search for alternatives in order to get a workable solution whilst keeping costs down, *'it was a case of getting a result as quickly as possible. They charge so much for it... you've got to try and get it right... if you took long enough you probably could have got a much better way to do it'* [No.1 printer]. Once such a problem had been solved, the knowledge gained passed into the crews' repertoires and future similar jobs would not be perceived as problematic.

Some types of job started out as unusual and inherently problematic, but became routine as crews gained experience,

'sometimes you get jobs that you think are going to be a headache, and they're not... Once we had ... this job with fluorescent ink on it, and I thought "oh, it's going to be a nightmare, this", but it ran really well.... It was in a sort of orange... and we use it all the time now, just as a matter [of course]... Because we've done it before, we know it will go OK. But we didn't think it would go the

first time' [No.1 printer].

Sometimes customers with some printing knowledge might be drawn in to resolve problems or confirm solutions, particularly concerning matters of visual taste, although this was still in their role as "outsiders" providing information,

'yesterday afternoon we had a job on, and we had a proof. But the proof had been done in special colours, and the job was now getting produced in process so there was no chance that I was going to be able to match that. So I had to phone the customer and explain over the phone what the position was. And he told me "there's another cromalin in there with the same sort of illustration, and that's the sort of weight of colour I want". Had I not done that, they could have rejected the job. Because what we ended up with was night and day compared with what was on the proof' [no.1 printer].

For particularly difficult jobs, the engineers were called upon, even when it was primarily a printing problem. Figures normally more remote from hour-to-hour production might appear : the production manager and production director. Crews, engineers, supervisor and managers together would draw upon their previous experience of similar jobs or problems to compare solutions, using all the material objects they considered relevant : the press, the printed image, job bag, proofs, diagnostic instruments, press manual, and the engineers' toolkits. This was when the wider knowledge of older workers was most useful, *'Something will happen in here.. you can relate it back to an incident that perhaps happened several years ago, twenty years in some cases.... it's called experience'* [production manager], and both supervisors and managers found their previous work as printers vital for troubleshooting.

According to the engineers, two types of technical problem arose : real problems and ordinary faults, *'things break regularly, and it's just a matter of course, and you just go along and fix it, and that's it'* [engineer], the source of which could be traced with relative ease,

'you've got this big machine - it doesn't mean a thing to say that every single thing's going to break down on it. You know there are parts that always go wrong or they're a weak design fault, and nine

times out of ten when a machine goes wrong, it's going to be one of these areas' [engineer],

Real problems called for a different approach. When technical problems which the crew could not solve themselves halted production, the same workers and objects would assemble as for problem jobs, but with the in-house mechanical and electrical engineers, the basic press manual and fault-finding manuals, and the engineers' toolkits having added importance. Granted that such occasions provided a workbreak and a chance to socialise, it was clear from observation that a significant mutual exchange and mobilisation of knowledge occurred in the course of this apparently casual chat¹. This was supported by the engineers, *'you'll figure it out between you... Even the slightest wee bit of information, it maybe seems irrelevant, but then you say "ah well, that means this", or "that means that", and you take it from there'* [engineer].

Different bodies of knowledge were being pooled in such situations. The engineers brought their knowledge of general engineering principles, learnt at technical college during their apprenticeship,

'it wasn't about production... they didn't say "you'll find this or that on the machine". It was just a general "how a clutch works" or "how a pump works"... Because there's hundreds of different kinds - but basically they all work on the same sort of theory' [engineer].

This was combined with practical engineering knowledge, which had a large tacit component, acquired through work experience, *'It's just a case of hands-on.. If a thing breaks, that's when you learn how to fix it... [laughs]'*. Over the years, the engineers had built up a store of such knowledge, seemingly more resistant to the passage of time than more formal knowledge that was not put to practical use or contextualised, *'when you do something, it always sticks in your mind.. you can recall it, even if it was done three years ago - ten years ago, even. It always seems to be there'*.

See also 6.1.2. on the importance of seemingly desultory conversation with customers as an important source of knowledge at Freedom.

Through being called out to fix faults that were not actual breakdowns but essentially set-up problems, the engineers had acquired specific practical knowledge of printing machinery and techniques from a printer's point of view, *'And you've then got an insight into the machine.. but really that's not what you're employed to do. But that's what makes the job interesting, because then you know what they're talking about'* [engineer]. Through constant exposure, in-house engineers gained meta-knowledge about print, and had adopted its domain values.

To this, crews added their knowledge of printing, and of printing machinery. The engineer knew that printers had *'a general knowledge of what - how - the principles of the machine'* and that there were differences of knowledge between individual printers, *'there are certain operators who know more than others... and they're interested in their machines'*. The printers' knowledge of machinery, like the engineers' knowledge of printing, was at least in part gained unofficially, and was often self-taught.

The combination of the two groups' knowledge was mobilised by questions like, *'what about this ? has it happened before ?... what do you think ?'* and drawing on memories of past jobs or situations, *'And they'll say "oh, I remember it happened, and it was something in here", and point you in the general direction, and you'll start to figure it out'*. If the process was not mutual, problem-solving was slower, *'if he comes along and says "I don't know" [laughs], that's it - you could just sit there for ages, or you could go away in the wrong direction'* [engineer].

Under these circumstances, objects related to printing, such as the job bag, printed image, cromalins, and (print) diagnostic instruments were excluded from the problem-solving process, since they were not well understood by the engineers. Objects from one domain could not communicate with people from the other, since they carried knowledge that was either domain-specific or mobilised through hands-on experience. Only the press made a transition from the print world as it was worked on with engineering tools : it

shifted domain and became a machine.

If the crews and the engineer could not solve the problem, the supervisor would be told, and the manufacturer's engineers would be called in, '*[they] will diagnose it quicker, because they've been trained what to look for. They know exactly how to follow the drawings a lot quicker than us*' [engineer], although this was not a favoured solution, '*they don't muck about fiddling with things. If it's anything mechanical, they won't repair it, or strip it down and clean it and put it back together. They'll just replace the whole part*' [engineer], being costly and disruptive to production. The external engineers wanted to work alone with the press to preserve their economic status as experts, '*a lot of them are reluctant to give you tips, because that's you doing them out of a job*', although the in-house engineers would try to gain knowledge by offering their services, '*there's other things you can do for them, things that they don't like doing. Crappy jobs. And if you're helping them out, they'll help you*'.

The unease between internal and external engineers was exacerbated by language : the need for speech, '*Because you know what you want, you see, but you're not really used to speaking to folk*'; vocabulary, including the use of different terminology by external engineers to reinforce their status, '*they would talk in strict technical terms, whereas I would just say "it's the side lay"*'; and English accents '*They drive me nuts. You're talking to somebody from Birmingham, or London, and they can't understand you, or you can't understand them [laughs]*' [engineer]. When these "experts" were present, sources of everyday printing and engineering knowledge were discarded, and only those who could speak the language of the engineers' domain convincingly were attended to. Those who could not were silenced, either because their knowledge related to another domain (printing), or because it was non-formal, and could not be expressed fluently, or even, perhaps, verbally. External engineers then went through their own domain's definition and problem-solution processes until the difficulty was resolved.

The two types of knowledge mobilisation process noted at Freedom occurred at Weirs also, where they extended into production activities, such as defining production standards and troubleshooting. The same distribution of print knowledge operated. Everyone at this plant carried common basic print knowledge, including meta-knowledge about the industry. The various occupational groups, such as estimators or printers, additionally carried more specialised knowledge about their own area of work, gained from training and experience. Internal networking was significant, but there was generally less subcontracting and fewer workers had extensive everyday external contact. Both this and the preceding case study demonstrate that print knowledge is complex and varied, including fundamental design concepts of products and processes; criteria and specifications as mobilised for the production of works instructions; mathematical tools and device-specific rules of thumb for estimating cost, time or materials usage; a wide range of quantitative and qualitative information for categorising different aspects of jobs; and practical considerations. Mental procedures and ways of thinking about production, including visualisation of product, process and the interaction between them were extremely important, both prior to and during production. The ability to translate between two and three dimensions, and from original image to representations thereof to final product was essential. Workers carried all these aspects of print as a variety of cognitive components, which altered over time with experience, from formal to informal to tacit knowledge.

The final data chapter examines the distribution of print knowledge amongst workers and managers at Trinity, and the presence of substantial numbers of people carrying knowledge of another domain : engineering. It tells of a very different approach to everyday print production premised on a combined mobilisation of the two domains, together with technologies and products that simultaneously require and enable this. Throughout the account of preparing for and achieving production which follows, the substantive and cognitive content of workers' print knowledge is highlighted, revealing similarities and differences between this site and the others - in particular the importance of visualisation and contingent, device-specific knowledge, and a lack of industry-level meta-knowledge. Common knowledge (or lack of it) is again in evidence, and definition is shown to be far more significant during production activities than problem-solution and any concomitant collective mobilisation of personal knowledge, which appear notably absent. Even pre-emptive problem-solving strategies are demonstrated to entail definition, primarily from an engineering perspective. Yet this chapter too shows the construction of customers as "outsiders", partly because they are not considered to know about print, and partly because they work outside the plant. It also describes a reversal of Weirs' relations between in-house personnel and their equipment suppliers and engineers.

Contexts in which knowledge was created or mobilised occurred when the following questions were being addressed by personnel, and these are considered in turn in the sections below :

ACTIVITY	QUESTION	SITUATION
Assembling knowledge	What is this firm ?	Definition
Planning production	How do we produce jobs ?	Definition
Routine operation	Are we doing it right ?	Definition
Preventing problems	How do we make sure ?	Definition

8.1. ASSEMBLING KNOWLEDGE : DEFINING THE PLANT

This section examines the set-up of the new plant at Trinity in terms of the knowledge required for newspaper production. This could be seen as the deliberate social shaping of a technological system. By combining the introduction of new technology at a new site with changes in working practices designed to break the 'entrenched' and 'ridiculous' [Plant Manager] power of the print unions, current management aimed to cut costs, increase output, and raise productivity, in line with other newsprint companies which had already made similar moves¹. Yet the end products remained the same, as did its customer - its parent company in the city centre (North Bridge), where editorial, advertising and pre-press departments were located. The latter now supplied Trinity with all its work as final film, ready for plate-making and printing. There was thus a balance to be struck between old and new. Which knowledge had the firm attempted to preserve, and what new knowledge was acquired and created as the new plant began to operate ?

Who were the "carriers" of knowledge in this new "milieu" ? Trinity's Plant Manager had previously been Press and Pre-Press Manager at North Bridge. He had knowledge of the newspaper industry and its production stages, and years of senior management experience. However, he had not run a web offset litho plant. A second layer of management specifically oriented to litho production provided twenty-four hour production cover. They came from sectors of the industry with a less confrontational history of relations between workforce and management, and were unfamiliar with newspaper printing.

he first and most contentious example being Rupert Murdoch's move to News International plant at Wapping early in 1986. This was followed by exodus of other national titles from Fleet Street, and similar actions he regional press.

The Press Manager was in overall charge of the press. He had started out as an apprentice, become a No. 1 printer, and then a press supervisor in the commercial web sector. He brought to the plant hands-on knowledge of working on colour webs as part of a crew (see 7.3.1). His formal knowledge of print and presses enabled him to undertake and understand the more complex control settings. The Mailroom Manager's responsibilities on the finishing side were similar, although he also arranged set-up of the machinery for each run, often with the engineers. He had entered the industry as an apprentice bookbinder on leaving school some twenty years before, and had been a commercial finishing supervisor prior to working at Trinity. The Night Manager provided nightshifts with a combination of the knowledge of the Plant, Press and Mailroom Managers (who worked days). He had previously been a commercial miniweb manager, printing direct mail¹, and his earlier employment history was similar to that of the Press Manager.

These four managers all had conventional print backgrounds, and were time-served printworkers. Their years of experience had built on that formal training, and their knowledge was similar to that of management at Weirs. On the other hand, press crews had been assembled from a variety of backgrounds, which included some workers from the old plant, printers from the commercial web sector, and recruits from outside the industry. They were expected to work together and pool their respective areas of knowledge. Crews were trained in-house in a "classroom" situation and on the press as its construction was completed. Several reasons were stated for this mix of people : experienced web offset litho

is former boss was now Production Director at Weirs. This was an
ance of industry networks at regional level, unexpected because it
sed sectoral boundaries. Historically, there would not generally have
job mobility between newspaper printing and other sectors of the
stry at supervisory and managerial level. That this had occurred at
ity was a measure of socio-technical upheaval in newspaper printing :
shift from letterpress to offset litho, the introduction of colour, the
e towards better print quality, increased competition between a smaller
er of multinational firms with interests in a variety of media, and
ges in industrial relations.

printers were needed to start the new press working; non-printers were selected for their ability to '*work on their own initiative and not need someone on their back*' [Night Manager].

Reasons for retaining North Bridge workers were not made explicit, but it was possible to piece together the evidence : union militancy at the old site was considered largely the work of a small number of '*bully boys*', who had ruled over '*the silent majority*' [Plant Manager], with management collusion. Talent at the old site had never been given a chance, because years of service rather than ability dictated who became the letterpress No.1s and No.2s. Wholesale redundancies were seen as '*throwing the baby out with the bathwater*'. Those who showed potential for retraining were transferred to Trinity, although far fewer were employed.

Workers from the old site were steeped in the ethos of the firm, and in the tradition of working for a long-established company with a reputation for editorial quality. They provided a sense of continuity, and socialised incomers into the plant, rather than Trinity beginning life as a disparate collection of individuals starting from scratch without history. They had knowledge of what it was to print newspapers [as opposed to other printed products]; to print jobs to a fast turnaround at set edition times; and of the newspaper sector as a whole. This knowledge was not necessarily related to printing. One platemaker had previously worked in despatch. Those selected to go to Trinity had narrowly avoided unemployment and were perhaps grateful and compliant. Three years later, the glow had faded for some, '*the grass is always greener...*' [crewmember]. Others remained eager to prove themselves, '*just watch me go*' [No.1].

In short, these workers were carriers of essential meta-knowledge, and highly motivated to make the plant work. Some of them had an aptitude for the kind of technical knowledge possessed by engineers, expressed as '*being good with machinery*' [No.1]. One had done a motor mechanic's apprenticeship after leaving school, before entering the newsprint sector, where he had now been working for 21

years. This knowledge overlap made it easier for printers and engineers to work together.

The commercial web printers brought web press and printing knowledge, albeit to a slower turnaround and looser deadlines. This was important not only in the technical transition from letterpress to litho, but in coping with the vastly increased speed and output of the new press. They were familiar with CPC from a print perspective, in the same way as web crews at Weirs, and could identify whether problems were process- or job-related. They knew about colour and quality standards in non-newspaper industry sectors. This was important as full colour was a new departure for Trinity, and the press permitted higher quality output.

At the old plant, management had '*paid for peace*' [Plant Manager], and production had been loosely controlled with little regard to costs, as long as papers appeared on time. Commercial web printers were more cost and waste-conscious, having experienced production under the constraints of estimates and budgets. They understood the importance of keeping the press occupied in order to recoup capital investment. Hence they accepted matters when Trinity began to print an increasing number of one-off jobs behind the main paid-for titles, thereby eating into the time when printers could go home if there was no more work.

Recruits from outside the trade included plumbers, mechanics, electricians and electronic engineers who did not know about print or the industry. In common with the web printers and some of the North Bridge workers they had experienced a period of craft apprenticeship, the acquisition of a body of practical and theoretical knowledge validated by examination, and the subsequent distinction of "having a trade"¹. Some had been self-employed, which gave them confidence to work on their own. They were less likely than printers to have been trade union members, and perhaps

see 7.3.2. for the finishing supervisor's comments on "tradesmen".

less bothered about working in a non-unionised plant. In addition, their domains of knowledge overlapped with the engineers, so when technical press problems arose, they could attempt diagnosis or solution, thereby sparing engineers to work on major faults, or in the mailroom. If the press workers could not find a solution, they could communicate with maintenance engineers using their language, thereby bridging the two domains.

The mailroom was highly automated and usually functioned with the Manager and two workers. The finishers performed tasks like those of the assistants at Weirs : making sure copies were correctly bundled and that the stackers produced the right amounts. Some had worked as bindery assistants in other sectors, acquiring knowledge of production processes and machinery through experience and observation rather than formal training. Casual workers were regularly employed in the mailroom feeding items of direct mail into hoppers for automatic insertion into the passing newspapers. Automation had abolished the distinction between finishers and assistants.

Given the investment in plant and equipment and the importance of meeting edition deadlines, in-house maintenance and engineering support were considered vital. Each crew included three maintenance engineers : mechanical, electrical and electronic. When the new plant was set up, three mechanical and three electrical engineers were selected from the old site. They carried a recognised body of formal and informal knowledge derived from their initial training that was considered universally applicable, 'a gear's a gear' [No.1]. They were not perceived as party to the previous industrial unrest that had existed between unionised printworkers and management. At the same time, they were familiar with a newsprint environment, tight production deadlines and the need to ensure that machinery was maintained regularly and repaired quickly. Electronic engineers were needed, because of the design of the new press technology, and three were recruited from outside the printing industry, mainly from electronics firms in the region. At the beginning, all engineers were sent on '*extensive training courses*'

[Chief Engineer] particularly in electronics, and went abroad for device-specific training to the headquarters of the mailroom equipment supplier.

During dayshifts, engineers reported to the Chief Engineer, who spent much of his time walking the factory, observing machinery and discussing production with crew members, Press and Mailroom Managers. On nights, they were unsupervised, although the Night Manager was available for a second opinion. The Chief Engineer provided continuity by passing engineering information between shifts. His main function was not to supervise crews, but to maintain an overview of the whole plant, including the building; fire-fighting equipment; waste disposal; and all the services needed to run production equipment, such as air conditioning, compressed air for the hydraulics, and utilities. Finally, he had a network of external contacts for technical problem-solving : equipment manufacturers, parts suppliers and peers in other firms.

Retaining some of the former workforce seems to contradict the idea of the new plant as providing a fresh start. However, this notion is problematic - how to start production without knowing how it has been done before ? Trinity's new knowledge built on existing knowledge, albeit differently configured, and assembled from inside and outside the firm, the sector and the industry. Even so, knowledge of how production had been carried out at the old site persisted. This was partly due to an inability to forget the past. However, the knowledge served in part not as an example of how things should be done, but of how things should NOT be done.

Comments were passed contrasting other methods of introducing new technology unfavourably with the Trinity solution; in particular, employing unskilled or younger workers for lower wages was criticised as implementation '*on the cheap... crap in, crap out*' [Plant Manager]. The parent plant, which was in the process of transition between old and new (digital) pre-press technologies, was criticised for employing workers who knew more about operating computers than they did about printing. However, opinions expressed

by people at Trinity about North Bridge were coloured by their experience of dealing with pre-press in a production context, and there was also an element of constructing the latter as "outsiders", against whom workers at Trinity could be united. The construction of customers as "outsiders" is not surprising : it occurred in the other case study firms. What may appear strange is this status being applied to printworkers in the same group of companies, albeit in different departments at another site. It becomes more explicable if many workers lack print identity and industry meta-knowledge beyond their own immediate context, and if the dominant domain of knowledge within the plant is engineering.

Machinery and computer systems embody knowledge about production, and are objects about which knowledge can be accumulated. Trinity was equipped with highly automated and computer-based "state-of-the-art" production technology, so new that when the plant began to build the press, the manufacturers had not yet completed its design. The unfinished parts were primarily the complex electronic monitoring and control systems centred on the CPC, and their on-press relay systems. Press settings were automatically pre-programmed to default levels, intended to serve as the basis for fine adjustments by the crew during the run. Magic eyes and sensors embodied knowledge about correct measurements; those in the ink tanks signalled when a replacement was needed. In the MIS, knowledge was embedded in the system, in terms of the data entered to begin with or subsequently collected, the way its databases were organised, and the links set up between various fields and modules. Press and MIS together were a fully integrated CIM system - one could not operate without the other.

To the extent that it could at least partially set, monitor and correct itself, the press could be thought to require a workforce less skilled by comparison with those needed to operate less automated presses. Yet it was said by ex-commercial printers in the crew to have fewer sensors than a web press such as the one at Weirs, so there was no clear link between greater on-press self-adjusting controls and deskilling. It was not a straightforward

transference of knowledge from manual to automatic setting. Operating the web at Trinity did not require less knowledge, but a different kind. More specifically, it could be said to require a different domain of knowledge.

8.2. PLANNING PRODUCTION : DEFINING PRODUCT AND PROCESS

Trinity printed exclusively under contract, and did not tender for individual jobs. The production equipment had been chosen to suit its work. This regularity had important implications for the mobilisation of production knowledge. Evaluating initial job feasibility was not an issue, nor did the eventual specification come as any surprise. Contracts had been entered into precisely because they were possible. Given the time-sensitive, transient nature of the product, questions of feasibility were posed in temporal terms : could deadlines be met ? To a greater extent than at any other site visited, job specifications were predictable. They were embodied in the design of the production technology and the characteristics of the products, in that newspapers were broadsheet or tabloid. Quality was uniform for all jobs, unlike variations at Freedom, and to a lesser extent, Weirs.

Prior to production, a job was further defined in greater detail. Trinity's jobs differed from each other at a number of levels. The first was between each title in terms of finished size and time of appearance: broadsheet daily; tabloid evening. Giving workers the title of a job was sufficient for them to be able to define its size, the paper on which it would be printed, and the times at which it would be produced, since these were constant. The second was at the level of each day's paper, in respect of total pagination and position of colour pages which were the features distinguishing it from other days' or weeks' output. Pagination ranged from a minimum 18pp broadsheet/36pp tabloid to a maximum 48pp broadsheet/96pp tabloid. Colour could vary : mono throughout, or using process colours in the colour tower of A press, and black

plus one spot process colour [cyan or magenta] in the colour tower of B press. No pantones or mixes were used. The final differences were page changes between individual editions of the same job, and the run lengths for successive editions. In production terms, these were insignificant, since the speed of the press enabled the plant to cope with run length fluctuations, and page changes were easily effected.

Trinity's major areas of uncertainty about specification lay at the second level of difference : pagination, inserts, and colour page positioning. They were the most significant characteristics of a job, differentiating it from others in terms of production set-up and makeready. Hence the job was specified on the imposition form almost exclusively in terms of pagination and colour position. Each specification was elaborated only in so far as it differed from others of the same basic type. Characteristics shared with other jobs were tacitly assumed by workers.

Production management at North Bridge sent Trinity a running order for the week ahead, with a rough total pagination so that paper could be ordered if necessary. It was often Monday before this document arrived, but workers knew that the first edition of the Evening News was always the first job on the press on Monday mornings, and the reel store held ample paper stocks. Advertising and Page-Planning at North Bridge sent Trinity's Plant Administrator a list of all in-house features and inserts needed during the week, and memos about future inserts, including those of direct mail printed outside the firm (see 8.4.1) by firms such as Weirs.

Confusion occurred between the pagination schedule and the inserts/features list. Pages on one list were sometimes omitted from the other. People at North Bridge did not consider the printing implications of features, and did not know whether they constituted inserts or not. To be worth printing separately, inserts had to be more than 8pp. Otherwise they had to be printed as part of the main paper. Advertising often did not understand or

remember that shorter features printed as part of the paper used up press colour capacity, in their desire to achieve paid-for advertising targets, and Pre-press did not always notice that capacity had been exceeded. This created uncertainty.

Normally, North Bridge notified Trinity of exact pagination and the location of full-colour pages the day before the job was due to run. These details enabled the No.1 printer to declare the job "live" on the MIS, because he now had sufficient data to identify it in terms the system could recognise. First he generated a job number, based on the date, month and a numeric code for the paper's title. This enabled the platemaker to start making plates, as the information generated by barcode and ink scanners could be stored in MIS memory under the job number until needed.

The No.1 printer then decided the imposition needed, largely on the basis of colour requirements. This was a sometimes complex task, although restrictions on colour capacity helped to make solutions more obvious. He first worked it out manually using an imposition form (fig.8.1). This was a pocket-sized slip of paper, showing all possible black plate positions on the press (including those in the colour towers, whose position he took into account), on which he filled in the page numbers of the paper. Depending on the design and layouts produced at North Bridge, not all pages running through the towers would be colour, so imposition was not entirely regulated by colour requirements.

Imposition was not a matter of trial and error. Familiar formats were retained as tacit knowledge or '*second nature*' [No.1]. Less frequently encountered schemes could be checked out using rules of thumb. The No.1 used the system's "Imposition Catalogue" to select an appropriate template with which to preset these page details on the press. Ultimately this set the ink controls to an appropriate starting level for each page, depending on the images and text thereon. Every template could be customised. If he chose the wrong one (and there were over 500), the CPC might reject the job so that it could not run. Printers found it easy to press the wrong key by

accident when selecting the imposition number on the MIS, which resulted in problems with inking levels and damping controls when the job ran, as incorrect pre-settings did not correspond to actual plate position.

Selecting the imposition was done only by the press manager, No.1s and No.2s. Although familiar with sheet-fed and single-reelstand web impositions, this was one aspect of production I found baffling. Whilst I understood the underlying intention of imposition schemes, I could not have attempted any but the very simplest. Once the computer system had accepted the chosen scheme, a definitive imposition form was filled in with a note of the colour pages, and photocopies made. The Plant and Press Managers each received one as a double-check, as did the reel store manager; the platemaker needed the imposition to know how many plates to make, and with what information to barcode them; and crews used it as a guide when plating up the press.

The imposition scheme had implications for the route travelled by paper through the press. The No.1 used the "Web Path Catalogue" of the MIS and the imposition form to select the web path [the passage of all reels through the press] to ensure that the printed webs would be drawn together and folded in sequential order. To some extent, web path was a consequence of imposition. However, the press was designed to give flexibility of colour position, so webs could be slit, turned and shuffled on the turning bars. Additionally, if jobs were 24pp or less, the No.1 could use the colour tower of the other half of the press as well as the 3 units on one side, thereby gaining a further 8pp (spot) colour capacity. All this made choice of web path more complex, as the No.1 had to visualise turning parts of the web when selecting it.

This flexibility was needed because there was a conflict between what the press could be most easily set up to do - colour on the first and last four pages, which roughly corresponded to editorial preference for colour on the main news and sports pages; and those favoured by the papers' advertisers for maximum impact on the

reader - early right-hand pages or the "lifestyle" sections usually found in the centre. By 1993, North Bridge were reasonably familiar with what impositions were technically possible, and if uncertain they could phone to check up in advance, although there were still problems with feature inserts.

There were no job bags at Trinity. The completed imposition form functioned as both job specification and works instructions. From this document alone, crews could work out product and process. The ability of printworkers to visualise the 3-D final product from a written job specification, via a 2-D interim stage of flat sheets, has already been remarked upon¹. Doing and interpreting impositions involved a double translation : from written details of pagination and colour positions to make a 2-D diagram of a 3-D production process, during which 2-D web was converted into a 3-D product. It was easy enough to visualise the final product from the job spec. The hard part was working out how the press would achieve it. Because of the integration of printing and folding on the press, there was little point in making up a dummy of the finished product to work from, and crews knew from experience and common knowledge what each newspaper should look like.

Production at Trinity was easily scheduled. At the end of each shift, the outgoing crew brought paper to the reelstand for the incoming crew's first job. Only once during fieldwork did this routine falter. A long run one-off job took longer than anticipated, and reels were not prepared for the next shift. No other site was so predictable. There was a rhythmic flow of production through the plant, having both a daily and a weekly routine. At Weirs and Freedom, which were jobbing printers, workers often did not know what kind of jobs they would be producing the following week (nor even precisely which would run later that day), although they might have some idea of particularly long run or important jobs in the pipeline. Crews at Trinity knew to within

¹ chapter 4, as well as in the previous case studies.

minutes which job they would be doing at any given time of any day, and what this would involve. This was a kind of internalised informal and contingent knowledge (a site-specific rule of thumb). If a visible, tangible production schedule embodies knowledge, so does an internalised routine. And if knowledge can be transferred partially from human to non-human carriers and formalised, as with MIS, this process might be said to happen in reverse through the tacit memorisation of texts.

Knowledge about materials specification, handling and performance was important when planning production. Every day the Reel Store Manager transferred paper for next day's production into the inner storage area by the reelstands. He knew how to handle the reels using a fork-lift with a reel grabber (see video) : where to position the arms, how much pressure to apply to grip securely but without damage, and when to turn the gripper from vertical to horizontal before stacking the reel in the store. Contact between his body and the reel was mediated by an instrument, and his knowledge was thus an instrumentality, and an example of tacit knowledge gained from experience, building on initial rules of thumb.

To work out what paper was needed, he used the week's production schedule, which included a pagination estimate for each title; and the imposition form, which told him the number of pages being printed on each reelstand, and hence the width of reel required. This was combined with his past experience of actual run lengths and paginations, and helped by the regularity of the schedule. He used his knowledge of the likely imposition pattern for any given pagination to set out reels of the correct sizes if the form was delayed. This was complicated, as there were three reel widths¹ and 500 imposition schemes in common use, hence many variables to take into account, including the probable number of reelstands to be used, their position on the press, and whether or not they led to

known as "mains", "three-quarters" and "halves".

the colour towers.

The reel store manager knew about the performance characteristics of the materials - which ran with least problems (such as web breaks) and were thus most popular with crews; which had a level of absorbency most suited to the dot gain settings on the press and should thus be allocated to the two colour towers (given that annual quotas for ordering paper from certain manufacturers restricted their use); and which were least likely to stretch during production, particularly after splice, which affected the register of colour images on the web.

Every Monday afternoon at 3pm, before the final run of the evening paper, there was an 'informal' [Plant Manager] meeting in the staff canteen attended by the dayshift web crew, and press, night and plant managers. There was no written agenda and no minutes were taken. The subjects were usually the coming week's production schedule; manning levels and casuals needed; and any problems management or crew wanted to raise. The choice of topics was illuminating, in terms of the way it reinforced meta-knowledge about Trinity, its parent plant, and relations between them; and stressed the importance of containing costs. The Plant Manager felt these meetings were useful because they helped him to 'control' and sort out production problems at Trinity at an early stage. The physical position of participants in these encounters reflected power relations. The crew sat on benches round the table and the managers stood at one end of it. This was no collective mobilisation of knowledge. It was a definition by management of how production should and would happen.

8.3. ROUTINE OPERATION : DEFINING PRODUCTION

Printers rotated between locations such as the reelstand or on-press controls, or between activities such as helping the platemaker, changing plates, or working at the CPC. The No. 1s

allocated tasks among the crew at the start of each week. Given the size of the press, speed of production, and cost of mistakes, it was vital that everyone know what they were supposed to be doing and were able to do it. Equally, when problems such as web breaks arose, it was necessary for all to lend a hand. Rotation ensured that they remained competent in all activities, and did not specialise at the expense of flexibility. This system broke down the traditional division between printers and assistants, and made the crew cohesive, since everyone took turns to do unpopular or routine jobs, as well as more interesting ones where they had the chance to 'use *their brains*' [night manager]. Because of the nature of the production process and the technology, crew members were heavily reliant on each other. They knew each others' strengths and weaknesses from working together over time, and had expectations or made allowances accordingly. As long as each person pulled their weight, whatever that was, the crew functioned as a team, '*there are no passengers down here*' [crewmember], and there was a strong element of peer pressure to reinforce this.

8.3.1. Set-Up

The most remarkable aspect of the temporal division of labour at Trinity was the time spent setting up jobs compared to making ready and running them. This was a function of the size and the speed of the press, which had been designed specifically to print high-pagination newspapers so deadlines could be met. It was considered important to get the job right first time, without delays and without wasting materials. Ink was supplied from bulk tanks via an automated pumping system, so the main tasks were to web and plate up the press.

On the ground floor of the plant, ten nave-like pairs of pillars supported the weight of the machine above. Three pairs at each end housed the reelstands. Each had three reel arms, one in use and two in reserve, so at any one time between nine and eighteen reels were loaded. Beyond stretched the inner reel store, cool and light, its

floor covered with a pale sea of reels laid out on their sides ready for the day's production.

The reel stand crew worked steadily, rolling reels out of the store, rocking them to build up enough momentum to heave them onto the floor conveyor, and rocking them again as they travelled, in time to roll them off beside the reelstand. This required strength and tacit knowledge of how much push was necessary, given the varying weights and speeds of the reels. Coordination and positioning were essential to ensure that reels did not overshoot their destination, and that there was time to roll one off before starting to rock the next. Sometimes these operations were carried out by a single printer; at other times, one would send reels from the store, and others would rock and unload.

At the reelstand, they stripped the reel's protective end coverings, rolled it onto a movable metal plate set in the floor, rotated it 90 degrees, and pushed it onto a platform between the pillars which slid sideways to take the reel into the waiting reel arm, where it was slotted and bolted in before its outer cover was removed. It was important that reels sat correctly in the arms, otherwise there would be web breaks or problems with uneven unwinding. Printers' knowledge of how to achieve this was largely tacit - manual (did the reel feel secure ?), visual (did it look right ?) and auditory (did the reel sound right when it went in ?).

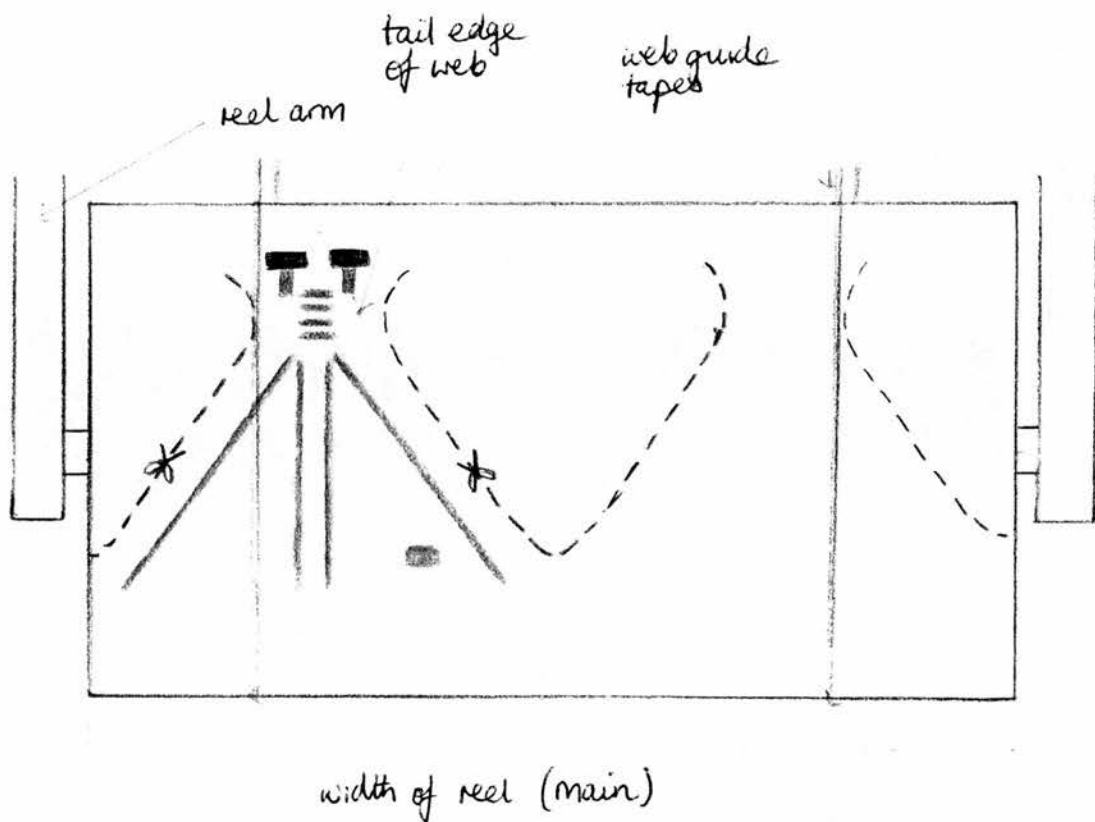
After the arms had been loaded, the loose tail end of the topmost reel was made ready for webbing up - drawing the paper web almost the entire length of its path through the machine while the press was at a standstill [see video]. The printers trimmed the incoming end of the web to a point, like a dinghy sail, reinforced both leading edges with sticky tape, strengthened the pointed end crosswise with tape (like sail battens), and tied the tip of the point to webbing tapes that ran beside the web path through the press (think halyards). The printers upstairs waited for the signal. Although there was a bell to indicate imminent web-up, what actually happened was that the reelstand crew shouted up through

the press, "there she goes", and the other printers helped haul the tapes from above. I almost expected to hear sea shanties. Once the webs reached the top of the printing units, they travelled horizontally to where they were wound round the turning bars in accordance with the web path, and pulled back down over the former to just before the folding unit.

Back on the ground floor, the other two reels on each stand were prepared for automatic splicing, the process whereby spent reels were replaced without stopping the press (see video). Air was expelled from the new web by smoothing it from the centre outwards by hand, arm and body pressure. Then its tail end was folded and the rough edge trimmed straight across with a scalpel. Putting on the splicing patterns required considerable precision, as various types of tape had to be exactly positioned on the tail edge of the new reel. Printers knew the function of each kind and how its position related to the design of the press and the production process. With a measuring stick and crayon, they marked out the position of the tapes, the guide belts which held the web taut in place, and the web points. Then they arranged the tapes in a complex pattern (fig.8.2)

Finally, they trimmed away the sides of the tail so it formed a neat point - two per full reel, one per 1/2 reel, and one full-sized and one half-width point per 3/4 reel. The geometric precision involved in this task was in complete contrast to the physical force required earlier. The hardest labour in the plant took place at the reelstand. Rolling and rocking the reels, which weighed up to a tonne each, made the printers run with sweat. Nevertheless, this was not the centre of the action.

During press set-up, the first stage of production began with reproduction of the image onto plate. Finished artwork was received electronically in digitised and compressed form by scanner. An integral processor developed and output each page automatically as film. Using the imposition form as a guide, the platemaker used the barcoding module of the MIS to record each film's identity before



Key :

- Black target tape ; read twice by reelstand scanner to trigger splice
- Red masking tape ; holds tail edge down
- Double-sided tape ; sticks old and new reels together. Covering left on where it crosses the path of the web guide tapes.
- Double-sided tape : initial point of contact between old + new reels
- Silver metallic tape : read by electric eye after folding unit, which triggers opening of the dump gate to let 6-8 copies fall, one of which will contain the splice. Not used if inserting, as missing copies foul up mailroom equipment timings

Fig. 8.2. Reel marking patterns for automatic reel splicing, Trinity.

plating it. This would interact with the imposition module to preset the inking level on the correct cylinder of the press. Since there were 22 plate cylinders with 2 x 4 positions on each, this was crucial.

Film was positioned in the plate processor, blank plates inserted, and the machine did the rest. Trinity needed a technology that could produce a large number of plates at high speed, since every shift required between 84 and 176 plates for the first job alone. Finished plates passed under a barcode scanner, then under one which read their inking levels, and the MIS relayed these instructions to the press. Lastly, plates were bent automatically so they would slot quickly onto the cylinders. Each end bent differently so that plates were always put on the press the right way up. The printers did this using the imposition form as a map.

8.3.2. Makeready and Run

Before each job, the No.1 called up the "current status" screen at the CPC terminal. This confirmed specification details, such as title, edition, pagination, colour page positions, and run length, which he now keyed in. The way a job specification was given indicated how jobs were categorised, and structured knowledge about them. Filling in forms and entering data at the MIS terminals about each job reinforced the way workers at the plant knew about what they were producing. It was difficult for them to think about production in other terms. Content - words and images - was rarely a method of reference to jobs at Trinity.

Once the press had been prepared, and the final plate fixed on, it was time to print. By then, the crew were congregated around the CPC desk, waiting for the last few pages almost until the deadline for starting production. At this point, they put on earmuffs and dispersed to their positions at the press. The No.1 started the web, running the job slowly, at about 10,000cph, in order not to waste too much paper. From then on, the system's production module

collected data in realtime and displayed them on screen. These included how many makereadies were being produced.

During makeready, the No.1 ran up the ink levels on the plates, so that an image appeared on the paper; set the position of the heads and margins using compensators that controlled the position of the web as it passed through the inking units, so that the image sat square; and fine-tuned inking on the mono pages so it was consistent throughout the paper. Once this was achieved, he speeded the press up to 45,000cph, and let it settle, performing the same adjustments again if necessary. This took only minutes. Finally, the machine was set to its usual running speed of 60,000cph, settled and readjusted.

When the No.1 was satisfied with the copies he examined, he raised the dump gate from the CPC, keying in confirmation that the run had begun. At this point, the "current status" screen started to clock up the number of good copies produced beside the total required. Until then, makereadies poured down a chute onto a moving belt which carried them directly into the waste paper compactor. Closing the dump gate activated the conveyor into the mailroom and stackers. It was possible to tell when this was about to happen because the sound of the press changed as it speeded up. Likewise, it was possible to tell when a run was ending.

All these tasks were undertaken from the main CPC console, rather than using on-press controls. This was more convenient, given the size of the machine, and gave an overview of what was going on from the information screens at the CPC, an area to which the crew returned from time to time during the run. The design of the press meant that the CPC was the only place from which a finished copy could be obtained¹. Printers pressed a button, automatically extracting a single copy from the flow, delivered down a chute.

compare with Weirs (see video), where printers hovered at a delivery snatching copies as they emerged, and rushing back to the control

This was examined on the spot, and immediate adjustments made.

Other crew members made settings and adjustments during makeready and run. The press had been designed with space for more than one person to work at the CPC. A further exception to task rotation among the crew was the setting of inking levels at the on-press colour tower controls and any adjustments made either there or at the CPC during the run. The full colour tower was usually the province of the No.2, although responsibility for the spot colour tower was passed around.

Because the press produced 60,000 finished newspapers an hour (1000 each minute), even a few seconds' delay using instruments before adjusting the controls could waste hundreds of copies. Printers at Trinity did not work from colour proofs, nor did they use linen testers or densitometers, because there was no time. To compensate for this, the press was pre-programmed to the UK Newspaper Society standard (UKONSS) which established acceptable levels of dot gain for each process colour and +/- percentage tolerances.

Their judgment was therefore based on examination of the printed image with the naked eye under daylight fluorescent lighting at the CPC. This involved knowing what quality of colour was adequate and how to attain it with maximum speed within the agreed tolerances, since there was no absolute standard such as a proof for comparison. The skill needed here was "an eye for colour", a visual form of tacit knowledge. This was seen as an innate ability which, even if never used before, would develop from scratch within a couple of weeks. Printers could train for months and still not acquire the knack, '*you've either got it or you haven't*' [plant manager]. Printers knew what was acceptable given the perishability of the medium and customer expectations, '*it's only newsprint*' [No.2 printer]. They looked for accurate registration as far as the eye could see (rather than to the micron), so that the image was not blurred, and sought a colour balance appropriate to the subject. Apart from not using diagnostic instruments, they were sometimes hampered by the quality of the original image. Crew who

lacked colour coordination developed other areas of specialism, such as making fine positioning adjustments to the web so that the printed image sat square on each pair of pages and was consistent throughout the finished folded copy of the paper.

These functions were performed mainly at the CPC, but sometimes on the press itself. Apart from the "current status" screen, the CPC had a second terminal, on which other control screens could be displayed. These were diagrammatic representations of press sub-systems. Those for position could be operated directly by pressing touch-screen controls denoted by arrows indicating movement to the drive or operator side of the press. There were no calibrations. Printers had to know how much pressure to apply and for how long to achieve the desired result. They could only check the effect of their action by examining the product. The "logged events" module recorded every single adjustment made, and the press manager, No.1s and engineers had seen enough printouts to know that crew members had different approaches to the controls. For example, some only touched the screen a couple of times, with wide swings around the final setting; others made smaller, more numerous alterations, inching their way.

Inking levels were set using touch-control strips along the console desk which represented the positions of the ink ducts on any cylinder. Above this a copy of the paper was spread so that the printed image could be related to the duct controls (see video). Although there was an imposition form at the CPC, printers tended not to refer to it. They knew which page of the paper was printed on each unit. The printer then specified which inking cylinder to adjust by calling up the inking system screen diagram, and selecting the duct he wished to adjust. Touching the screen activated the link between press and control strips. Strips with up arrows increased the flow of ink; those with down arrows decreased it. Again, these controls were not calibrated.

Taken together, screen and desk strips provided a 3-D representation of the press. The screen display showed the height

and length of the machine, whilst the strips enabled printers to control what happened across the breadth of its cylinders. When adjusting inking, printers had to look at the page as a set of strips from top to bottom, and select the best level for each strip as a whole, bearing in mind the overall look of the page, and adjacent strips in particular.

Performing these settings and adjustments at high speed required knowledge that had been internalised and made tacit. These were instinctive, almost reflex actions. The crew did not have time to stop and think about what to do to obtain the effect they wanted. From looking at a copy of the paper, the printers needed to know what result the settings they were responsible for had on the appearance of the product, and to isolate this from those done by anybody else. They needed a clear idea of what the final paper should look like and its print quality. Working from a copy of the product, the imposition form and the screen diagrams, they had to be able to recognise instantly which pages were being printed or folded on which individual unit of the press : to relate a 2-D representation of a machine to the 3-D output produced by that machine. Finally, they needed to know how to set and adjust the controls with speed and accuracy.

Each run lasted between 20 minutes and one hour. Throughout, printers monitored the end product and made any adjustments necessary. Meanwhile, the "current status" screen displayed the required run and the number of copies produced so far. This figure did not update in realtime, but at 30-second intervals (about every 500 copies). As the end of the run approached, the No.1 slowed down the press to about 45,000cph, and finally hit the "stop" button, gauging how long it had been since the last update. This finalised the count, disengaged the clutch that drove the machine, threw the inking cylinders off the web, and opened the dump gate for surplus copies. On every run, he aimed to produce no more than 200-500 overs, so his timing had to be accurate to within 10-30 seconds, allowing for the CPC display timelag.

Once the first edition had been printed, the platemaker waited for amended pages to make new plates. At the reelstand, old reel ends were removed from the arms and new ones fitted and prepared for splicing. Production areas were cleared of waste, and the crew waited for the next edition time. Then the process started again.

8.4. PREVENTING PROBLEMS : DEFINING MACHINERY

8.4.1. Pre-emptive strategies

Most problem-solving at Trinity was pre-emptive. Since the end product was so time-sensitive, the site could not afford for anything to go wrong during production. Jobs delayed by more than 5 minutes were considered problematic, and there were targets of <5% waste and zero overs. A variety of pre-emptive strategies were employed : regular maintenance of all equipment; weekly cleaning of machines; the use of simulations after engineering work; and test runs prior to production. Once jobs were running, pre-settings, defaults and self-monitoring devices ensured a minimum print standard, unless unexpected faults developed. Information collected by the MIS combined with the experience of production and engineering crews provided a basis for discussion of problems, with the aim of avoiding them in future.

Manufacturers' engineers were infrequently called in to solve technical problems. In the case of the press and stackers, this was because Trinity knew more about the machinery than they did, having seen it through the final stages of its development and worked with it ever since. Contact was more likely to be because the manufacturers needed information. Even the purchase of spare and replacement parts by the Chief Engineer was mainly conducted directly with smaller independent component suppliers, in order to cut costs and delivery times. The MIS had been reconfigured extensively from the original specification during implementation. This process had been so protracted and problematic that relations

with its supplier were infrequent. By contrast, engineers from the buffer reel and inserting equipment supplier visited Trinity when need arose, working closely with the engineers and the mailroom manager on serious technical problems, such as timing difficulties on the insertors. In-house and external engineers worked together as equals, sharing a domain of knowledge largely untouched by print considerations.

The in-house engineers were an integral part of the crew, rather than a separate service. As a team they had a mix of knowledge, although each had particular experience of electrical, mechanical or electronic engineering. The problems they dealt with could not neatly be compartmentalised into one or other type, and even if a fault appeared at first to be mechanical, it might turn out to be electrical. Where tasks required specific knowledge of one branch of engineering, the worker with that knowledge would take charge, with the other two assisting. Their principal skill as a group was said to be rapid problem diagnosis.

They were frequent users of the MIS, which included two modules especially relevant. One enabled them to print out a list of routine maintenance jobs and the frequency with which they should be done. These had been defined by the press/MIS manufacturer and incorporated into a database. A clock in the system interacted with this to flag work needed on any given shift, day or week. Some tasks, such as oiling gearboxes and pumps, were part of the engineers' daily routine because they were fundamental to the operation of the equipment. Others had been added because the consequences of not checking them were serious. They examined daily the pins that pierced and held the web steady before it entered the second folder, to ensure that they were in good condition. If these sheared during a run, production would be severely disrupted and the press would be damaged.

Because the mailroom was not linked to the MIS (apart from the stackers), an alternative had been devised. This consisted of a card system in a boxfile, which listed jobs to do, their frequency,

and the item of plant involved. The maintenance crews had drawn this up themselves, using the equipment manufacturers' recommendations as a guide to setting up their schedule. With experience, they had amended this where they had found that in practice more work was necessary, although they had not reduced their workload correspondingly where it was not.

Because production was so regular, there was little difficulty in scheduling times for equipment maintenance. This was done between jobs and during set-up prior to makeready and run. The engineers knew the edition times, and by looking at an imposition form or the weekly pagination estimate, they could find out which units were not being used, and plan work accordingly. The main problem was finding time to carry out all the manufacturer's recommendations. In practice, maintenance engineers did what they could when they could after prioritising the most important tasks, and hoped for the best.

Cleaning press and mailroom equipment was another way of preventing production hold-ups. Production generated paper dust, or "lint", which settled on the machine like cobwebs (see video). Where oiled parts were exposed, lint eventually clogged and stopped them working if not regularly removed. This was also the case with the magic eyes. If the reelstand eye clogged, it failed to register the new reel's target tape, and splice would fail. The press needed to be cleaned of excess ink which rubbed off the web onto the turning bars and folding units. This caused the web to adhere momentarily to the machine, slowing it down and throwing out the timing. Worse still, the web might stick fast and break, halting production. Ink and lint combined on the impressions cylinders increased hickeys, with no opportunity to remove their cause during the run without stopping. Apart from specific times set aside for the crew to clean the press, they cleaned up before makeready, paying particular attention to the magic eyes.

Test runs were an attempt to problem-solve in advance, pre-empting potential mishaps and stoppages. They were another example of how

Trinity tried to reduce uncertainty about jobs as far as possible before production occurred, in order to meet edition deadlines. They were done for a variety of reasons.

Small items of direct mail for insertion were received in advance so Trinity could decide on the method to be used : hand feeding into the inserting machines, or reeling on and off buffer reels. Hence test runs could be a means of selecting from alternative production methods on the basis of the experience they provided. Usually only crew and supervisors were involved, unless there were unforeseen difficulties, in which case the engineers were called.

When jobs were to be run on machines infrequently used, such as the stitching lines, they functioned as a means of ensuring that the equipment was still in working order, and as a reminder to the crew of how it worked. The test run was an opportunity to set up and makeready in advance, although a final makeready would be carried out immediately before running the job. This type of test run was usually carried out by crew and engineers together. It occurred most often in the mailroom, since there were few units of the press not in daily use. Engineers were needed in case technical faults had arisen since the machine was last used. In the mailroom, engineers became involved in set-ups and tests because the two crew members were not considered to have sufficient knowledge to assist the mailroom manager, and the dimensions of the equipment were too great for one person to perform the task single-handed.

Lastly, test runs were used to rehearse complex jobs, such as multi-section Sunday papers with magazines and direct mail inserts. Both engineers and mailroom manager took part, because of the combination of technical and production knowledge required to problem-solve. It was important to coordinate timings correctly on all the different equipment, so that the end product was complete and in the correct order. Testing could be done incrementally. If each successive insertion of one item into the main section of the paper could be demonstrated to work, it was considered reasonable to assume the whole job would run.

Some inserts were less problematic than others, and did not require practice. Since printing had not yet occurred, old copies of other jobs of similar pagination and finished size were used as substitutes. During test runs, the same part of the process was repeated over and over, with gradual adjustments, until the crew were sure it was right. Rehearsals provided experience of how the job should run, and confidence that machinery was correctly set and should therefore perform according to plan, barring accidents.

Test runs emphasised technical aspects of jobs; making sure machines were correctly calibrated and ran within the parameters laid down by the manuals for their operation. Unlike the problem-solving situations that united production workers and engineers at other sites, there was little tinkering with the equipment to fit the specific requirements of each job. Solutions were generated predominantly using knowledge from the engineering domain, with the underlying assumption that if machines worked properly, jobs would run smoothly. Given the relative uniformity of the product, and the fact that the technology had been designed and set up to run these jobs, this approach reflected the importance accorded to the engineers and the wider distribution of this domain of knowledge among production crews.

Simulations were performed in downtime between jobs, or when equipment was not in use. After engineers had repaired or recalibrated part of the press or mailroom equipment, they ran that part in isolation from the rest of the machine to make sure it functioned. Unlike test runs, simulation did not use materials, such as paper, ink, finished copies or inserts. It was especially useful for adjusting reel arms or compensators, since there was no need to web up. Simulation was an economical way of proving that the machine worked, and hence that production could occur.

8.4.2. Fire-Fighting

Despite these measures, problems still arose during production, either with the material inputs and outputs, or with machinery. The commonest cause of stoppages was a web break. The printers had dealt with so many that they knew to expect them shortly after splice as the new reel was brought up to speed, and in the printing units, particularly the colour towers, where tension and pressure were first applied to the paper. They had a routine involving the whole crew which enabled them to clear away waste, web up and resume production within 10 minutes. Compared with between 30 and 90 minutes for webbing and restarting a much smaller press at Weirs, some explanation is required : Trinity had seven crew members to lend a hand; web guide tapes to rethread the web; no intricate dancing rollers or infeed unit at or near the likely breaking point; no production processes additional to printing and folding (not even edge trimming); a press designed for swift makeready; and a product that did not require rigorous quality control.

Catch-up and filling-in were printing problems with standard solutions, almost not worth mentioning and easy to remedy. Knowing what to do was a fundamental element of printers' knowledge, based on an understanding of the chemical processes involved in offset litho. This was part of the formal knowledge that remained relevant after training ended, elaborated by daily experience. These did not often occur because of the automated ink/water regulating system and because a routine of running up jobs on the press had been established that would avoid them. Only if press speed was suddenly altered was the level upset, particularly at high speed. Paper passing through the printing units took more ink off the cylinders than the pumping system had yet been directed to replace, producing an excess of water, and hence a scummed image. This occurred during fieldwork. The press manufacturers used Trinity as a showcase to demonstrate their products in action to prospective customers. One such group were being shown the press in operation. The Plant Manager asked the No.1 to take the press up to its maximum of 65-

70,000cph, instead of the usual 60,000cph. Hundreds of scummed, wasted copies poured through the dump gate as the visitors watched. Sorting the problem meant slowing the press considerably, and letting the balance settle before working back up to a comfortable top speed.

Process-related problems like these were relatively easy to diagnose and their remedies were straightforward, being incorporated into production routines. Only the crew, and sometimes press or night managers, were involved; there was no need to summon engineers unless a broken or faulty part was discovered. Trinity was unlikely to experience the product-related difficulties other fieldwork sites faced running unusual jobs, because of the homogeneity and repetitive nature of its output, and the simplicity of the production process.

Apart from a limited range of routine running problems, there were almost no non-routine production-related problems. Jobs always ran. An interesting side-effect was that production workers did not tell horror stories. Jobs were not sufficiently problematic or distinguishable one from another to be recalled individually. Nor were difficulties producing jobs at their previous workplaces useful as examples to draw on for problem-solving, since equipment and working practices at Trinity were so different.

Because of the size and complexity of the plant, engineers spent much of their time "fire-fighting", rather than undertaking preventative maintenance beyond that specified by the two systems referred to in 8.4.1. This was compounded by their deployment around the site as cover for absent crew. Many commonly failing equipment parts, such as bearings and hydraulic cylinders, were sealed, and could not readily be inspected for signs of wear. The first indication that they needed replacement was when they malfunctioned.

It was therefore vital that crew and engineers should be able to find and solve problems as fast as possible. Some printers had

engineering knowledge, and engineers had been selected for their fault-finding abilities, so they were able to exchange information. When engineers were summoned to a press breakdown, they worked with the crew, who *'hate[d] standing back and letting someone else do it'* [plant manager]. They had assistance from the press itself. The CPC indicated the general location of a problem on a screen display, flashing at the affected area of a system. Having established which subsystem was most likely to be malfunctioning, they used the "logged events" module to obtain more details. This recorded every single adjustment to the press, at what time and by which crew.

This was an important diagnostic tool when problems arose, because it noted actions the press took, such as "clutch jumped out" or "web break in unit 1, colour tower, B press". The engineers could scan preceding entries to see what had happened in the run-up to failure. This included finding out whether adjustments made by production workers had contributed to the problem. They could search the MIS log to see when the same problem had last occurred, and if there were any discernible patterns. The press had so many parts that this facility saved time locating and analysing faults.

Maintenance engineers kept a manual log of all incidents they were called to attend; a handy reference tool based on their own experiences. In writing up this log, they described the problem and actions they had taken, to render it comprehensible to engineers in other crews. This made them remember the incident and think through what they had done. When not under time pressure, engineers assigned problems to existing categories of faults they had encountered before, or created new ones.

Calling the in-house engineers was not always the first action of production workers when technical problems occurred. Printers knew which faults were likely to be job-related and hence soluble by their own efforts, and which required engineering assistance. However, they sometimes wrongly assumed that certain problems

should be within their competence to solve¹. They saw failed pastes and web breaks as the result of inadequate splicing practice. One reelstand had recently given particular trouble. When the engineers were finally called to examine it, they discovered that the angles between the arms were out by 7 degrees, well outside the tolerances laid down by the manufacturers, *'I don't know how they ever got a splice'* [engineer].

There was a general tendency at Trinity to treat problems as technical, with engineering rather than printing solutions. Given the nature of the production process and the technology, including the background and training of most of the crew members, this was not surprising. The crews' existing knowledge shaped the problem-solving processes which generated new knowledge by defining which domain was most useful, and confirming this in practice through solutions deemed successful. Trinity's emphasis on engineering knowledge stood in contrast to the problem-solving routines of Weirs and Freedom, which drew on printing and internal engineering domains of knowledge.

compare their situation with that of Weirs' finishing operators (7.4.2).

At Trinity, print knowledge was unevenly distributed, being concentrated towards the top of the plant's hierarchy. Engineering knowledge was more widely distributed, but not among top management, apart from the Chief Engineer. Overall, crews lacked print and industry knowledge, although the plant was designed to operate without their carrying the full range of that knowledge. Their print knowledge was device- and context-specific, and largely contingent, tacit and instrumental, all forms of "subjugated" knowledge. In particular, they lacked print meta-knowledge and formal knowledge which might have provided them with a framework for making sense of what they did. This was remarked upon by the Press Manager, an experienced printer with a great deal of knowledge, not just about printing, but about the technical aspects of presses from a printer's perspective. Most printers could not set roller or cylinder pressures, and although they could do mechanical adjustments when directed, they did not understand why these were necessary, what the effects were, or what they were doing in print terms : *'they're toiling'* [press manager]. On the other hand, they knew the press as a machine from an engineering-oriented perspective, which was perhaps more useful in the circumstances. Even so, workers still needed print knowledge for everyday production, most notably in terms of ability to visualise process and process/product interaction. Most crew members did not need to know more about printing, since managers could supply that knowledge when necessary, and the plant functioned adequately without a wider distribution of this domain of knowledge.

9.1. INTRODUCTION

The preceding chapters (6, 7 and 8) illustrated the content, distribution and mobilisation of technological knowledge involved in everyday print production activities. In the context of these case studies, this chapter reexamines theoretical perspectives and frameworks reviewed in chapter 2 which were posited as useful for conceptualising technological knowledge and practice within organisations. It does so with particular reference to the work of Vincenti (1990) and Fleck (1988). The chapter also discusses the extent to which "social shaping" theory, "actor-network" theory and Foucauldian perspectives can address knowledge and practice in everyday manufacturing production. This possibility was sketched out in chapter 2, but is further commented here in the light of the empirical material.

Print production requires an immense variety of substantive knowledge relating to product, process and the interaction between product and process. This knowledge may relate to technical (Vincenti, 1990), social, or other aspects of printing. The cognitive content of print knowledge is likewise varied, exhibiting the full range of components (Fleck, 1988) amongst its carriers.

In the course of production activities, meta-knowledge (Fleck, 1988) about the industry and the individual firm is created and re-created. More specific bodies of knowledge, such as those related to print estimating or printing itself, may be carried by occupational groups of practitioners within the firm. These are acquired through common training, and elaborated and reinforced by shared working experience. Each worker carries personal or otherwise unshared knowledge about production, arising both from individual perception and from experience of working in other organisations. In order for production to happen, members of these

groups need to communicate with each other and with groups or individuals outside the formal boundaries of the firm. The use of a common domain-based language enables this to occur. Where two groups do not speak the same language, a translation process involving the presence of a non-human "dual-identity" actor, such as the image or a machine, becomes necessary. Texts, tools and technologies, the non-human actors of the production process, play crucial roles in the content, distribution and mobilisation of knowledge.

Such relations of knowledge are not value-free, but are shaped by a complex of social, technical, economic and political factors. In a printing context, some forms of knowledge are more highly regarded than others, although they are not generally considered to constitute "expertise". Industry-wide changes alter the content and distribution of printing knowledge - its "socio-cognitive structures" (Fleck, 1988) - within and between firms. The internal and external networks activated by individuals in firms when mobilising production knowledge reflect and sustain the printing industry's technological communities. The breadth and heterogeneity of networks vary considerably between sectors, but relate to product and process variety and the incidence of subcontracting at firm level, rather than to organisational size or structure.

The case studies suggest that there are underlying similarities in the way that print firms mobilise technological knowledge, depending on whether the situation in question is perceived as one of definition or problem-solution. These commonalities have to do with the type of collectivity apparent during the mobilisation process. Mobilisation of knowledge entails creating and recreating networks of carriers whose composition varies according to the milieu in which a particular situation occurs. Definition situations call for the mobilisation of common bodies of knowledge whose content and distribution are largely shaped by structural factors. The mobilisation process is further structured by the discourse of the domain, often institutionalised in the language of texts and images, and instrumentalised in tools and technologies.

During problem-solving, more contingent and temporary networks are constructed in order to mobilise a greater diversity of knowledge. These cut across existing hierarchies and groups of carriers, and sometimes transcend domain boundaries. However, the collectivity of this process is premised on shared discourse and the existence of relevant bodies of common knowledge which provide a framework for making sense of the personal and the hitherto unshared. When domains of knowledge other than printing are mobilised, "dual-identity" actors such as presses/machines temporarily assume their non-printing identity, and human actors, such as in-house engineers, may act as "translators" (Vincenti, 1990).

Whether a particular activity, such as estimating or trouble-shooting, creates a definition or a problem-solving situation depends on the characteristics of the individual firm's production process and its technological configuration. The mobilisation process does not only mobilise existing knowledges; it also generates and distributes new knowledge and recreates the old. But are "actor-networks" (Callon, 1986) useful for conceptualising these assemblages of carriers, and how much structural "explanatory scenery" (Bijker, 1992) is necessary for understanding the operation of such networks ?

Sections 9.2. and 9.3. deal largely with the substantive and cognitive content of technological knowledge related to printing at the level of the firm, and the usefulness of various taxonomic frameworks, including socio-cognitive structures (Fleck, 1988). Section 9.4. examines the distribution of that knowledge in the light of debates about the nature and existence of technological communities, and suggests that communities and networks are both useful concepts. Section 9.5 outlines the processes for knowledge mobilisation, and 9.6. discusses the explanatory power of various theoretical perspectives in accounting for the mobilisation of technological knowledge during production activities, and suggests how the mobilisation process may be conceptualised.

9.2. WHAT PRINTWORKERS KNOW : DOMAIN KNOWLEDGE

9.2.1. Categorising print knowledge

Firstly, what do printworkers know about that distinguishes them from others ? The substantive content of print knowledge is so varied that it is useful to establish overall categories for its analysis. Of the taxonomies of scientific and engineering knowledge reviewed in chapter 2, Vincenti's (1990) six types of engineering design knowledge (fundamental design concepts; criteria and specifications; theoretical tools; quantitative data; practical considerations; design instrumentalities) are most useful as a basis for examining technological knowledge in general, and technical print production knowledge specifically, being more relevant to manufacturing activity than scientific knowledge taxonomies. Indeed, the idea underlying the definition of engineering adopted by Vincenti, 'the practice of organising the design and construction... of any artifice which transforms the physical world around us to meet some recognised need' (1990:6) is very similar to that of production as a "transformation process" (Muhlemann et al., 1992).

However, in applying this framework to print production knowledge, certain provisos are required. This is not surprising : manufacturing and engineering are distinct activities carried out by different groups of people. As Vincenti himself points out 'all engineers... count as technologists, but not all technologists count as engineers' (1990:14). At the same time, some of the comments which follow could be used to refine or extend Vincenti's own work.

Firstly, Vincenti is concerned with the product design and design process knowledge used by design (as opposed to production or operation) engineers. In print production, workers carry knowledge about product design; the design, set-up and operation of the production process; and the interaction between these in practice

to achieve the finished product. The use of Vincenti's taxonomy can indeed be extended to cover the broader scope of manufacturing design and production knowledge, incidentally supporting his own claim that although his study does not address production engineering, his framework would not require major revision if applied thereto.

Secondly, Vincenti is concerned with categorising the knowledge of a distinct professional/occupational group : design engineers. The thesis demonstrates the applicability of this same framework to the knowledge of diverse occupational groups in the printing industry, none of whom would describe themselves as members of a profession : production, administration and sales workers; craft, skilled and semi-skilled workers; senior, middle and line managers. This is not to downgrade engineers or engineering (as opposed to scientific) knowledge; rather it suggests that such categories of knowledge are not limited to members of the professions, or those operating within domains of knowledge otherwise considered privileged or restricted. It is perhaps our thinking about manual and clerical workers, and about knowledge itself, that should change. Debates concerning workers and technology have tended to centre on skill rather than knowledge, and where knowledge has been addressed, the major focus has tended to be on physical, tacit (for which read 'inarticulate') knowledge. It is clear from the case studies that all printworkers carry and are able to talk about their richly complex substantive knowledge of technical matters, although the breadth and depth of individual knowledge varies and for some this is highly context- and device-specific.

9.2.2. Features of domain knowledge

Vincenti's types of engineering knowledge can all be found in a print production context. For example, the "fundamental design concepts" carried by production workers related both to product design ("this is what a book is like; this is what a calendar can be like"), and to the operational principles and "normal

configuration" of production equipment such as presses and finishing machinery with which the process was carried out. Similarly, Vincenti's "criteria and specifications" then relate to the establishment of the job specification, to the use of standard imposition formats (and web paths, where applicable), and to the type of equipment required, how it should be set up and made ready for the job in hand, the parameters for its operation, the treatment of raw materials or work-in-progress, and the deployment of labour to produce the job. In other words, they relate to the creation and practice of works instructions.

The mathematical "theoretical tools" that Vincenti ascribes to design engineers have production equivalents too. In printing, these ranged from purely mathematical formulae for ink coverage or paper usage to "mathematically structured" physical knowledge which could be further modified to produce "device-specific theories", such as the interaction between press speed, weight of paper, and the amount of air needed to separate the sheets to prevent "doubles" occurring, or the interaction between ink coverage, paper weight and absorbency, and drying time to avoid "set-off" in stacks of newly printed sheets.

Vincenti extends his definition of theoretical mathematical tools to include what he rather dismissively terms "phenomenological theories" and 'quantitative assumptions... too crude even to be dignified as theories... used for practical reasons and because they are known from experience to give conservative or otherwise acceptable results' (Vincenti, 1990:215). In print terms, this encompassed more personal but still explicit rules of thumb, such as those for ink usage based on ink coverage combined with paper absorbency and the number of sheets needed for a specific job. Maybe these are "crude", but they work.

Among the theoretical tools which form one category of substantive engineering knowledge are "intellectual concepts" which 'provide the language for ... conceiving and analysing... artifacts' (Vincenti, 1990:215). The case studies demonstrate the importance

of domain-specific language which structured what it was possible to think or say about a print job, and which defined how its specification and works instructions were expressed, as well as how departures from these were accounted for or dealt with. In printing, the intellectual concepts relate to artifacts and activities (product and process), and include size, shape, colour and number of product, and speed, torque, pressure, and tension in relation to processes. But the most fundamental concepts were the production and reproduction of text and images, and the immiscibility of oil and water which enables the litho printing process.

In intellectual terms, these concepts differ in degree of complexity or abstraction from design engineers' concepts of force, mass, and the boundary layer. They are less theoretical and more concrete, deriving less from systematic research and more from day-to-day practice. Most people, not only printworkers, would understand them. But despite their apparent simplicity, they underpin and inform the language in which print products AND production processes are thought of and thought about. Manufacturing knowledge is more practical than design engineering knowledge, and if Vincenti had investigated the knowledge of production (rather than design) engineers, his findings might have been similar to mine.

Design engineers' knowledge includes quantitative data of two types : descriptive (how things are) and prescriptive (how things should be) (Vincenti, 1990). Again, these can be found in print design and production. The descriptive numerical data on which mathematical formulae are brought to bear in order to produce estimates and job specifications include the following : paper weights; paper sizes (imperial and metric); standard allowances for bleeds, trims and gutters; tint percentages; packed quantities of materials; price/quantity tables for materials or subcontract work; number of impressions for which different types of plate will last; and for specific jobs, run length and run-on quantity.

Estimates and job specifications utilise prescriptive quantitative data. Such data are even more in evidence where works instructions are concerned, since they embody knowledge of how things "should" be done. They include generally accepted data such as industry standard tolerances for press settings (such as UKONSS); trade tolerances for waste and overs; and standard ink mix percentages for each pantone colour. They also comprise device-specific data : time to clean or change a unit; max/min limits on paper weight usable in various machines; max/min paper sizes through each model of press, max/min printed image sizes ditto; max/min/working machine speeds. All of these can be refined to produce site-, machine-, job- or operator-specific quantitative data. The more specific or local these data, the more contentious they may become. This issue is not explored in Vincenti's (1990) work. Nor does he draw a distinction between data and information. It is not raw data that printworkers use, but data structured by domain language and values, which is information.

Print workers in design, production and administration departments use a wide range of sometimes complex qualitative data (as in non-numerical and probabilistic rules of thumb), when working out how products should or could be designed and produced. An example might be "substrate A is more likely to scuff than substrate B, so lamination might be necessary, but if the customer cannot afford it, suggest a different paper". These may interact to produce sets of qualitative parameters which incorporate Boolean logic, such as "Y is more likely to happen IF you are using process C AND ambient temperature is high AND machine speed is high, BUT ambient humidity is low, although when we last did a job like this on press 1 it ran OK". These provide guidance on how products should be designed or jobs produced. They too may be device-, firm-, customer- or job-specific. Vincenti's term for these types of knowledge is "practical considerations", 'less sharply defined... derived from experience in practice... that do not lend themselves to theorising, tabulation or programming into a computer' (1990:217). In printing, this is the kind of knowledge needed to tweak a price, product or process into (or beyond) basic acceptability or

feasibility. In cognitive terms, this general knowledge is heuristic, but its specific details are contingent (Fleck, 1988).

The properties and performance of materials are often only known in this way, and not as quantitative data : comparative or approximate drying times of ink on paper (a function of ink viscosity and paper absorbency); when a web break is most likely to occur (a function of the failing strength of paper and machine speed and acceleration); or the weight at which board cracks when folded and needs pre-scoring. So too are the properties of machines, such as appropriate run lengths for certain types of job, given the anticipated job mix and work loading in other production departments.

9.2.3. Visual and tactile knowledge

Every case study revealed the vital importance of visual knowledge and visualisation ability for all printworkers : office-based staff, shopfloor workers and management alike. The work of both Ferguson (1977) and Vincenti (1990) stresses the visual nature of technical knowledge; the importance to engineers of modes of non-verbal thinking such as visualisation, and the prevalence of sketches, formal and informal drawings as means of capturing and conveying knowledge. The same is true of print production, particularly with regard to 2-D to 3-D and 3-D to 2-D translations. Verbal and visual thinking are directly linked in the ability of printworkers to visualise the finished product and the processes by which it will be manufactured from the written job specification. Like engineers, printers work from the results of visualisation : from sketches (2-D roughs of the flat image), and from drawings both formal (finished artwork or machine manuals) and informal (rough diagrams).

Visualisation requires knowledge about the spatial relationships entailed by product and production process : imposition, colour position and web path for varying paginations and finished sizes of

job. It may sometimes involve knowledge about colour : saturation, mix and hue, especially in combination with the type of paper to be printed. However, visualisation not only involves passively looking at an object in the mind's eye, but entails its mental feel and active manipulation by the mind's hands. Production workers learn that these modes of thinking exist, and when to use them. In addition, 2-D images have tangible formal and informal 3-D counterparts which serve as means of establishing or transmitting knowledge : prototypes, samples, and more or less accurately constructed dummies.

In his discussion of the category of knowledge termed "practical considerations", 'derived from experience in practice... that do not lend themselves to theorising, tabulation or programming into a computer' (1990:217), Vincenti states that because this type of knowledge is not codifiable, 'a mock-up or prototype must often be built to check the designer's work' (1990:218). Apart from the implication that non-codifiable engineering knowledge is less trustworthy than other kinds, this suggests that models are only made to verify knowledge, and that they are not intrinsic to design or production processes.

In printing, however, their construction is an essential exercise of such knowledge, providing opportunity for debate or a rehearsal for actual production. Their role in defining jobs and problem-solving is crucial. Dummies and play with sheets of paper are a significant means of confirming or disputing that the methods and materials proposed will yield the desired result in practice. In any case, looking at the model is not enough; workers need to be able to touch and manipulate it. Tangible 3-D models to work to or from are as important in production as 2-D images (even those employing perspective).

The tactile aspects of technical knowledge need to be emphasised, as well as its visual elements. Neither should be subsumed into discussions about tacit knowledge. To do so is to confuse the substantive with the cognitive content of knowledge. Printworkers

know what products and production equipment should feel and look like. Such knowledge may be tacit, or it may not.

9.2.4. Design instrumentalities

The final category of substantive knowledge identified by Vincenti is that of "design instrumentalities", by which he intends 'the [mental] procedures, ways of thinking and judgmental skills by which [engineering design] is done' (1990:219). A number of points are raised below about this category : a terminological difficulty; important differences between printing and engineering; and the beginnings of a more serious critique of the scope of Vincenti's work, which is discussed further in section 9.2.5. The components of "design instrumentalities" are set out below (fig.9.1).

Fig.9.1. The components of "design instrumentalities" (Vincenti, 1990)

DESIGN INSTRUMENTALITIES

- mental procedures
 - hierarchical decomposition of systems
 - optimisation
 - incorporation of feedback mechanisms
 - parallel organisation of related activities
- ways of thinking
 - mental processes
 - from intellectual concepts to shared ways of thinking
 - from shared ways of thinking to intellectual concepts
 - non-verbal processes
 - visualisation
- judgmental skills

Given the importance of material objects to engineers, it is surprising that when Vincenti discusses the "design instrumentalities" of the engineering design process, he concentrates on their mental rather than their material and physical aspects. Whilst using de Solla Price's (1984) terminology, Vincenti leaves out the role of tools and instruments and their

interaction with the human body which are central to de Solla Price's definition of this kind of knowledge, and to its practice by workers. The difficulty is increased by the fact that the term "instrumentalities" is elsewhere (de Solla Price, 1984; Fleck, 1988) used to refer to a cognitive rather than a substantive component of knowledge. Vincenti appears to con-fuse the cognitive processes of knowledge (how) with its substantive content (knowing what). If he means knowledge ABOUT the mental procedures, ways of thinking and judgmental skills of engineering and how to put them into practice (knowing how), this needs to be more clearly stated.

The ability of non-production as well as production workers to visualise becomes explicable if visual thought about products and processes (Ferguson, 1977) is understood as a "design instrumentality" (Vincenti, 1990) rather than as the cognitive component, tacit knowledge. It is then a substantive part of printing knowledge, rather than cognition stemming from printing practice. Hence in order to visualise, hands-on ^{production} experience resulting in tacit knowledge would not be necessary¹.

There are a number of important differences between the mental procedures of printing and engineering. Firstly, in production, a holistic view of product and process is needed rather than a hierarchical decomposition of systems into sub-systems. Indeed, a concentration by practitioners on one part without thought for the whole is said to lie at the root of many production difficulties. However, potential problem areas such as paper feed, colour balance (inking levels), image position (register), and ink-water balance (damping levels), do tend to be associated with particular press or other machine sub-systems, although they may interact with each other. Secondly, in an everyday production context operating under time and financial constraints, satisficing wins out every time over optimisation, and knowing when this point has been reached is

I did not come across any non-production workers who had not had at least some production experience, so I could not test this out.

an important judgmental skill acquired through experience.

Finally, as well as ordering UNrelated activities in parallel, such as different jobs proceeding simultaneously between or within various departments, production workers need knowledge about how to organise activities relating to the same job in sequence, given that each stage is dependent on the one previous. Increased automation of production equipment and the integration of production and its administration make the entire process more amenable to ^(related) parallel organisation, for example twin CPC consoles on a single machine, or the interaction via a CIM system between platemaking, plating-up and setting press inking levels. Other recent technical developments such as DIP (see Ch 4) reduce the number of stages in the production sequence, but do not in themselves make activities more parallel. However, engineering and print share one important concept : feedback. This is highly relevant to production, particularly when setting up and running jobs using machinery which provides facilities for adjustment during production.

Vincenti identifies two "ways of thinking" common to design engineers. Firstly, "mental processes", by which he seems to imply verbal thinking, and secondly "non-verbal processes" such as visualisation (9.2.3). The former involves either starting from intellectual concepts to produce 'shared ways [of thinking] for apprehending the operation of a device and imagining the effect of alterations in its design' (1990:220), or starting from such shared ways of thinking to produce intellectual concepts, often by the use of analogies. It has already been pointed out that the "intellectual concepts" of print are more concrete and based on practice. These certainly provide shared ways of understanding the workings of both production equipment and printed products.

Printworkers share ways of imagining the effects of changes in machine setting or job specification (and hence too, perhaps, in the production methods to be used), and of then implementing them with the aid of feedback. This is a further instance of production

workers having knowledge not only about product design, but about production processes and the interaction between the two, an issue not touched on by Vincenti in relation to design engineers, but central to manufacturing activity. The reverse verbal thinking process (starting from shared ways of thinking to produce intellectual concepts by the use of analogy) also applies. Printworkers often make analogies between current and previous jobs to draw out case-based differences/similarities for problem-solving.

According to Vincenti, judgmental skills can relate to purely technical matters and hence be straightforward to apply, or they can involve social and economic considerations and hence be very unclear, or they may involve a mix of both - weighing technical considerations with the demands and constraints of the social context. Vincenti does not claim to explore such non-technical matters in depth. There are at least three difficulties here : firstly, the assumption that technical considerations are in themselves easy to resolve and uncontroversial; secondly, the idea that technical things are ever wholly separate from their social, economic and political dimensions; and thirdly, the inference that judgment itself is unproblematic, when it inevitably has a strong subjective element, being based on personal opinion of situations and previous experience, and is hence open to negotiation and dispute. Finally, if skill is a social construct, who is to be allowed to exercise judgment and on what basis ?

Social demands and constraints shape the substantive content of printing knowledge in a number of ways : they influence what is considered to count as knowledge, and what knowledge is transmitted or valued within the industry (see 9.4). More directly, the social and financial requirements of customers shape product design, and managerial expectations regarding costs and labour relations likewise influence the selection and use of methods and materials. These are issues unfortunately beyond the scope of Vincenti's discussion of design engineers and their domain knowledge.

There is a further related major shortcoming in Vincenti's work. Because of the emphasis on technical knowledge, he misses many important but not strictly technical aspects of the substantive content of design engineers' knowledge that would enhance his analysis, particularly in conjunction with an examination of its cognitive content. Engineers know more than just the technicalities of engineering. To do this with production knowledge would be to omit a large and important part of what printworkers know and do. Non-technical knowledge is therefore examined in greater detail below, and a framework for addressing its substantive content sketched out.

9.2.5. Non-technical print knowledge

Just as technology does not consist purely of hardware, so technological knowledge cannot be purely technical, as the two parts of Harper's (1987) work, which deal with skill and community, suggest. It is clear from examining everyday activity in the case study firms that other knowledge is required for print production to happen. Much of this relates not only to fact, but also to judgment, opinion and belief. It may even be factually incorrect. Because of this, it is contentious, contestable, and continually changing. However, it must nonetheless be counted as knowledge, since in combination with interests it provides a basis for action (in this case, production).

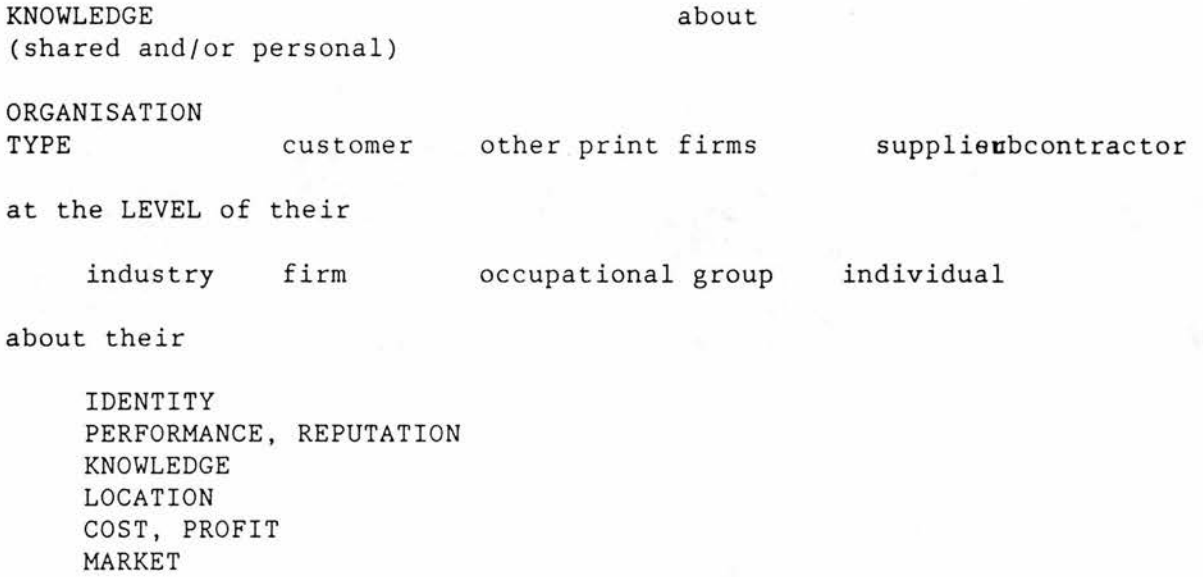
Printworkers know, in greater or lesser detail and extent, about the industry in which they work : its history, structure, financial health, industrial relations, technical developments, training, and markets. They carry the same kind of knowledge about their own and other firms, and about where these fit into the industry. This not only includes other printing firms as collaborators and competitors, but subcontractors, and materials and equipment suppliers. More specifically, printworkers know about the technical expertise, performance and reputation of firms.

This knowledge extends to customer organisations, and named individuals representing them. Printworkers know about markets for print in general, and the markets their firm serves; the identity of customers, their expectations in terms of quality, price and turnaround, their financial situation, their knowledge of print products and processes, the way in which they present jobs as copy, artwork or film, and any special requirements they might have.

Similar areas of knowledge exist among printworkers about occupational groups and individuals : their history, career patterns, typical and prospective rates of pay, industrial relations, relevant technical developments, training, and job markets. They know where they as individuals, others in the same occupational group, and those in other occupational groups fit within the firm and the industry. They also know what technical and non-technical knowledge those groups or individuals are likely to carry.

All this knowledge shapes the establishment of job specifications and works instructions, and the production process itself. It may be general or abstract, a matter of common knowledge or hearsay, but it may relate to specific sectors; named customer, supplier, and subcontractor firms; and individuals : all known and experienced personally. In other words, this non-technical knowledge may be highly context-specific, and its actual substantive content will vary widely from person to person, depending on their occupation, firm and industry sector. As such, it is largely, although not entirely, non-codifiable. Its status as recognised knowledge frequently depends on the occupational or hierarchical status of its carriers. The aspects of technological knowledge which are not strictly technical may thus be seen as a useful example of "subjugated" knowledge (Foucault, 1984), but whose degree of subjugation varies with prevailing power relations within print firms. It is more difficult to establish categories of substantive non-technical knowledge which could parallel Vincenti's (1990) typology of technical knowledge. However, a provisional scheme is suggested below (fig.9.2).

Fig.9.2. The substantive content of non-technical print knowledge



This knowledge has social, geographic, political, technical and economic dimensions. It consists of knowing who DOES what, for whom, how well, where they do it, at what cost and for what gain; and of knowing who KNOWS what. It is knowledge and practical experience of the knowledge and practice of other organisations and individuals, including "outsiders" to printing. It is knowledge about technological communities and their members; and knowledge relevant to active networking by practitioners within those communities (see 9.4.). Hence it is an essential component of technological knowledge, and should not be ignored by researchers in this field.

9.3. HOW PRINTWORKERS KNOW THEIR WORLDS : DOMAIN COGNITION

9.3.1. Categorising print cognition

Before these communities and networks of knowledge are addressed, it is necessary to look at how printworkers perceive their worlds :

the cognitive content of their knowledge, which links the substantive content of knowledge with its social distribution. The cognitive part of Vincenti's (1990) taxonomy of knowledge does not achieve the explanatory power of Fleck's "socio-cognitive structures" (1988) when applied to everyday print activities. The limitations of its focus on the technical knowledge of an assumedly homogeneous occupational group become apparent by comparison. The weakness of Vincenti's cognitive analysis has been noted, but not elaborated by Sorenson (1993), who subsumes it into his critique of the lack of social analysis in Vincenti's (1990) work.

Fleck's (1988) conceptual framework proves applicable to everyday manufacturing knowledge, and not just to science, engineering or other professional or privileged domains of activity such as innovation (see 9.5.1). Its categories are sufficiently abstract and generalisable for this to be possible without the need for context-specific revisions. The case studies demonstrate that all Fleck's (1988) cognitive components are present and significant in a production context. Technological knowledge and practice are not composed principally of tacit elements, just as scientific knowledge is not purely formal. Nor does print knowledge consist of the practical application of formal components : technology is not an "applied" subcategory of science, but a distinct activity; hence concepts like "technoscience" (Latour, 1987) are problematic in a manufacturing context.

Moreover, the same thing or concept may be known simultaneously in different ways (as different cognitive components) by individual carriers. Fleck (1988) intends this, but the point bears emphasis. The importance of particular cognitive components of knowledge to each carrier can change over time through experience. In a production context, much formal knowledge is either taken for granted by practitioners, or has been translated through experience into informal rules of thumb. These may become internalised as tacit knowledge, or as instrumentalities where the use of tools is involved. For example, the mathematical SPANKS formula for calculating ink usage by reference to ink coverage on the sheet is

known, but rarely used; printworkers preferring rules of thumb, such as "one tin does 1000 sheets of text", which are eventually taken for granted. All Vincenti's categories of substantive knowledge can be known as any cognitive component. This would make it possible to unite Vincenti and Fleck's categories of substantive and cognitive elements to provide a comprehensive framework for addressing the content of technological knowledge.

The following sections (9.3.2 and 9.3.3) discuss issues emerging from the empirical evidence about the cognitive aspects of print production knowledge, including comments on meta-knowledge; the transfer of formal knowledge into computer applications software, such as estimating systems; the difference between Vincenti's (1990) "device-specific" knowledge and Fleck's (1988) "contingent" knowledge; whether tacit knowledge can be articulated; and the implications of print production automation for the tacit knowledge of shopfloor workers and management.

9.3.2. Features of domain cognition

Although meta-knowledge can survive independently of individual human carriers, as noted by Fleck (1995), and despite its embodiment in texts and images representing the history and previous practice of the firm, it can and does alter. Meta-knowledge is not a permanent bedrock of knowledge upon which all other components rest or shift. It changes (or is confirmed) continuously in response to day-to-day experience. It may be lost or replaced by new knowledge over time. However, attempts to fix or alter meta-knowledge about a firm deliberately through the production of texts such as mission or quality statements may be problematic if these do not match individual perceptions of everyday practice. Ironic forms of "counter-meta-knowledge" may develop among the workforce which reflect perceived reality more closely, but which are not necessarily shared or overtly acknowledged by all. Meta-knowledge is difficult to manufacture, which may account for some of the problems organisations experience

in implementing change. In the light of the case studies, one rather drastic solution may be to change the prevailing domain of knowledge and hence the cognitive components (including meta-knowledge), say, from printing to engineering, together with the introduction of new personnel, plant and premises consonant with the new domain. As a final observation, meta-knowledge may be couched in negative as well as positive terms : "not like that".

In printing, computer-based production and production management systems transfer some of the formal mathematical knowledge previously required from human users of manual systems into the program itself, in the shape of formulae or algorithms. This may cause problems as the workings of the computer system are less transparent to everyday users than those found on a handwritten sheet, and the assumptions which underpin the system may be hidden from users or lost with the passage of time, making it difficult to flex the programme for products or processes that do not fit the range of options provided. It makes it more difficult for estimators/job planners to produce costings that accurately reflect the eventual costs of a job, by removing the opportunity to "tinker" with the estimate in the light of their existing knowledge and experience of production matters.

Transferring formal knowledge into computer-based systems has other implications. Users who no longer need this knowledge may lose it through lack of practice. New users may be employed who never carried this component of knowledge, and who are thus unaware of the system's incompleteness or shortcomings. Finally, this shift concentrates ^{formal} such knowledge in the hands of the designers and devisers of instruments, replacing that of the users with tacit knowledge and instrumentalities, which can be seen as more "subjugated" forms of knowledge (Foucault, 1984) since they are partly less articulable and hence less codifiable. A shift in power relations may well accompany these changes, and user feedback may go unheard or unattended to.

In a cooperative context, the consequences of this type of

knowledge transfer may perhaps be less serious or fixed. If such users are also designers, they may be able to later modify (or discard) the instruments they have created, as at Freedom, where estimating and elicitation knowledge had been instrumentalised into various manual forms collectively by workers. However, attempts to institutionalise this knowledge into a computer-based estimating system, even when undertaken with a system designer sympathetic to collective working practices, had not produced a workable package.

Vincenti (1990) states that all the categories of substantive knowledge which he proposes can range in content from the general to the "device-specific". At first sight, the latter appears so similar to Fleck's (1983) cognitive component "contingent knowledge" (2.4) that some confusion may arise. Whilst it is true that the substantive content of much contingent knowledge is device- or context-specific, this is not what makes it a localised form of cognition. Contingent knowledge is non-portable. The carriers of contingent knowledge are unable to generalise from it or to apply it to other situations by drawing parallels or analogies.

To do so, they would need to know its substantive content in other ways, as formal or informal knowledge, which would provide a framework for making full sense of it in terms of "why" as well as "what" and "how". Hence it may be not only possible, but also highly desirable to carry substantive knowledge as a variety of cognitive components. In substantive terms, printworkers without broad-based formal training can be seen as lacking knowledge about what Vincenti (1990) refers to as "fundamental design concepts" regarding the operational principles (how and why the device works) and the normal configurations (the usual arrangement) of product and process.

Purely contingent knowledge is non-tradable outside its context, and this lack of broader economic value is another reason why it can be seen as one of Foucault's (1984) "subjugated knowledges". However, once again, it depends on who is carrying the knowledge

and their social position. Even though an increasing number of finishing operators have little or no formal training, in common with their (usually female) assistants, there is a division of labour and a status hierarchy between them which can be seen as grounded in and sustained by structurally determined gender relations which bear little relation to actual knowledge. And the worker without training, or who has only received on-the-job training is at a greater disadvantage and has their knowledge taken less seriously than the manager with contingent print knowledge and no formal managerial training.

9.3.3. Tacit knowledge revisited

Much of the literature which mentions tacit knowledge (Polanyi, 1958, 1967; Collins, 1974; Laudan, 1987; Zuboff, 1988) assumes that it cannot be verbalised. This raises theoretical and practical difficulties in a number of fields, including that of knowledge elicitation in general, and specifically the design, construction and use of computer-based expert systems (Diaper, 1989) and knowledge-based systems (KBS). The case study material suggests that the content of tacit knowledge can only be grasped fully by its skilled practitioners, but that some parts of it can be conveyed to other people. The concepts underlying Fleck's "cognitive components" (1988) can explain why this might be the case.

Although there may be some essentially inarticulable aspects of tacit knowledge, such as "an eye for colour", which derive purely from personal physical experience, it is not completely inexpressible, for ^{either} one of two reasons. Firstly, if the same thing can be perceived in several different ways, the activity about which tacit knowledge is carried may also be known in terms of other cognitive components, which can be either articulated verbally, or conveyed visually through examples, images and gestures. Secondly, if it is the case that the tacit knowledge in question was once carried as another cognitive component (such as a

heuristic), but has since been internalised (or "indwelt") by its original carriers, this renders it recoverable and describable, albeit at a fairly low level shorn of the richness of experiential qualifications. It would take so long for practitioners to recollect and explain every personal modification to their original knowledge that the listener might as well acquire their own instead. It is in the form of cognitive elements such as informal rules of thumb, or anecdotal forms of contingent knowledge such as "horror stories" or "war stories" (Orr, 1986,1987,1990) that tacit knowledge re-emerges as the spoken word, particularly when explanations are given to novices, or new workers initiated into site-specific practice.

Automation does not necessarily destroy production workers' tacit knowledge by removing the need for physical labour, as suggested by Zuboff (1988) and assumed by Vincenti (1990). The implication of this for Zuboff appears to be that loss of tacit knowledge by workers through the introduction of new technology may bring with it a corresponding diminution of control and discretion over work, and hence that those workers are deskilled by automation. On the other hand, Zuboff suggests that computer-based technologies have the potential to "informatize" work, and workers may thereby acquire new forms of tacit knowledge. A number of issues need to be addressed with regard to these hypotheses in the light of the case studies, apart from the comments that knowledge and skill are two different things; and that production workers carry much knowledge that is not tacit, as amply demonstrated by the empirical material of the thesis.

Firstly, even with automation, print production is still a physical experience requiring tacit knowledge, although using off-press controls is more like manipulating a sound mixing desk or keyboard instrument than heaving coal, and thus can be seen to preserve the human body. Unlike the pulp mill workers described by Zuboff (1988), sitting in their control room divorced from the product they once used to test by smell, taste and touch, printers in even the most highly automated case study firms still had extensive

physical and visual contact with the product, and with the process technologies they used. This may be explicable by reference to the type of production process : automation of flow production may lead to loss of physical contact with product and process because of the scale of production and the sealing of tanks involved, whereas the automation of batch production does not have these consequences. So preserving the body does not mean eliminating it altogether, and the distancing of workers from product and process depends on the manufacturing context.

Secondly, automation does not always cancel existing tacit knowledge. It sometimes relocates it in knowing how (for example) to manipulate the CPC console rather than the press itself : a change in the proximal and distal terms of tacit knowledge (Polanyi, 1966). Use of CPC still requires an ability to visualise products and processes in 3-D from their 2-D screens, keyboard and console representations, and to adjust these in realtime, in response to sight of the printed image compared with the proof, or of the finished product alone. Workers still control the press, but mainly using an off-press console instead of on-press controls. They control the control system, as well as the mechanical system. And this takes new knowledge (Zuboff, 1988) and a "kinaesthetic correctness", to use Harper's (1987) evocative term, of its own. However, this is not to deny that the new jobs created in an automated environment can be repetitive and boring, and proceed at a pace which would be almost intolerable with automation, and impossible without it.

Thirdly, although workers' control over certain aspects of the production process may be reduced, as with pre-programmed initial machine settings, it is debatable whether they can thereby be considered deskilled. Apprenticed and time-served printworkers (though not their assistants) using automated production equipment still have craft status, confirming the earlier findings of Goss (1988). Skill is a social construct which depends for its force on who is doing the work. It is not (yet) suggested that surgeons learning to operate using remote-controlled instruments rather than

working directly on the patient's body are thereby being deskilled, although this involves a similar type of tacit knowledge change to the adoption of CPC in printing. This is perhaps because they are surgeons, with all the social and professional status, scarcity and uniqueness of labour power that this implies, rather than production workers. As well as being skilled, they are able to define themselves as experts, operating within power relations which permit them to define what counts as knowledge (Fleck and Tierney, 1991; Fleck, 1992). Hence the deskilling issue depends on whose work is being automated, and whether their tacit knowledge is being abolished or its terms relocated.

Automation also has implications for managerial tacit knowledge. However, in printing, the implementation and use of computer-aided production management and computer-integrated manufacturing systems is still so problematic, and managing production by physical presence on the shopfloor so heavily entrenched, that production managers still need tacit knowledge of how to use their bodies as managers (Zuboff, 1988). The reasons for managerial presence may change : not to supervise the process directly, but to coordinate workflow between departments, because of the increased volume of production possible with automation. The formal structure of the crew may instead perform the direct supervisory function through its internal hierarchy combined with peer pressure. Equally, it could be said that the craft tradition which still pervades the industry and the apprenticeship system that went with it have always acted as powerful internalised forms of self-policing and regulation among printworkers.

Where inter-departmental workflow is automated, managerial presence may not even be required for coordination. Trouble-shooting becomes their main shop-floor activity, apart from "being there". Most production managers were themselves once printers and come from within that system, so they know the occasions when their presence as supervisors is most necessary, and have themselves previously internalised the disciplines of printing. Although changes in print production technologies towards automation (machine-discipline) and

lower staffing levels (self-policing through peer/crew-discipline) have eroded the need for middle management (as in other industries), managers are still needed for problem-solving, especially if fewer print workers have printing knowledge that covers the whole process, and the question of "why" as well as of "how" and "what".

9.3.4. From cognitive components to socio-cognitive structures

The previous subsections illustrate the connections between the cognitive content of knowledge and its socio-technical distribution, and the difficulty of separating one from the other. The strength of Fleck's (1988) analytical framework is that, unlike most other taxonomies or frameworks of knowledge (see 2.4), it explicitly unites the cognitive content of knowledge with its social distribution in the form of "socio-cognitive structures" in which cognitive components of knowledge, human carriers, AND inanimate objects (Fleck, 1995) related to "domains", meet in "situations" and "milieux". Fleck draws on Ludwig Fleck's (1979) concept of "thought collectives", and his contention that all thought is socially-shaped cognition. Latour's view (1986) that cognitive factors should only be examined if actor-networks cannot be described or explained by other (socio-technical) means is thus suspect : it is not possible to exclude the cognitive from consideration. Examining the cognitive aspects of technological knowledge enhances our understanding of how and why it is distributed and mobilised.

Moreover, Fleck's (1988) cognitive components do not make sense without a consideration of their distribution, because each is inherently social, and implies a particular, socially structured distribution. This point is not made explicit in Fleck's work, but is a valid interpretation of it. For example, meta-knowledge (Fleck, 1988) or its taxonomic equivalents such as "metaphysical values and beliefs" (Whitley, 1975) or "cultural values" (Bijker, 1992) are likely to be carried in common by workers within an

industry, firm or occupational group, whereas tacit knowledge is carried only by those with particular personal experience. The carriers of formal knowledge have undergone specific education or training programmes, and contingent knowledge is shared by those working in the same spatio-temporal location.

Once the social nature of thought is accepted, it becomes easier to see how power inserts itself into the apparently innocent activity of cognition. To know anything is to participate (willingly or otherwise) in the power structures of that domain, and to put that knowledge into practice is to become entangled in the networks of power and knowledge specific to that milieu and situation.

9.4. WHO ARE THE PRINTWORKERS ? COMMUNITIES AND NETWORKS

Discussing print knowledge in the abstract is all very well, but who are the people who carry that knowledge, and how do they recognise and know each other ? The previous sections discussed the substantive and cognitive content of print knowledge. Section 9.2. demonstrated the importance to printworkers of non-technical print knowledge about technological communities and networking within them, and section 9.3. suggested that carriers of domain knowledge belong (until proved otherwise) to a particular socio-technical community, and that to mobilise that knowledge in response to a situation arising in a specific milieu is to become part of an active network of practitioners. This is similar to Knorr-Cetina's (1981) characterisation of scientific communities as "variable transscientific fields" linked by constantly negotiated "resource relationships", but applied to an industrial context.

Conceptualising printworkers as belonging to both communities AND networks provides a useful starting point for analysing the distribution and mobilisation of knowledge. It moves the debate on from the differences and similarities between scientific and technological communities. And it begins to address how "macro" and "micro" levels of activity link together, and hence how to

conceptualise organisational knowledge and power relations in the context of everyday manufacturing production.

9.4.1. Technological communities

The studies of scientific, engineering and technological organisation and activity reviewed in 2.3. concentrate, because of their level of analysis, on a critique of the notion of "communities" : cultural and social groupings more or less stable over time and distance, composed of identifiable practitioners sharing a common domain of knowledge. Attempts to define further this rather amorphous yet monolithic concept of "community" include acknowledging local and temporal variations (Whitley, 1984), which can be applied to the printing industry and its various sectoral and geographical divisions; and drawing a distinction between formal institutions such as professional bodies and informal communities of active practitioners (Vincenti, 1990). However, in printing, it is not a question of institutions such as the BPIF, PIRA and the GPMU as opposed to practising printworkers, but of more or less formal communities (including institutions) and informal networks. And in printing, as suggested in 2.3., these communities and networks are heterogeneous in their membership and composition.

The idea of community in printing applies in two spheres : industry sectors, firms and institutional bodies; and occupational groups. The former is the community of which an individual firm (and by extension those who work in it) is part; the latter the community to which its individual workers belong. Adopting this approach, the distribution of production-related knowledge and practice within and between organisations and occupational groups, as influenced by macro-level factors, creates the relatively durable "technological communities" of printing. These can be conceptualised as interlocking and overlapping groups carrying various bodies or domains of knowledge in common, and bound together over time by that knowledge and its practice.

A print firm may belong to several technological communities : one sectoral, one technical and one geographical, for example. The case study firms all employed offset litho technology, but were part of different, albeit sometimes overlapping, technological communities. Similarly, workers belong to an occupational group, and additionally have sectoral, technical and geographical identity. However, in terms of everyday practice, it is not "the print community" that matters, but "membership" of that community (Bauman, 1978).

Membership of technological communities is acquired and preserved in a number of ways. Firms set up in business, obtain equipment, make the contacts necessary for purchasing materials and subcontracting, and produce work for customers. The existence, survival and performance (as judged mainly by subcontractors, peer firms and customers) of a firm automatically gives it membership of a print community : practice is the relevant factor. Individuals undergo formal (college, apprenticeships) or informal (on-the-job) training and examination / assessment, thereby becoming provisional members of a particular occupational group and its labour market. Thereafter, it is adequate practice in the workplace, as judged by managers and peers, that confirms them as full members of a technological community. Firm and individual community membership is subsequently reinforced or retracted in a number of ways, including through reputation, use of domain language and the telling of horror stories.

The organisation of technological communities differs from that of discipline-oriented scientific communities (Whitley, 1984) or aeronautical, mechanical or electrical engineering communities (Vincenti, 1990). To be part of a print community does not necessarily require individual or firm membership of formal institutions, such as professional bodies. Printing is an industry, not a profession. Nor does it require the personal reputation of individuals among their peers and beyond the formal boundaries of the organisation. At community level, specific named firms acquire

reputations based on practice, which then reflects upon the individuals within them. When workers move firms (or start their own print businesses), it is the reputation of their previous employer(s) that accompanies them, rather than their own, until the latter is established through everyday practice in the new firm. Printworkers as individuals tend to be anonymous outside their own networks, as indeed do most firms.

Knowledge about the domain, and the ability to speak the domain language are significant for establishing and maintaining firm and individual membership of print communities. Domain-specific language, spoken or at least understood by everyone within a firm, structures what it is possible to think and say about products and processes, particularly when embodied in formal texts such as job specifications and works instructions. Through such texts the domain's discourse is institutionalised. Not to use the language of the domain, or to be seen to misunderstand it is to reveal or bring upon oneself the status of an outsider (Bauman, 1978) or interloper. Customers may be "outsiders", and their lack of knowledge is excusable, whereas the term "interlopers" can be used to describe those within the firm who are judged unsuitable as employees because they have not acquired or are not seen to use domain knowledge and language (and will probably become outsiders).

However, between proven members of a print community, the rules may be somewhat relaxed. Where the content or appearance of the printed image are significant to workers (and at the level of the firm), these are allowed to function as informal terms of reference when "insiders" recall specific jobs in problem-solving situations, even though they are not part of the official product specification or are not expressed in domain-specific terms. For example, references by printworkers to "the orange job" were permissible, even though this would have been described on the job bag as 'Pantone xyz'. For outsiders or interlopers to use these terms would be taken as a demonstration of print ignorance, and confirmation of their non-insider status.

One means of proving identity and creating community among printworkers is the telling of "horror stories" - the equivalent of Orr's (1986, 1987, 1990) "war stories" told by Xerox service engineers. Horror stories are a way of generalising from particular personal experiences of products or processes, often in a problem-solving situation (see 9.5.3.). They are useful for storing or passing on knowledge to other, perhaps younger or novice workers, as in the anecdote about Robbie Burns' moustache and the tin of shortbread (see 1.3). In this sense, their absolute veracity does not matter, nor is it relevant whether they recount the teller's own experiences : it is the lesson they embody that is important. Being able to tell "horror stories" is a means of proving one's identity as a printworker. Insofar as the worse (and funnier) the situation described, the greater the relish with which it is retold, it is also a perverse way of celebrating identity, as noted by Orr.

Horror stories are passed on within firms, and between firms and their suppliers and subcontractors, as a method of exchanging knowledge and experience about particular types of job or materials performance with which the other party may be unfamiliar. At this level, they reflect firms' competence and provide anecdotal proof of past practice and experience. Customers often feature in such tales, usually because the supposedly outrageous nature of their requirements is seen as having brought about the problem in the first place. This can be seen as analogous to the situations described by Orr, where service engineers repair the results of 'the extremes of human behaviour... with machines' (1986:6), and it reinforces the division between "insiders" and "outsiders" in the industry. Printworkers know about printing, which holds them together as a community; customers are characterised as lacking printing knowledge, which explains their behaviour but does not always excuse it.

Where press crews did not tell horror stories (Trinity), this may reflect the regularity and relative uneventfulness of the production process, although it is more likely to indicate a lack

of identity as printworkers. Maintenance engineers did tell such anecdotes - about the press crews' setting and operation of the machines - as proof and celebration of their engineering identity. In this firm, engineering rather than printing was the predominant domain of knowledge among production workers. Perhaps only members of a dominant community are in a position to tell horror stories (in domain language), thereby excluding competing informal accounts of events and further strengthening their position ? Orr (1986, 1987, 1990) only examines one domain of technical knowledge, and does not explore power/knowledge relations between potentially equal and valid technical domains, and how this might affect the telling of "war stories".

9.4.2. Technological networks of the firm

Everyday production activity keeps print communities alive. In order to make production happen, individuals in firms have to communicate with other people, either within the same firm or in different firms. This can be conceptualised as the creation of temporary technological networks for the provision of goods and services, and the mobilisation of knowledge. For every job, previous networks have to be reactivated and renegotiated, or new ones created. As suggested in 2.7., these can be seen as networks of reciprocal power/knowledge relations, performed as collective actions between knowledge carriers. Although all the networks are person-to-person, they operate on two levels : people dealing with each other as representatives of their firms (business contacts); and people dealing with each other as individuals (personal contacts).

Relations between members of networks at firm level may be premised on close familiarity, acquaintance, reputation or hearsay. They may be created or sustained both formally and informally. Although they are often contractual and hence legally regulated, such relations involve substantial non-economic elements of informal advice and feedback. However, there are aspects of barter about this process -

no money or tangible items of financial value are exchanged, but approximate scores are kept of the knowledge or information thereby transferred. Firms which do not reciprocate equally in knowledge exchange over time, in either quantitative or qualitative terms, may find that particular node of their knowledge network blocked. It is however possible for the transmission of technological knowledge to flow all in one direction in return for contracts awarded or a more feasible job.

The plurality and diversity of a single print firm's everyday networks of knowledge are considerable. They are more heterogeneous in composition than communities, since they include outsiders such as customers. Previous studies which noted the variety of actors found in an industrial context (Sorensen and Levold, 1992; de Solla Price, 1982) did not distinguish between communities and networks, and hence failed to spot this difference. In addition, this heterogeneity may be internal or external to the firm, varying with the industry and the sector.

A firm's external networks extend beyond the formal boundaries of the organisation to access or create the knowledge needed to produce jobs. Knowing where to search is itself a form of localised knowledge, contingent to a particular firm (Fleck, 1988). The networks thus formed may be sectoral, comprising other printers, and their sectorally-related materials or equipment suppliers. They may also be regional or very local, including other printers in the same geographical area, together with regional or local suppliers. Depending on the size of the sector and the number of firms in it, networks may be both sectorally AND geographically bounded.

The importance of trade work and subcontracting to a firm's activities influences the extent of its participation in external networks. The more homogeneous its products and the more processes carried out in-house, the less chance of its external networks including a wide range of firms. The degree of specialisation, the number of firms providing the service, and the frequency with which such processes are required determine whether these networks are

sectoral, local, regional or even national in their dispersion.

The time costs of subcontracting may dictate whether a particular process is set up to be performed in-house. Where speed of turnaround and control over the timing of production is crucial to the product's saleability, subcontracting is not an option. Such firms have neither time nor need to cultivate the type of everyday network which provides a sense of being part of a wider print-related community, and of having access to a vast spread of knowledge. Their community is obvious and visible : similar firms, usually in fierce competition. Effectively homogeneous single-product producers keep all their printing knowledge in-house, most of their engineering knowledge, and much of their computing knowledge too. The heterogeneity of such firms' networks is internal and hermetic.

9.4.3. Technological networks of individuals

At an individual level, personal networks vary considerably in their heterogeneity, depending on a number of factors. The external networks to which printworkers have access as carriers of knowledge reflect their occupational group; perceived position in the firm's hierarchy; training history; age; kinship, cohabitation or marriage; previous or potential job mobility; sectoral/functional experience; present task-related activities; and their principal domain of knowledge. Individuals create knowledge networks through the channels open to them as representatives of a firm. Those with functional responsibility for mobilising resources, such as materials or subcontract work, tend have more external networks than those who do not. Workers create their own personal networks over time, often starting with meeting their peers in other firms whilst training, and subsequently through moving around the industry from job to job. This can be seen as the printing equivalent of von Hippel's (1987) "knowledge leakage". Sectoral boundaries sometimes curtail this process, particularly if individuals move from general printing into a more specialised

sector, and their networks contract accordingly. Through personal networks, workers can access the networks of individuals in their own or other firms.

Internal networks between individual workers may be formally mediated, as in the case of production meetings, or informally created by parties who both hope to gain from the exchange or transmission of knowledge. They enable cross-functional liaison (for example, between materials purchasing and production) and inter-departmental linkages (for example, between design and platemaking) to occur. Through such networks, knowledge is exchanged about different activities within the firm and their effect on one another.

But it is not through some form of functional "position power" or personal charisma that workers gain and retain access to their networks. Proof of identity as members of a technological community is a prerequisite for network maintenance (see 9.4.1.). Appropriate use of domain language and the ability to exchange mutually comprehensible and relevant horror stories sustain individual networks, as do the "knowledge leakage" and barter whereby firm-level networks operate, and their more personal equivalents of gossip and "the grapevine". Being a good listener, able to appreciate, comment, and thereby demonstrate understanding of print, is as important for networking as the ability to tell horror stories.

The telling of "war stories" between members of different occupational groups operating with the same domain of knowledge is not examined within the scope of Orr's (1986, 1987, 1990) work. Where this occurs in printing, it functions less as celebration, and more as proof of respective identities and means of passing on knowledge. If one party has specialist knowledge, war stories may serve to delineate and demarcate this area of "expertise" as theirs. Where the division of practical knowledge is unequal, for example between printers and specialist subcontractors, war stories may be a way of warning the party with less experience of how not

to behave, or what not to do with a prospective or actual job.

Technological change in the printing industry has wrought corresponding changes in the networks of individual printworkers. With changes in production and production management technologies and a decline in the number and scope of apprenticeships, formal and heuristic printing knowledge has become concentrated amongst older production workers towards the top of the firm's hierarchy. These are the cognitive components which provide a framework for making wider sense of daily experience, and thus enable workers to tell horror stories which have meaning beyond the immediate work situation. Moreover, it is often heuristic knowledge that "leaks" between firms as "tricks of the trade". Hence these workers have more of the currency necessary to barter knowledge in networks, and greater ability to use what they learn. Growing emphasis on the formal training of print administrators, including estimators and account managers, puts them in a similarly advantageous position for networking, which forms a significant element of their production-related activities.

Workers without this type of training and knowledge, such as printing and finishing assistants, gain knowledge that is task-related and primarily contingent; and less highly valued (as reflected in their pay) and less portable between production departments, firms or industry sectors. Hence they are less able to form networks through job mobility. Younger production workers lose the possibility of networking at college with their peers in other firms during apprenticeship : informal but vital channels for the exchange of knowledge, as observed by Fleck (1995), which might once have lasted a working lifetime.

9.4.4. The relationship between communities and networks

Technological communities and networks are both somewhat ambivalent concepts. The former are durable, but largely irrelevant to the everyday industrial practice of firms and individuals. The latter

are more immediately meaningful, but are contingent on the actions of individuals within firms, and only exist when knowledge is being mobilised; they are transient. Communities and networks are interdependent : communities are brought to life and acquire meaning through the mobilisation of networks; and the creation and operation of networks are only possible or comprehensible in the light of the communities which structure them, and which in turn they themselves sustain. At the same time, a two-way process of institutionalisation links technological communities and networks. Communities can be seen as sets of related networks which have become institutionalised over time, whilst networks can be viewed as localised expressions of those communities. However, as stated earlier, networks involve elements which are not community members, such as "outsiders". They also include elements conventionally disqualified from "community" membership because they are non-human, even though it is members' common concern with those things which binds them together. The material world in the form of texts, procedures, jobs, machinery, tools, and materials is an essential participant in any technological network.

To see technological knowledge as distributed among members of a community who are at the same time actors in their own contingent, local networks is crucial for an understanding of the processes of knowledge mobilisation as conceptualised in the sections which follow, and to the characterisation of those processes as collective.

9.5. WHAT PRINTWORKERS DO : PUTTING KNOWLEDGE INTO PRACTICE

So far, this chapter has discussed the world of printing in terms of the knowledge and perceptions of its inhabitants, and their communities and networks. But what do printworkers do with their knowledge, and how do they mobilise and translate it into practice ? The short answer is : they produce jobs.

9.5.1. Activities which mobilise knowledge

The mobilisation of existing print knowledge in a practical situation produces new (or at least additional) knowledge. It is pertinent to examine here the applicability of Vincenti's (1990) categories of design engineers' knowledge-generating activities (transfer from science; invention; theoretical engineering research; experimental engineering research; design practice; production; direct trial) to the context of manufacturing production : what printworkers actually do on a daily basis. This aspect of Vincenti's taxonomy requires greater modification and comment when applied to printing than do his categories of substantive knowledge. As with the latter ^{when applied to print prodⁿ} (see 9.2.), the knowledge generated may relate to product, process or product-process interaction.

Given that jobs have to be feasible for completion to a timescale and within an organised schedule, most print firms have neither opportunity nor need to undertake formal, systematic theoretical or experimental printing (or engineering) research in order to get the final product out of the door. Most do not have R&D programmes or departments. This is NOT to state that no print firm ever undertakes or participates in technical (or other) print research. Transfer from science - whether well-established or current - is not usually a knowledge-generating activity for printworkers for similar reasons. To paraphrase Vincenti, knowledge used in everyday design and production originates and develops mainly within printing. Although there are exceptions (see 7.3.2.), such as the application of basic scientific concepts like gravity to specific problem-solving situations, these do not attain the complexity of the instances reported by Vincenti (1990). The results of print research undertaken or supported by PIRA and reported at TAGA or IARIGAI conferences are more likely to reach firms through the mediation of materials and equipment suppliers who have already arrived at a prototype for field trials or a finished product. This is also the case with the application of theoretical and experimental engineering research by print production equipment

suppliers. Information about such developments reaches printworkers through the trade press and industry exhibitions. Hence the processes of selecting and implementing new materials or equipment becomest the related major knowledge-generating activity for most print firms.

Whilst the use of new materials is part of normal production practice for printers (see 6.3.2 and 7.3.2), the acquisition of new capital equipment occurs less often. However, given the lengthy timescales required for the implementation of complex technological systems (Fleck, 1993), such as CAPM or CIM, many firms (including those in the case studies) operate in a state of perpetual implementation, and as such, this could be construed as part of everyday production practice generating technological knowledge.

There is one difficulty with Vincenti's list not specific to printing : the inclusion of "invention" as a discrete knowledge-generating activity. Although Vincenti engages with debates on the science-engineering-technology relationship, he does not tackle those relating to linear versus feedback theories of the invention-innovation-diffusion processes. From a wish to concentrate on normal design engineering knowledge and practice, Vincenti appears to characterise "invention" as some kind of "radical" activity, separate from what engineers normally do, and hence ignores it deliberately and by his own admission (1990:8,230) in order to delimit the scope of his work.

The innovation literature suggests that it is not useful or possible to treat the various stages of the innovation process in isolation from each other; that innovation can occur in an everyday design, production or operational context as well as in a ^{Fleck (1988)} laboratory or R&D department; and that most innovations are incremental rather than radical. ^(Pasajia, 1988) And all five of ^{Vincenti's (1990)} ~~his~~ case studies relate to the development of incremental aeronautical innovations. The empirical evidence of this thesis demonstrates that local, incremental innovations to both product and process are regular features of print design and production problem-solving. Hence

innovation is an intrinsic part of all the other knowledge-generating activities listed by Vincenti, not a distinct category.

Finally, Vincenti intends these categories to be a list of design engineers' activities which result in knowledge-generation, so why is "operation" included? According to him, it is customers who operate the designed devices, and so it should be engineers receiving their feedback on the finished product which generates the knowledge. This type of knowledge-generating activity certainly occurs in printing, as does the gathering of similar feedback from subcontractors about work-in-progress. Where members of print or print-related communities are involved in feedback to printworkers (or vice versa), this will often be a two-way exchange. For example, printworkers providing graphic designers with information about how their artwork translated into print in practice find out more about design activity and customer demands in the process.

9.5.2. Knowledge-mobilising situations and milieux

Knowledge mobilisation and generation during everyday print production involved the gathering together of different types of substantive domain knowledge carried as diverse cognitive components by their human carriers (Vincenti's (1990) "personal agents"), in combination with a variety of non-human elements, such as texts/images, tools and other technical objects. People without domain knowledge, such as customers, might be involved as providers of information. This represents the creation of technological networks. These activities generally (though not always) occurred on firm premises, in either production or office areas, although some people participated by telephone.

Such processes of network assembly can be seen as creating "situations" arising in particular environments, or "milieux", to use Fleck's (1988) terminology. In the light of the empirical material, a number of comments can be made about this part of Fleck's framework. The 'other elements' referred to as forming part

of "situations" in Fleck's revised (1995) taxonomy have to include the non-human world. A "milieu" is not necessarily spatial : the location in which knowledge-mobilising activities happened was often not their most salient feature; the material objects found or brought there as originals or representations by the people involved in the situation were more important. For example, the milieu for production problem-solving was not always the shopfloor, as long as the relevant carriers of knowledge and material artefacts were present. Hence particular situations are not confined to certain milieux, although they may be more likely to occur in some than in others.

Empirical description and conceptualisation of the mobilisation process lie outside the scope of the work on knowledge taxonomies by Fleck (1988) and Vincenti (1990). Although Vincenti looks at the growth of normal engineering design knowledge in some detail, he does so from a historical perspective, and without attempting to analyse the concomitant social processes. The following section conceptualises the everyday mobilisation of print production knowledge.

9.5.3. Definition and problem-solution

The case studies provide evidence of two main types of situation in which knowledge is mobilised in technological networks. These I have termed "definition" and "problem-solution". Each has distinct characteristics regarding purpose, the range of actors and objects involved, and the kind of collective knowledge at issue. It should be noted that the specific activities which give rise to each situation differ between firms and industry sectors : what is definition for one organisation may require problem-solution in another, as the case studies demonstrate.

In a manufacturing context, product and process novelty, uncertainty and variety influence these differences, as do the technological ensemble and customer base of the firm, but it is

outside the scope of this thesis to predict which factors will be most significant in a given situation. However, it would appear from the case studies that size and formal organisational structure do not affect the degree or type of collectivity displayed in knowledge mobilisation situations : people in hierarchical firms are as likely to problem-solve collectively (in an aggregate rather than a political sense) as those in worker cooperatives. The empirically-based conceptual categories summarised below provide a framework for thinking about knowledge mobilisation processes within print firms, which is sufficiently generalisable to be applied in other contexts.

Definition is concerned with setting limits, standardising, or stating the exact meaning or performance of things and people connected with production : the job (and by extension, the firm), an item of machinery, the finished product. Such processes draw upon existing standards and established problem solutions already framed in the language of a single domain : parts of the common knowledge of print communities at industry, firm or occupational level. Situations in which definition occurred in printing usually involved a single printworker at any one time, working with a wide range of objects, such as presses, Pantone books, price lists, production schedules, proofs and printed images. "Outsiders", most frequently customers, might participate as providers of information rather than as active definers. The networks created during definition thus largely consist of the non-human world. Definition may be a social process, but it is often not a particularly sociable activity.

It is precisely because definition mobilises institutionalised common knowledge that it can be undertaken by a solitary individual carrying domain knowledge. The exercise of this knowledge is underpinned by its embodiment in texts, tools and production equipment, as well as its internalisation by carriers. Definition tends not to alter existing knowledge and power relations, but rather to recreate and confirm them. Material objects and the use of domain language play a significant role in limiting the degree

of interpretative flexibility possible when definition takes place, thereby ensuring an outcome which other practitioners would support, even though they might arrive at a slightly different version if presented with the same situation because of their own past practice of that common knowledge : their personal knowledge.

Any category of technical or non-technical substantive knowledge carried in common by domain practitioners may be mobilised during definition, albeit modified to its current context of use by local practical considerations, or by its context- and "device-specific" (Vincenti, 1990) aspects. Likewise, such knowledge may be known in terms of any of Fleck's (1988) cognitive components, but a contingent element will almost always be present as well, in order for knowledge to be applied in the specific situation.

Problem-solution occurs in situations either where definition is recognised as an impossibility from the outset, or where attempts to produce a definition or standard using common knowledge fail in practice. The printworker whose task it is to define or standardise a product or process is unable to do so by combining their own common domain knowledge with that carried by the available texts and tools and with any information supplied by "outsiders". A search process for a workable solution begins. To the (hitherto insufficient) network thus far assembled, printworkers use their "non-technical" knowledge (see 9.2.2) to draw on personal contacts from within their technological community, both internal and external to the firm. These actors may also refer to or bring relevant material objects with them to the situation, as well as other people they know to be potentially useful for solving the problem.

Networks for problem-solution therefore include several (even many) domain practitioners as well as a wide variety of objects. The more seemingly intractable the problem situation, the wider and more heterogeneous will be the problem-solving network created in response, and the more actors will be added to it. Mobilisation of knowledge for problem-solving in printing, unlike most instances of

definition, is a visible, public and often sociable occurrence. It frequently brings together people from different departments and all levels of the organisation's formal hierarchy, as well as domain practitioners from outside the firm.

The knowledge mobilised is of a different kind of collectivity from that employed in definition situations. Instead of the individual mobilisation of common knowledge, problem-solution calls for the collective (in the sense of "aggregate") mobilisation of personal knowledge gained from practice and experience, often in the form of "horror stories". Such contributions require a framework of common knowledge for evaluation and interpretation : in particular, meta-knowledge, formal and informal knowledge of fundamental design and production concepts, criteria and specifications, and theoretical tools. Without such knowledge being carried by at least one participant in the situation, a workable solution is difficult to achieve¹. Problem-solving activity still occurs, but the process takes longer and a conclusion is less likely.

Just as domain language, texts and tools structure the outcomes of the definition process, so the validation of personal experience by reference to common knowledge serves both to codify (and hence to legitimate) otherwise "subjugated" knowledges, and to contain any subversive potential of problem-solving in terms of its apparent temporary suspension of prevailing organisational power and knowledge relations. However, the networks thus created are themselves temporary and renegotiable, lasting only as long as it takes for a solution to be found. Attempts to perpetuate these problem-solution networks tend to expose their members to the full weight of previously established power/knowledge relations, and are hence unlikely to create durable or useful sites for knowledge mobilisation. Voices which were attended to in the heat of problem-solution because they offered workable knowledge may be ignored

e 7.4.2 re finishing assistants at Weirs, and 8.5.2 re press crews at ty. Both groups lacked this common framework of knowledge.

when everyday hierarchies reappear.

By contrast, the problem solutions themselves are more amenable to incorporation into common knowledge and practice, at least within the firm. A degree of institutionalisation is required for satisfactory solutions to be incorporated into the firm's production knowledge in ways that are not utterly contingent on the presence of individual actors. This might consist of changes in procedures, such as the setting up of regular cross-functional meetings to discuss production problems; or the conversion of knowledge into textual form, such as log books, new categories of job specification or works instructions. However, product and process variety may limit the extent to which institutionalisation of solutions is possible, since variables can always be invoked which stress the difference between one problem-solving situation and another, rather than the similarities. What works for one job may not work for another almost or apparently identical.

9.5.4. Moving between domains of knowledge

There are situations in which problem-solution using the knowledge of a single, "primary", domain does not achieve a workable outcome, however many actors and objects become involved. In print production, the next most likely domain of knowledge to provide a solution is engineering. Production workers with a full range of substantive printing knowledge usually have enough mechanical understanding themselves to recognise that a given situation calls for engineering knowledge and practice, either in combination with print knowledge or on its own. They will know people who are likely to carry that knowledge and who can become involved in the mobilisation process.

Carriers of knowledge from that domain are then brought into the situation, together with any material objects they may think relevant and of practical use. There are two scenarios for what follows. Either some people and objects from the primary domain

remain to problem-solve collaboratively with those from the other where the solution is thought to span both domains; or problem-solution is appropriated by actors from the new domain with their texts and tools, with only certain objects from the primary domain still participating - generally the production equipment which is causing the problem. The latter case may arise because of established power relations between the two domains. It may also be explicable in terms of this section of the thesis. If the issue is one of definition for the new domain, printworkers will become outsiders providing information but not being active definers, or their presence may not be necessary at all. Once a problem has passed into a second domain, if definition does not achieve a result, then subsequent problem-solution will be sought within that domain until its possibilities have been exhausted. At this point, either a third domain of knowledge will be brought into play or there will be ^{renewed} collaboration with the primary domain.

When problem-solution shifts to a different domain, or occurs in an area of substantive overlap between domains, some of the people and objects involved need to operate in the networks of both : they require a "dual identity". Vincenti's (1990) "translators", and Hughes' (1986) "heterogeneous engineers"¹, able to function in and speak the language of more than one domain, are similar concepts. However, there are some differences in the meaning and scope of application of these terms.

Firstly, both Vincenti and Hughes appear to see dual identity in positive terms. The case studies suggest that this is not always so, particularly if one domain of knowledge is usually carried by "professionals" (engineering) able to define themselves as experts, and the other is not (printing). In-house engineers whose knowledge has been "contaminated" by print knowledge gained from close contact with printworkers may be regarded as inferior by external engineers. The print knowledge they carry may not be formally

consider too, the concept of the "hybrid manager".

recognised within the firm, as with the unofficial engineering knowledge that some printworkers carry. Nevertheless, these dual-identity actors are important members of problem-solving networks and are acknowledged as such, though without the significance of their dual-domain contribution being fully appreciated. They themselves find their own mixture of domain knowledges fascinating and practically useful, hence a potential means of enhancing reputation through practice within the firm.

Secondly, the question arises of who or what can have dual identity. Vincenti only intends people, such as test pilots, to be "translators" - in that particular instance between the domains of aviation and engineering. It is less clear from the general tenor of Hughes' work whether "heterogeneous engineers" can only be human, but the examples he uses, such as Thomas Edison (Hughes, 1983), suggest that this is so. The case studies show that material objects, such as presses/machines, also have dual identity, can be described in more than one domain language, and are part of the networks of different domains. This applies equally to intangibles, such as job specifications. The aeroplanes in Vincenti's work can thus be seen to have dual identities (plane/machine; means of transport/machine). This sheds light on some of the substantive knowledge he categorises as "practical considerations", and the user feedback types of knowledge-generating activity : they involve the translation of knowledge between various domains implicated in design, production and operation processes. The example Vincenti uses to demonstrate the acquisition of tacit knowledge by engineers flying with test pilots can then be read additionally as an exercise in inter-domain translation for problem-solution. Returning to the two scenarios discussed above, it is clear that objects must have dual identity if a second domain of knowledge is to be interrogated. If a domain-collaborative solution is sought, dual-identity people are essential too.

9.6. CREATING NETWORKS : MOBILISING KNOWLEDGE

The framework for thinking about knowledge mobilisation which I have outlined in the preceding section leaves open questions about how such processes might be theorised. This thesis does not attempt to provide a conclusive answer, but some of the possibilities sketched out in chapter 2 are discussed below in the light of the empirical material. Assertions made earlier in this chapter about the substantive and cognitive content of knowledge, and its acquisition and distribution amongst carriers as common or personal knowledge should also be borne in mind.

9.6.1. The social shaping of knowledge mobilisation networks

If common domain knowledge is shared by practitioners who are part of various technological communities which are relatively stable over time and distance, then how people come to be in definition situations and what they do in them can be analysed using frameworks which refer to existing social, technical, economic and political structures, and which utilise theories based on explanatory concepts such as capital, class, race and gender. The social, economic and political interests of those involved provide them with reasons for mobilising knowledge and for at the same time performing power relations. Although only one person is usually present in a definition situation, their actions are nonetheless given direction and meaning by existing power/knowledge relations within the firm and other technological communities, as well as by the embodiment of those relations in all the material objects which surround them, and with which they choose specifically to create networks in that particular situation.

But this does not give the whole picture. Human actors have some choice over which objects to include during definition, and common knowledge does not cover every eventuality and is not entirely or rigidly codified. There is scope for reinterpretation of basic

domain knowledge in the light of personal experience, and this latitude is essential for everyday printing practice to occur. However, where increasing amounts of the knowledge to be mobilised are already embedded in the material world, there is correspondingly less opportunity for workers to add their own contribution, as with various forms of automation seen in the case study firms - especially the CIM system at Trinity and the estimating system at Weirs. On the other hand, such technologies may provide some, though not all, workers with new areas of knowledge (see 9.3.3.).

Personal knowledge and experience are even more important in problem-solution, when the micro-level interactions between individuals appear to transcend organisational structures, albeit temporarily, in the collective interest of the firm. However, an existing social order underlies this seemingly cooperative anarchy, in parallel with the interpretation of individual contributions to problem-solution by reference to a framework of common knowledge. Just as such a framework of knowledge is used to evaluate the viability of suggestions, so the existing frameworks of power determine in part whose voice is attended to, and whose knowledge is considered to count.

The knowledge which workers carry and the networks to which they have access are shaped by external factors as well as by their own actions and volition. The tension between structure and agency discussed theoretically in chapter 2 is thus present in a real and practical form during production activities. Their interplay can be considered productive in practice, and could maybe be seen as equally productive at a theoretical level.

9.6.2. Actor-networks, or networks of actors ?

Although both definition and problem-solution involve the creation of temporary networks of human actors and objects and result in what can be seen as "closure", it is difficult to apply Callon's

(1987) microsociological "actor-network" theory with its four-stage "translation" model, and to derive much explanatory value from the exercise. There are several problems.

Firstly, some of the model's stages and participants are absent. During definition, "problematization" does not occur and "interessement" is not an issue : there are no other human actors involved to offer competing solutions. In problem-solution, the element of problematization for human actors is not how to make their knowledge indispensable, but how to make the job happen. However, the creation of technological networks could be construed as "enrolment", and the mobilisation of knowledge by those networks which produces a workable definition or problem-solution could correspond to the final stage of "mobilisation". But all in all, the four-stage model does not fit well with the empirical details of definition and problem-solution in a day-to-day manufacturing context.

Secondly, who or what is then the "major actor" ? Looking at empirical situations, it is difficult to tell. The original creator of a network is not always in a position to accept or reject suggestions. Although whoever offers the suggestion that is taken up and works could be said to have "got between" other actors and their solutions, production-related problem-solving is not necessarily a competitive process; rather, the case study evidence points to its collective and collaborative nature, albeit in the light of organisational power relations. Perhaps the Production Manager is the major actor ? But the evidence of the case studies and the industry chapter suggest that this is a complex and distributed function, collectively performed. Law's (1986) paper suggests that texts are a method of long distance control, through the power/knowledge relations embedded therein. Production could be seen as managed indirectly through the use of documents like the imposition form (Trinity), or job specifications and works instructions (Weirs and Freedom). At Trinity, the CIM system could be seen as a production manager : automated, non-human and impersonal, where power/knowledge relations indeed 'function in a

function' (Foucault, 1977), as production cannot happen without using the system. This might suggest that an inanimate object without intentions, interests or agency can be the major actor in a situation. Such a position would be problematic theoretically, as well as not being very useful for accounting for the mobilisation of knowledge.

Thirdly, both definition and problem-solution can be seen as everyday moments of varying "interpretative flexibility" (Bijker and Pinch, 1986) that require actual closure. Rhetorical closure is not a possibility in a production context, as Sorenson and Levold (1992) point out : a tangible product has to be finished to an agreed specification within certain time limits. Each job has successive moments of closure, beginning with the definition of its feasibility, and ending with the customer's acceptance of the finished product. Closure is temporarily achieved when a workable short-term solution, not necessarily acknowledged by actors to be "the best" or anything like it, is found during knowledge mobilisation to progress a job. However, this does not mean that the same difficulty will not recur, and the debate be reopened. Closure is not necessarily permanent, even if it is actual. What works for one job may not work for another almost or apparently identical. Product and process variety limit the extent of long-term closure, since new variables can always be invoked which stress the difference between one problem-solving situation and another, rather than the similarities.

Finally, all four stages assume that there are no a priori factors to be considered; everything is open to negotiation. This is not the case in print production. Structural factors are not merely "explanatory scenery" : a backdrop against which actors function, but with which they do not interact (Bijker, 1992); they shape and are themselves shaped by micro-level social processes. How people become printworkers; the knowledge they carry; the domain language with which they express themselves; and the texts, tools and technologies they use have already been "blackboxed", in that when problems arise in the normal course of production, they do not

result in a reopening of such issues. Latour (1986) might argue that everyday production problems are insufficiently "controversial", being part of successful ready-made technology, and hence the microsociological processes at work remain hidden. In purely practical terms, there is no time to redesign a press, invent a new domain language, retrain workers or call into question the industry's structure : the job in hand has to be completed. But apart from that, a constructivist approach to the mobilisation of knowledge for definition and problem-solution is unsatisfactory not because certain things have been blackboxed, but because it does not hold the key to open those boxes.

Nevertheless, some aspects of this approach are helpful. Network formation, although not unique to microsociologists of technology, is a useful image for conceptualising the processes of knowledge mobilisation. The emphasis on the importance of the non-human world as part of such networks is a valuable contribution to our understanding of such processes. However, whilst the creation of "actor-networks" suggests a Machiavellian spider's web with the major actor busy spinning to entangle others in its schemes, other kinds of network might provide a more appropriate metaphor for the mobilisation of knowledge during production and the cooperation exhibited during problem-solution.

9.6.3. Foucauldian perspectives on knowledge mobilisation

The concept of constantly renegotiated networks of two-way knowledge relations, homologous but not identical to power relations, would be consistent with a Foucauldian interpretation of the knowledge mobilisation process, as suggested in sections 2.7 and 2.8, with knowledge as a reciprocal relation performed as a collective action by networks of multiple, heterogeneous human actors and non-human objects. Foucault's focus on the process of institutionalisation as a mechanism for exchange between macro and micro levels of social process is valuable for understanding some of the issues connected with the distribution and mobilisation of

knowledge : the relation between technological communities and networks; and the interaction between personal and common knowledge.

It is clear from a reading of Foucault's work (1977) on prisons that much of his analysis (see 2.8) could be applied to business organisations (see Zuboff, 1988; Loft, 1990; Sewell and Wilkinson, 1992). It would be feasible (but of no great additional explanatory value) to perform a Foucauldian reading of power/knowledge relations in an industrial context, as an example of the institutionalisation of disciplinary power in the "factory-monastery", especially in the case of Trinity Press. However, in the light of the case study material, a number of comments can be made and reservations expressed about such a project.

Firstly, Foucault's own work, and that of others adopting similar approaches, concentrate on the disciplinary techniques whereby power relations render the human body "docile", and which utilise the material world to achieve this. And certainly the human carriers of knowledge could be seen as becoming active participants in power/knowledge relations through their exercise of that knowledge, always with the possibility of effective resistance by either side. However, in a production context, the non-human world of product and process is also subject to the disciplinary techniques of observation, standardisation and examination (Foucault, 1977) using diagnostic instruments as well as the naked eye. The sociotechnical ensemble is disciplined, not just the people in it.

Secondly, the illuminating insights afforded by Foucault's (1977) interpretation of Bentham's "panopticon" cannot be extended so categorically to other contexts. The workplace is not a prison. Even though some computer-based technologies, such as CIM systems, may have panoptic characteristics or surveillance potential (Zuboff, 1988), their main use in printing appears to be product and process control by workers at the CPC console. Their application as a form of workforce control by management is by no

means certain. The modular nature of CAPM and CIM systems makes possible a choice whether or not to implement shop-floor data collection (SFDC) modules. Implementation difficulties may delay or prevent this. Where linkages are made between the CPC and terminals off the shopfloor, data accumulated by the system can be used in two ways : converted instantly to information about production events in realtime, or manipulated at a later date to provide management reports or historical information for further analysis. There are problems with both, as the information provided is not always used or useful.

According to Foucault, the panopticon is supposed to function as a disciplinary mechanism creating docile bodies regardless of who is at its centre, or whether there is anyone at the centre at all. But in a production context, it does matter who is inside the panopticon. It is difficult for just anyone to understand the information on screen. A knowledge of print production is necessary, combined with contingent knowledge of what the figures might mean in the particular context of that plant and for that job. Even the "current status" display at Trinity - the main summarising screen - required that level of knowledge. Screen representations of the production technology needed to be translated from 2-D into 3-D : knowledge not carried by outsiders. Diagrams representing various subsystems, such as inking levels or web path, were not much use unless an observer knew where and how they fitted into the whole process, and how to move between the various screen displays within the system.

At Trinity, workers could know whether or not there was anyone at the centre of the "panopticon". Managers considered realtime screen-based surveillance via SFDC insufficient compared to direct presence, and were thus frequently visible on the shopfloor. What appears on screen is a model of production couched in formal and heuristic terms, which constitute only part of overall production knowledge and experience. The model is not an adequate representation of the complex reality (Orr, 1986) and therefore can supply only incomplete cues for managerial action. Visual

representations may be simplified "docile bodies", but their originals still break down and misbehave in unexpected and sometimes inexplicable ways, despite maintenance programmes, diagnostic systems and quality control procedures.

Even if workers are aware that a CIM system is inadequate as a realtime means of surveillance, the fact that it accumulates and manipulates information about all production activity for subsequent examination might be thought to influence their actions. But the use of historical production data for surveillance purposes is problematic. Workers may become aware of this in a number of ways : managerial difficulties with the technology heard about through the grapevine; through their own experience of no comeback on their activities other than the most obvious comments which could have been made without the system; and through their own use of the system for production control purposes. The sheer volume and minute detail of data collected by such systems may make it difficult to extract reports which convey information useful to managers or production workers.

Firms may hardly use the report-generating facilities made feasible by SFDC. Firstly, the process is time-consuming, and the results may not be considered worth the effort involved. Secondly, if everything is recorded, there may be problems defining what is relevant, and who is to be the judge of this. Prior to "information overload" comes data overkill. Thirdly, someone needs to decide how the relevant data should be linked together, which raises questions of causality, dependent and independent variables, and other aspects of quantitative analysis - and again, of who is to determine this. Contingent knowledge and tacit knowledge gained from practical experience risk being sidelined in favour of more abstract, formal measures. Being able to see the firm 'under a microscope' (Schweisser and Rettberg, 1989) is pointless if overall perspective is lost, and in printing, managers appeared well aware of this.

9.6.4. Conceptualising the knowledge mobilisation process

One possible way of conceptualising the distribution and mobilisation of knowledge in organisations is as the creation of a dynamic type of crystal lattice, in which atoms are the human carriers of the various substantive and cognitive components of knowledge in different mixtures, and also the non-human elements of the domain, such as texts, tools and machines. Each atom has some properties or characteristics influencing which other atoms it is most likely to bond with. These may be structural or contingent. The bonds between the atoms are those of power/knowledge relations which enable knowledge to be mobilised as a basis for action. Some bonds are stronger, last for longer, and are more durable than others. Other alliances are more temporary, although some may eventually become institutionalised over time, and standardised through repetition and practice¹.

All bonds, however, are continually reformed and renegotiated (Foucault, 1977) in the course of day-to-day practice, even if it is to recreate and reinforce them as they were previously. In defining and problem-solving situations, both the atoms and the bonds between them are created anew, as different carriers become involved with each other and with different objects from the material world, forming different knowledge "compounds" with a diversity of "molecular structures". It should be noted that the shape of a firm's "knowledge lattices" is unlikely to correspond to any formal or informal organisational structure, because of the external and non-human atoms involved.

Conceptualising organisational knowledge as the process of assembling a crystal lattice, rather than the resultant entity itself, works against the potential reification of a dynamic and constantly shifting activity, inseparable from practice. It makes

or those of a non-chemical bent, the wind-driven neon light
installation on top of the Hayward Gallery may be a useful image.

it difficult to see knowledge as an individual "possession" - atoms are no use on their own without bonds to connect them to other atoms, whether those be other people, or tools, texts and images. The minimum requirement for any form of collective mobilisation of knowledge appears to be one bond linking two atoms. It takes two to make a knowledge relation. This would be consonant with Foucauldian views of power relations as requiring at least two participants, albeit with intrinsic and often strong or effective resistances.

9.7. SUMMARY

This chapter combined academic debates about scientific and technological knowledge with the empirical evidence of this research. It examined the detailed content of everyday print knowledge in substantive and cognitive terms, and suggested that it can be usefully conceptualised (with modifications) using taxonomic frameworks developed to account for design engineering (Vincenti, 1990) and scientific (Fleck, 1988) knowledge. Visualisation and tacit knowledge were discussed in the light of existing literature, but the case study material revealed other aspects of print knowledge, which increase our understanding of "normal" technological knowledge more generally. Print knowledge was shown to be more complex than "outsiders" might think. Fleck's "socio-cognitive structures" provide the link between the content of print knowledge and its social distribution, which is uneven and unequal, even among printworkers. Drawing on the sociology of scientific knowledge, the organisation of print knowledge can be conceptualised in terms of technological communities, but also by the idea of networks operating within them; the former at the level of industry sectors and occupational groupings generally, and the latter more specifically, involving particular firms and individuals. Membership of communities is largely shaped by structural factors, but there is more scope for contingent, personal action in the creation of networks for the everyday mobilisation of knowledge, albeit underpinned by community.

Thinking about the distribution of knowledge in this way serves to make the essential connection with practice. From the empirical evidence of the case studies, the chapter offered a framework for understanding the mobilisation of print production knowledge based on concepts of collectivity : definition in the light of shared, common knowledge, entailing the creation by printworkers of a network primarily consisting of objects embodying domain knowledge and language; and problem-solution, whereby individual, unshared knowledge of production (including that of "outsiders") is collectively assembled and interpreted in the light of common knowledge, through the creation of more complex networks of domain practitioners and related objects. What occurs when a domain-specific problem solution cannot be achieved was also considered, involving the participation of "dual-identity" objects and people ("translators"), and, ultimately, the appropriation of the problem by practitioners from another domain of knowledge.

Finally, the chapter discussed the advantages and limitations of structuralist, constructivist and Foucauldian approaches to analysing knowledge mobilisation. Reservations expressed in the review of the literature remained unresolved in the face of the empirical evidence, but could be more concretely expressed. Structural factors shape the content, distribution and mobilisation of everyday print knowledge, but do not determine it completely, so "social shaping" theory is useful, but does not illuminate the whole picture; constructivist "actor-network" theory appears to be unworkable when applied to everyday print production, although non-human objects are extremely significant in knowledge mobilisation networks; and a Foucauldian approach sheds light on the process whereby the contingent is institutionalised and made durable, and the structural made flexible and locally applicable.

CHAPTER 10 - CONCLUSION

This thesis demonstrates that the content, distribution and mobilisation of everyday print production knowledge are interconnected and cannot be considered in isolation from one another. All are collective, social and technical processes, ongoing and continually renegotiated by participants using domain-related language and objects, regardless of the organisational structures within which they occur. Structural, contingent and institutional factors shape these processes, but print knowledge is irreducibly and dynamically practical and collective. No other study appears to have addressed all three aspects of technological knowledge as being conceptually and analytically interconnected AND provided the rich empirical detail of this research.

10.1. SYNOPSIS

This research examined everyday production in the printing industry in terms of knowledge - a novel approach to the material, and one more usually reserved for grander subjects such as high-technology innovation or big technological failures. My own experience of day-to-day print knowledge and practice suggested that such a treatment would be useful and revealing. The project was carried out from my perspective as a "dual-identity" actor : ex-printworker and academic researcher. It explored in detail the variety of knowledge carried and acted upon by a wide range of printworkers during their ordinary production-related activities, in order to address the following issues and associated research questions :

A. The content of knowledge

a) What can be said about the domain-related *substantive* content of printing knowledge as an example of "normal" manufacturing knowledge, and what are its notable features, in the light of knowledge taxonomies previously developed to address scientific and engineering ?

b) Can existing taxonomies which conceptualise the *cognitive* content of scientific and engineering knowledge be applied to printing, as an example of everyday technological knowledge ? What are its notable features, and do changes in manufacturing technologies, such as computerised process control and automation, affect this ?

B. The distribution of knowledge

What is the distribution of technological knowledge within and between individuals and firms, and how can this be conceptualised and analysed to account for variations in individual and organisational knowledge ? How relevant are notions of scientific and technological communities, or might other concepts be useful too ?

C. The mobilisation of knowledge

How and when is knowledge put into practice during everyday production activity ? Can this mobilisation be termed collective ? How can it be conceptualised and analysed, and which frameworks or theoretical perspectives provide an appropriate basis for this ?

To investigate these issues, qualitative research was carried out. It employed secondary data sources and semi-structured interviews to obtain an overview of the printing industry and the social, technical and economic factors which shape it. Detailed case study fieldwork using a range of data collection methods was undertaken in three heterogeneous firms in different industry sectors :

general printing, direct mail, and newspaper printing. This generated primary empirical data about everyday print practice and knowledge which were analysed using an iterative combination of grounded theory, comparison between sites, and testing out conceptual and analytical frameworks on the data.

10.2. FINDINGS AND CONCLUSIONS

In order to make production happen, printworkers put into practice their richly varied and complex knowledge of products, processes and the interaction between these, in combination with equally important knowledge about the printing industry, print firms, materials and equipment suppliers, subcontractors, occupational groups, individual practitioners, markets and customers. All printworkers, from finishing assistants to administrators to senior managers, carry a wide range of this knowledge. However, the distribution of print knowledge is uneven : print-specific factors such as occupation, training, industry sector and production technology shape workers' daily activities in combination with more general factors such as class and gender to produce differentiated patterns of access amongst individuals and groups to print knowledge and knowledge networks.

The content of print knowledge has substantive and cognitive dimensions. The substantive content is what is known about this specific domain - the world of printing and printworkers - the people and organisations and the material objects which inhabit it, the activities which take place in it, and the various methods for thinking and going about these activities. So everyday print knowledge includes not just technical, but also social, economic, political and geographical elements. These include "knowing why" and "knowing how" as well as "knowing what". Vincenti's (1990) typology of substantive design engineering knowledge can be adapted to the more overtly technical aspects of manufacturing production knowledge. A typology of other kinds of print knowledge was

outlined. It should be stressed that the substantive content of knowledge is not always factual, and may indeed be contested and contestable.

Printing, as a domain of knowledge and practice, is therefore an ongoing social process. The domain language in which print knowledge is expressed is also social, as are all language and all knowledge, however seemingly abstract or technical the domain to which they relate. It is social in that people use it to communicate with each other, and in that it describes what has been socially constructed as relevant, useful or permissible to be known, acted upon and spoken about by the inhabitants of the domain. Substantive print knowledge is collective in that it is carried in common by domain workers (albeit unevenly distributed), and in the aggregate or overall sense of collective whereby the combined knowledge of printworkers adds up to the domain knowledge.

The cognitive content of print knowledge refers to the variety of ways in which the world of printing is perceived by individual practitioners : as, for example, meta-knowledge, rules of thumb, or tacit knowledge, and usually as a combination of several components. It is NOT a question of "knowing how", but rather of "how you know". Cognition too is a social process, occurring as it does in the course of socially structured and constructed mental or practical activity in a particular social context. The different kinds of cognition are in themselves inherently social and imply an uneven distribution of knowledge amongst various groups of printworkers. Thus the cognitive content of knowledge also brings collectivity, in terms of workers' shared perceptions of the print world, and in the aggregate sense of a combination of varied perceptions of the whole domain.

The substantive and cognitive content of print knowledge are interconnected. How workers perceive that world affects what they notice, say and do about it, and the features of the domain in turn influence how they know, describe and act upon it. Any of the substantive features of the domain may be known as any of Fleck's

(1988) cognitive components. Nevertheless, it is useful to address these aspects of knowledge separately in order to investigate a specific empirical domain such as printing, and to understand the significance of particular kinds of cognition in that context.

The research took taxonomic frameworks originally developed for conceptualising scientific and engineering knowledge, usually seen as privileged or professional domains of activity, and applied them to the everyday production knowledge and practice of the full range of manual, clerical and managerial workers in printing, an ordinary manufacturing industry. This domain is not one considered to be privileged, professional or particularly knowledge-intensive, and yet these conceptual frameworks were applicable and useful for understanding print activity, in its own right and as a more general example of "normal" technological knowledge and practice. Comments, revisions and additions made to those frameworks in the light of the empirical material on printing can be applied equally to their original subjects.

Printworkers become part of sectoral, local and occupational printing "communities" through everyday practice. Firm and individual membership of such communities is negotiated and reinforced through their daily activities, ability to use domain language and objects, and recounting of "horror stories". Firms acquire reputation which reflects on the individuals who work in them. However, the personal and firm-level "networks" workers create in the course of their production activities are more immediately useful and meaningful to them than more abstract notions of community. Industry sector and occupation also directly constrain or enable printworkers in creating knowledge networks in practice.

This research extended the idea of "scientific communities" to see if it served to conceptualise social groupings, and hence collective knowledge, in industry. The concept of community had been applied to groupings of technological practitioners, but without detailed empirical studies in support. My research found

that the idea of community, which in science has been taken as implying peer group collectivity, was paradoxically useful for understanding the unequally shared content and distribution of print knowledge in terms of industry sectors and occupational groups. These provided an underlying socio-technical structure constraining or enabling the knowledge and practice of workers in print firms. The concept of technological "community" also supported ^athe view of domain knowledge as collective in the aggregate sense. However, it did not account for the dynamic processes by which individual printworkers mobilised their knowledge during everyday production, nor for the inclusion of outsiders and the importance of material objects. For this, the concept of networks was more appropriate.

Printworkers acquire and generate both shared common and unshared personal knowledge of printing through training, everyday practice and experience. They bring these to bear on production-related activities in two main types of situation : definition and problem-solution. During definition, a single printworker defines product, process or the interaction between them, by drawing on their own common domain knowledge tempered with personal knowledge. To do this often involves assembling a wide variety of domain-related objects, and may include other people who are not printworkers - "outsiders" - as providers of information.

If product and process cannot be defined using common knowledge tweaked by individual personal experience, the situation becomes one of problem-solution. This entails the gathering together of several domain practitioners, plus the material objects they think might be helpful for finding a solution. The more difficult the situation, the more people and objects are physically drawn into the problem-solution process. Printworkers then share their personal knowledge and experience of production, sometimes expressed as horror stories, which they evaluate, interpret and test out in the light of shared, common domain knowledge, until a workable solution is found, eventually achieving definition. Defining and problem-solving are both social activities.

If a solution cannot be found which lies within the domain of print, workers carrying other domains of knowledge, such as engineering, are brought into the process, together with their relevant objects. If these workers also know about printing, a solution may be sought using a combination of knowledge from both domains, and the situation remains one of problem-solution, with many practitioners involved. If the new participants do not carry print knowledge, they exclude printworkers, other than in the information-providing capacity of "outsiders", and dispense with print-related objects, other than those which have a non-printing identity. The situation then shifts domain, and the definition process is repeated.

Although structural factors quite clearly underpin and inform knowledge mobilisation in print firms, structural explanations, whilst providing useful insights, were insufficient for analysing the processes of network creation, given their contingency and temporary duration. Although "actor-network" theory (Callon, 1986) appeared at the outset as a promising analytical framework, because of its microsociological emphasis and inclusion of the non-human world, its application to the empirical material of this research proved difficult. This was not because the subject matter was too mundane, but because the theory could not be applied to the processes of network mobilisation; underestimated the importance of structural factors which shaped the interactions between participants; and hence could not account for the relation between communities and networks. Constructivist approaches to science and technology "in action" cannot be extended to the everyday, otherwise workable operation of already "blackboxed" print production technologies.

A Foucauldian approach to knowledge mobilisation was proposed, which conceptualised the process as a collective action performed by many different human actors and non-human objects, who between them create temporary networks of knowledge. This framework has much to recommend it : the emphasis on action links knowledge to

practice; the diversity of social actors (including outsiders) and the importance of the material world are recognised; and the nature of the mobilisation process, as a shared, cooperative endeavour to aggregate knowledge in the light of prevailing power relations is apparent. Although the resultant knowledge relations are transient, lasting only until definition or problem-solution have been achieved, networks are not randomly assembled. The uneven, unequal distribution of domain knowledge and practice among carriers reflects and creates more permanent social and material arrangements - technological communities : which human actors are most likely to interact with each other when they form networks and what objects they will be able to access or use. In Foucauldian terms, the discourse of printing localises and structures the domain's power/knowledge relations through a process of institutionalisation.

The mobilisation process can be visualised as an array of human and non-human knowledge-carrying atoms linked by stronger or weaker bonds of power/knowledge relations, which are capable of forming more or less stable knowledge compounds with varied but non-random molecular structures, and which have defining and problem-solving properties : an everchanging crystalline lattice of knowledge and practice.

In an everyday printing context, the content, distribution and mobilisation of knowledge through practice are all part of the same collective socio-technical process. What is known cannot be separated from how it is known, who knows it and what they do with that knowledge. In order to make production happen, printworkers have to define product and process and the interaction between them, either directly, or as the result of problem-solving. To achieve this, they share their common and personal knowledge collectively with each other, perhaps not freely and almost certainly under context-dependent economic, social and technical compulsions, and drawing on the knowledge embedded in domain language, texts, tools and machines.

10.3. LIMITATIONS OF THE THESIS AND SUGGESTIONS FOR FURTHER RESEARCH

This research adopted a taxonomic approach to the content of print knowledge, partly through posing the initial question "what do printworkers know ?" This has shaped the answers suggested by the thesis to the research questions in no small way. Drawing on the conceptual frameworks of Vincenti (1990) and Fleck (1988) as means of generating and presenting the case study material produces a view of print knowledge as highly complex and technically detailed, and creates the impression of an organised body of knowledge. This is all very well if it provides unexpected insights into the richness of a domain which might otherwise be thought rather boring, old-fashioned and not worth investigation. Everyday manufacturing knowledge is fascinating, even in industries which are not so much at the cutting edge as some way down the handle; and every worker's knowledge is interesting, regardless of whether they are ordinarily considered experts or professionals.

However, employing such taxonomies risks presenting print knowledge as rarefied yet rigid, when it is neither. Even a slightly altered emphasis would have resulted in a very different research project. For example, discussing print knowledge from an operations management perspective, in terms of knowledge about "the 5 P's" (Muhlemann et al., 1992) : products, plant, processes, programmes (schedules) and personnel, might have been of greater practical relevance. Rejecting a schematic approach altogether, and allowing the data to suggest other ways of conceptualising print knowledge and practice (Glaser and Strauss, 1967) would have led in more ethnographic directions. Other disciplinary perspectives, such as cognitive psychology, would have approached print knowledge from other angles. And inevitably, the outcome of this thesis was dictated from the start by the research questions themselves, which might have been other.

After fieldwork, through further analysis, an unexpected finding

emerged from the data for which no allowance had been made when the research questions were formulated, or during data collection. I became increasingly aware of engineering knowledge being used in print production, and of possible positive connections between the importance of this domain and the level of automation, and negative correlations with the amount of problem-solution occurring during production, as opposed to definition by pre-emptive problem-solution. There is a lack of literature about the relation and overlap between different domains of knowledge in practice, which could have been addressed more fully here.

Although I interviewed plant engineers, system designers and others who worked within those domains, it was largely in connection with their print knowledge. In order to draw firmer conclusions about these issues, I would have had to find out more about their engineering and IT-related activities. One conclusion which can be drawn from this omission is that further empirical studies of technological knowledge in a production context will need to examine not only substantive knowledge related to the industry, but engineering knowledge too. In view of the complex computer-based manufacturing systems that exist, researchers should additionally account for knowledge of systems design, implementation and maintenance. The socio-technical relations between all three domains of knowledge and practice, and the dual-identity actors and objects which permit problem-solving interactions, would need to be explored further.

10.4. ROUNDING OFF

Inter-disciplinary research oriented to empirical concerns is problematic but interesting. Being a "dual-identity" actor and "translator" is often uncomfortable, at both empirical and theoretical levels. At the same time, it frees researchers to explore conceptual and analytical connections that might not be otherwise made, and to investigate new areas and issues for

research which cannot be adequately addressed from within a single disciplinary perspective. And even consultancy may have a useful (and enjoyable) role to play as an action research method.

At a more personal level, the concepts explored in this thesis - that print knowledge is a collective socio-technical process of definition and problem-solving, involving substantive domain content, cognition, distribution, and mobilisation in practice, in which domain language and material objects are extremely important - were discussed with friends with working knowledge of agriculture, forestry, construction and sound engineering, and found relevant to their knowledge, practice and experience. This suggests that the conceptual frameworks and arguments reviewed and put forward by this thesis as relevant to printing may be more broadly applicable - to the knowledge and practice of all workers engaged in organised industrial activity, and perhaps to all forms of knowledge and practice.

APPENDIX I : PRINT PERSONNEL INTERVIEWED (by job title)

1.1. Freedom Press (12)

1.1.1. On-site

Graphic designer (1 present of 2)
Camera-operator/platemaker
Printers (2 of 2)
Production coordinators (2 successive post-holders)
Sales, marketing and estimating workers (2 of 2)
Estimator
Finance worker/estimator

1.1.2. Off-site

Estimating system designer
Production coordinator at site for which the system was originally designed

1.2. Weirs Web (42)

Managing director
Production director
Production manager
Platemakers (2 of 3)
Web manager
No.1 printers (3 of 6)
No.2 printers (3 of 6)
Web assistants (4 of 12)
Finishing supervisors (2 of 3)
Finishing operators (3 of 15)
Finishing assistants (2 of 15)
Despatch/warehousing worker (1 of 3)
In-house engineers (2 of 2)
Sales director
Sales representatives (2 of 2 based at plant)
Commercial manager
Assistant commercial manager
Account managers (3 of 3)
Estimators (3 of 3)
Administration manager
Reception/administration workers (2 of 2)
Administrator/commercial clerk
Management accountant

1.3. Trinity Press (25)

1.3.1. Trinity site

Plant manager
Press manager
Night manager
Platemaker
No.1
No.2
Press crew (3 of 5)
Chief engineer
Engineers (3 : mechanical, electrical, electronic)
Mailroom manager
Mailroom workers (2 of 2)
Reelstore manager
Vans coordinator
Circulation coordinator
Plant administrator

1.3.2. North Bridge site

Deputy computer services manager
Advertising data processing supervisor
Pre-press manager
Scanner operator
Managing director's administrator

1.4. British Printing Industries Federation (2)

Director of consultancy, London region
Management information systems consultant, North-east region

APPENDIX II : OUTLINE INTERVIEW SCHEDULE

WORK HISTORY

1. How long have you worked in the printing industry ?
2. Have you always done your current job ? If not, what other print occupations have you had ?
3. Was that all at this firm ? Which other print firms have you worked in, and what did you do there / what were they like (sector, size, market..) ?

TRAINING

4. What kind of training have you had ? (apprenticeship / printing college; full-time/day-release; short courses/evening courses; in-house training)
5. What subjects did these cover ? (if not shopfloor worker, did training include print production ?)
6. Which parts of your training turned out most useful ? (day-to-day; occasionally)

STARTING WORK

7. Can you remember what you found most difficult when you first started work as a (occupation) ? / working here at this firm ?
8. Did someone show you round when you first started working here ? What was it like settling in ? Have you shown anyone new round since then, and what did you tell them ?
9. What have you learnt (since training) from your practical experience as a (occupation) ? In your previous print occupations (if any) ? Does your original training become more or less important as time goes on ?

EVERYDAY WORK

10. What kind of routine does your day have ? Things you do at the beginning and end of the day ? What about in between ? What might interrupt a "normal" day ?
11. What are your priorities in your job ? What gets left out when it's too difficult to do everything ? Have your priorities changed through experience ?

OUT OF THE ORDINARY

12. What kind of print jobs are most challenging, and why ? What makes jobs unusual or difficult ?
13. What sort of things can go wrong with jobs ? How do you find out if things are going wrong ? What can you do to put them right ? What happens after that ?
14. Which past jobs do you remember most ? Tell me about some of them.

NETWORKS

15. What information do you need to see a job through ? Where do you find it ? Is some of it in the computer system ?
16. Do you keep information on file ? What sort of things ? Where does it come from ? (departmental/crew, or personal)
17. What information do you send to other people in your crew/department ? People in other departments ? People outside the firm ?
18. Who visits / phones / faxes you ? What for ? Who do you contact ?
19. Who do you see and talk to most often ? How do you find out how things are going in other departments ? How do you find out what's going on with the firm in general ?
20. Do you keep in touch with people from your courses ? with people doing the same job in other firms ?
21. Do you get to see the trade press ? trade union newspapers ? other external publications ?
22. What information do you not get that would be useful ? Are there specific aspects of print that you wish you knew more about ?

SUMMING UP

23. What's the best/most satisfying part of your job ? How do you know when you've made a good job of something ?
24. What do you think makes someone a good (occupation) ?

GLOSSARY and ABBREVIATIONS

A sizes : Series of finished trimmed sizes in the International Standards Organisation (ISO) standard metric paper size range, eg. A4, A2.

Art paper : a paper coated after manufacture with a composition of china clay or other mineral.

Backing up : To print the reverse side of a sheet.

Bank : a lightweight (up to 70gsm) uncoated paper, for example, airmail letter paper.

Blanket cylinder : The cylinder on an offset lithographic printing machine on which the blanket (fabric coated with a rubber or synthetic compound) is carried and by means of which the printing image is taken from the plate and transferred onto the paper or other material, directly (as at Weirs and Trinity), or via an "impression cylinder" (as at Freedom).

Bleed : when a printed illustration continues off the edge of the page.

Body : the measurement from top to bottom of a piece of type

Bond : an uncoated paper, heavier than bank (generally between 70 and 100gsm), for example, standard photocopier paper.

BPIF : British Printing Industries Federation, the industry's employers' association.

Broadsheet : finished size of newspaper, approximately A2 (see also tabloid)

CAPM : Computer-Aided Production Management

Catch-up : common print problem, where the water-ink balance on the plate is upset, with not enough ink for the image. Water spreads onto the image area fading it, and carries ink onto non-image areas (like marbling the end papers of a book but not as pretty) producing printed sheets that look as though they have been left out in the rain. Also known as "scumming".

CIM : Computer Integrated Manufacturing

Coldset : printing process whereby the ink dries without the application of heat (see "heatset")

Colour control bar : a coloured strip on the margin of the sheet which enables the platemaker and printer to check by eye or instruments the printing characteristics of each ink layer.

Colour separation : in photo-mechanical reproduction, the process of separating the various colours of a picture usually by colour

filters or electronic scanning so that separate printing plates can be produced. The analytical dissection by photo-mechanical means of a coloured original to prepare for the synthesised reproduction by a graphic process.

Coldset : method of printing in which the ink dries on the sheet without the application of heat.

Convertible press : type of sheet-fed press able to print either on one side of a sheet or on both sides in a single pass.

CPC : Computerised Press Control

Cromalin : a quicker and cheaper form of proofing than machine or flat-bed proofing, in which the image, based on final film, is built up of 4 layers of French chalk (one for each process colour) and varnish.

Cut-offs : the number of cut sheets emerging from the delivery end of a web press. Speed of webs is often expressed in "cut-offs per hour"

CYMK : Cyan, Magenta, Yellow and Key (black) - the four process colours.

Densitometer : instrument for measuring ink dot gain of each process colour on a printed sheet.

Die-cutting : a finishing process in which the sheet is stamped with a shaped blade (the die), and the resultant impression then removed, as with cutting windows in sheets of card.

DIP : Direct Image to Plate (or Press) - the electronic transmission of artwork directly from DTP workstation to platemaking (or press) equipment, thereby omitting camerawork (and platemaking).

Dot gain : enlargement of the halftone dot between film and print, which should be assessed and allowed for in reproduction.

Doubles : in sheet-fed (as opposed to stream-fed) printing, a problem arising from incorrect setting of the air blowers at the feed end of the press, so that the grippers pick up more than one sheet at a time and feed them through the press, resulting in blank sheets in the printed pile. Blower setting is determined by stock weight.

dpi : [half-tone] dots per square inch

Drive side : the side of a press on which its driving mechanisms [clutch, gears, drive belts, etc.] are located and from which they can be accessed for repairs (see operator side).

DRUPA : the printing industry's main trade fair, held annually in Germany.

DTP : Desk-Top Publishing - the computer generation of finished artwork.

Dummy : a sample of a proposed job made up with the actual materials and cut to correct size to show bulk, style of binding, etc. Also a complete layout of a job showing position of type matter and illustrations, margins, etc. (the rough).

EDT : Electronic Data Transmission.

Etching : the biting effect of a mordant on a metal. In lithography, the effect of various solutions which are applied to the printing surface (plate) after establishing the image and for the purpose of rendering the non-image sections of the surface more water-attracting and more ink-repelling. Gum arabic is usually used after etching or in combination with the etching solution to preserve the image.

Extent : the finished size of the product, usually expressed in ISO sizes or millimetres.

Filling-in : common print problem, where the water-ink balance on the plate is upset, with not enough water to keep the non-image areas clean of ink. Ink spreads onto the non-image area.

Film stretch : film is an unstable image medium, prone to stretching, and hence distortion of the image prior to platemaking.

Finished rough : a drawing, generally for showing to the customer, showing actual size, colour, illustration, etc., and used as a guide for all type matter and colour matching.

Finishing : All operations after printing (or, the hand operations of lettering and ornamenting the covers of a book). This can be split further into "binding" and "fulfilment" [operations to prepare the bound product for mailing, such as insertion or stuffing into envelopes].

Flat-bed proofing : a method of wet-proofing from plates on a flat-bed press, in which the paper is kept flat while being printed with lithographic ink. Faster and quicker than machine proofs, and more realistic than cromalins.

(Foil) blocking : in binding, to impress or stamp a design on a cover, which can be blocked in using coloured inks, gold leaf or metal foil.

Font : American for "fount". Both are pronounced "font".

Fount : a set of type characters of the same design (and, with hot metal, same size); for example, upper and lower case, numerals, punctuation marks, accents, ligatures.

Four-colour printing process : colour printing by means of the

three primary colours (yellow, magenta, blue-green [cyan]) and black superimposed; the colours of the original having been separated by a photographic or electronic process.

Four-colour process inks : inks used for four-colour process printing (cyan, magenta, yellow and black). (see also "CYMK"; "pantone system")

GPMU : Graphical, Print and Media Union - the trade union formed by the amalgamation of the NGA and SOGAT in 1992.

Grid : a thick sheet of smooth board with ruled lines to ensure that artwork is pasted up squarely - these are printed in pale, non-reproducing ink so they will not show up under the camera.

gsm : grammes per square metre, the most common way of expressing the weights of paper and board.

Half-tone screen : glass plate or film, cross-ruled with opaque lines and having transparent squares; used to split up the image into half-tone dots.

Heatset drying : drying a web or sheet of paper by passing it through a drying unit which forms part of the machine. Special heat-setting inks have to be used, whose solvents are burnt off in the oven and released in gaseous form.

Hickeys (or bullseyes) : print problem arising when lint (paper dust) adheres to the plate, blanket or impressions cylinder of the press, drying the ink around it and producing a white ring in the printed image. The solution is to clean the offending part (and to keep the press as lint-free as possible).

Hot metal : The term used to describe the production of type for printing by casting individual letters or words in lead, which were then hand-assembled into pages for printing. This process was replaced by

IARIGAI : International Association for Research In the Graphical Arts Industries

Impose : to plan film or pages prior to litho platemaking

Imposition schemes : plans for the arrangement of the pages of a book so they will follow in correct sequence when folded.

Impression : the impress / impact of the printing surface onto a sheet of paper.

Impression cylinder : see "blanket cylinder"

Ink-jet : a non-impact printing process in which droplets of ink are projected onto paper or other material, in a computer determined pattern.

Knocking up : to make the edges of a pile of paper straight and regular or flush.

Large offset press : sheetfed press of A2 or larger size.

Letterpress printing : a process in which the printing surface, usually of metal but occasionally of plastic, is raised above the non-printing surface. The ink rollers and the paper touch only the printing surface. (rather like a rubber stamp, or the "John Bull" printing kits)

Letterset : offset letterpress printing, using a wraparound relief plate on a litho press. Also called dry offset.

Lithographic printing : a process in which the printing and non-printing surface are on the same plane, and the paper makes contact with the whole surface. The printing part of the surface is treated to receive and transmit ink to the paper, usually via a blanket (see offset printing), the non-printing surface is treated to attract water and thus rejects [oil-based] ink from the ink roller, which touches the whole surface.

Machine proofing : a method of wet-proofing plates on a cylinder press, identical to the normal lithographic printing process. This is the most reliable proofing method, but is time-consuming and costly.

Make ready : the operations involved in preparing a printing machine to run.

Matt coated cartridge : a type of cartridge paper with a matt coating of china clay or other material (see "art")

"mu" : microns. Unit of measurement for the thickness of board (using a micrometer), and an alternative to gsm as a way of describing a sheet. It is not used for stock of less than 1mu, hence not for paper.

Mono(chrome) : one colour, black.

NGA : National Graphical Association - print trade union formed in 1982 and amalgamated with SOGAT in 1992.

Offset printing : a lithographic method of printing in which the ink is first transferred from the image to an offset blanket and then to the stock which may be paper, card, metal or other material.

Operator side : the side of a press from which it is operated, on which the on-press controls and CPC console are sited (see "drive side").

Origination : the production of artwork which is to be reproduced.

Ozolid proofing : a method of proofing from film, consisting of

photographic prints developed from the negatives used in platemaking. The proofs are also known as "browns", "silvers" or "blues" (hence "blueprint").

Pagination : the number and order of pages in a printed product.

Pantone system : a system for mixing all shades of litho ink colour from the basic range of "pantone" colours plus black and white.

Pasting : in web printing, the process whereby a new reel is automatically attached to the tail end of another with adhesive tapes. The old reel is then severed (see "splice").

Perfect binding : threadless binding in which the leaves of a book are held together at the binding edge by glue or synthetic adhesive and a suitable lining.

Perfecting : printing the second side of a sheet.

Perfector (machine) : a printing machines which prints both sides of the sheet as it passes through the machine.

Photomechanical transfer (PMT) : a method by which an image is photographed and screened onto a paper negative which by chemical transfer produces a bromide print. This may be reproduced dot- for- dot in platemaking, or pasted up with unscreened text for further reproduction.

Phototypesetting : the setting of typematter on film or photographic paper.

PIRA : Printing Industries Research Association

Plate : any relief (raised image area), planographic (image and non-image areas flush) or intaglio (image area inset) printing surface.

Plate cylinder : the cylindrical surface on a rotary printing press, which carries the printing surface.

Point system : the use of a typographic standard 12-point pica of 4.23mm to which all other type measurements are referred.

Progressive proofs : a set of proofs showing each plate of a colour set printed in its appropriate colour and in registered combination to act as a guide for the printer.

Proof : a version of a document or colour illustration produced specifically for the purpose of review prior to reproduction.

Register : the printing of two or more plates in juxtaposition so that they complete a design if printed on the same side of the sheet or back up accurately if printed on opposite sides of the sheet.

Rotary perf(oration) : the making of perforations (as for sheets of postage stamps) in paper (web or sheet) while it passes round a cylinder (hence "rotary") carrying the pattern to be punched. As opposed to flatbed perforation, where the sheet is laid on a flat surface and punched with a flat pattern

Scanner : electronic colour scanners produce from colour copy or colour transparencies, colour corrected screened separations for the four printing ink colours.

Scumming : (see "catch-up").

Section : a folded sheet of paper forming part of the book. Sections are sometimes made of folded sheets of four, eight, sixteen or more pages inserted.

Set-off : printing problem, when the ink on sheets in a printed stack is not dry enough to withstand pressure, and "sets-off", or marks, the sheets with which they are in contact. The solutions are to reduce ink flow to the ducts; make smaller, lighter, piles; use more drying powder in the drying unit of the press; or raise oven temperature (on heatset presses).

Small offset press : sheetfed press of smaller than A2 size.

SOGAT : Society of Graphical and Allied Trades, print trade union formed in 1982 and amalgamated with the NGA in 1992.

Spine-gluing : a in-line (on-press) finishing method for single-section booklets, where pages are held together only by gluing at the spine (compare with "stitching"). This method is not robust, and is thus suited to direct mail and similarly short-lived products.

Splicing : On a web-fed press, after pasting, the severing of the spent reel from the new one with an automatic blade.

Stitching : to sew, staple or otherwise fasten together by means of thread or wire, the leaves (or signatures) of a book or pamphlet.

Stock : the material to be printed on, usually paper or board.

Stream-fed press : printing press into which sheets of paper are fed in a continuous stream (a faster version of the sheet-fed press).

Tabloid : finished size of newspaper, approximately A3.

TAGA : Technical Association of the Graphic Arts

UKONSS : United Kingdom Offset Newspaper Society Standard - industry standard setting for dot gain measurement by densitometer

Web : paper when made is wound on a roll or web. "In the direction of the web" means in the direction of the run of the paper-making

machine when the paper is made. The direction of the web is important in work printed to register, as paper stretches more across the web than in the direction of the web.

Web-fed : presses which are feed from a reel as distinct from separate sheets.

Web-offset : reel-fed offset litho printing. Three main systems of presses : blanket-to-blanket in which two plate and two blanket cylinders per unit print and perfect the web of paper [Trinity and Weirs]; three cylinder system in which plate, blanket and impression cylinders operate in the usual manner to print one side of the paper; and satellite or planetary system in which two, three or four plate and blanket cylinders are arranged around common impressions cylinders to print one side of the web in several colours.

YMP : Young Managing Printers; the national youth association of the BPIF.

BIBLIOGRAPHY

BOOKS AND ARTICLES

Ahonen, H. and Karttunen, S. (1990), "Knowledge-based systems for the graphic arts", 1989 Conference Proceedings, Technical Association of the Graphic Arts (TAGA):555-568, Rochester, New York.

Akrich, M. (1992), "The de-description of technical objects" in Bijker, W.E. and Law, J. (1992), pp205-224

Akrich, M. and Latour, B. (1992), "A summary of a convenient vocabulary for the semiotics of human and nonhuman assemblies" in Bijker, W.E. and Law, J. (1992), pp259-265

Ashmore, M. (1989), The Reflexive Thesis : Wrighting the Sociology of Scientific Knowledge, Chicago, University of Chicago Press.

Atkinson, P. (1990), The Ethnographic Imagination : Textual Constructions of Reality, Routledge, London.

Barnes, B. (1977), Interests and the Growth of Knowledge, Routledge and Kegan Paul, London.

Barnes, B. (1984), "Culture and History" in Hamson, C. and Orton, F. (eds), Modernism, Criticism, Realism : Alternative Contexts for Art :243-250, Harper and Row, London.

Barnes, B. (1986), "On authority and its relationship to power", in Law, J. (ed), 1986.

Barnes, B. (1988), The Nature of Power, Cambridge : Polity Press.

Barnes, B., and Edge, D.O. (eds) (1982), Science in Context : Readings in the Sociology of Science, Open University Press, Milton Keynes.

Basalla, G. (1988), The Evolution of Technology, Cambridge University Press, Cambridge.

Bauman, Z. (1978), Hermeneutics and Social Science : Approaches to Understanding, Hutchinson, London.

Bendix, R. (1956), "Work and Authority in London", Chapman and Hall, London, in Burns, T. and Stalker, G.M. (1961), The Management of Innovation, Tavistock Publications, London.

Berger, P. and Luckmann, T. (1967), The Social Construction of Reality : A Treatise in the Sociology of Knowledge, Allen Lane, London.

"Best Man" (1958), Marriage Etiquette : How to Arrange a Wedding, W. Foulsham and Co. London.

- Bijker, W.E. (1987), "The social construction of Bakelite : towards a theory of invention", in Bijker, W.E. et al., 1987:159-187
- Bijker, W.E. (1992), "The social construction of fluorescent lighting, or how an artifact was invented in its diffusion stage", in Bijker, W.E. and Law, J. 1992:75-104
- Bijker, W.E., Hughes, T.P. and Pinch, T.J., 1987, "General Introduction" and "Introductions" in Bijker, W.E. et al, 1987:1-6, 9- 15, 107-110, 191-194, 307-309.
- Bijker, W.E., Hughes, T.P. and Pinch, T.J. (eds) (1987), The Social Construction of Technological Systems : New Directions in the Sociology and History of Technology, MIT Press, Cambridge, MA.
- Bijker, W.E. and Law, J. (eds) (1992), Shaping Technology / Building Society : Studies in Sociotechnical Change, MIT Press, Cambridge, MA.
- Blauner, R. (1964), Alienation and Freedom : The Factory Worker and his Industry, University of Chicago Press, Chicago.
- Bloor, D. (1976), Knowledge and Social Imagery, London : Routledge and Kegan Paul.
- Bobrow, D. and Collins, A. (eds) (1975), Representation and Understanding : Studies in Cognitive Science, New York : Academic Press.
- Boguslaw, R. (1965), The New Utopians : A Study of System Design and Social Change, Prentice-Hall, Englewood Cliffs, NJ.
- Bolter, J.D., (1986), Turing's Man, Penguin, Harmondsworth.
- Braverman, H. (1974), Labor and Monopoly Capital : The Degradation of Work in the Twentieth Century, Monthly Review Press, New York.
- Bresnen, M. (1988), "Insights on site : research into construction project organisations", in Bryman, A. (ed)
- Brinkley, J. (no date), Design for Print : A Handbook of Design and Reproductive Processes, Sylvan Press, London.
- British Printing Industries Federation, (n.d), Getting the Measure of Your Business : How to use the BPIF Management Information System, BPIF, London.
- British Printing Industries Federation (1985), Printing Office Procedure, BPIF, London.
- British Printing Industries Federation (1986), Introduction to Printing Technology, BPIF, London.
- British Printing Industries Federation (1992), Printers' Yearbook 1991/92, BPIF, London.

- Bruno, M. (1992), "Status of Printing in the USA - 1991 update", IARIGAI 1991 Conference Proceedings, in Advances in Printing Science and Technology, Vol.21:1-20, ed. W.H. Banks, Pentech Press Ltd. London.
- Bryman, A. (ed) (1988), Doing Research in Organisations, Routledge, London.
- Buchanan, D., Boddy, D. and McCalman, J. (1988), "Getting in, getting on, getting out, and getting back", in Bryman, A. (ed)
- Burchell, G., Gordon, C. and Miller, P. (eds) (1991), The Foucault Effect : Studies in Governmentality, Harvester Wheatsheaf, Hemel Hempstead.
- Callinicos, A., Against Postmodernism : A Marxist Critique, Polity Press, Cambridge, 1989.
- Callon, M. (1986), "Some elements of a sociology of translation : domestication of the scallops and the fishermen of St. Brieuç Bay" in Law, J., 1986:196-233.
- Carlson, W.B., (1992), "Artifacts and frames of meaning : Thomas Edison, his managers, and the cultural construction of motion pictures", in Bijker, W.E. and Law, J. (1992), pp175-200
- Clair, C. (1965), A History of Printing in Britain, Cassell, London.
- Clark, N. (1985), The Political Economy of Science and Technology, Basil Blackwell.
- Clark, P. (1990), "International and Domestic Networks in the Diffusion, Adoption and Usage of Production and Inventory Control Systems (PICS) in British Manufacturing", IDOM Working Paper Series, No.7, Aston Business School.
- Cockburn, C. (1983), Brothers : Male Dominance and Technological Change, Pluto Press, London.
- Cockburn, C. (1985), Machinery of Dominance : Women, Men and Technical Know-how, Pluto Press, London.
- Cockburn, C. (1992), "The circuit of technology : gender, identity and power", in Silverstone, R. and Hirsch, E. (eds) (1992), Consuming Technologies : Media and Information in Domestic Spaces, Routledge, London.
- Cockburn, C. (1993), Gender and Technology in the Making, Sage, London
- Collins, H. (1974), "The TEA Set : tacit knowledge and scientific networks", Science Studies, Vol.4:165-86

- Collins, H. and Yearley S. (1992), "Journey into space" in Pickering, 1992:369:381
- Constant, E.W. II (1980), The Origins of the Turbojet Revolution, Baltimore MD : John Hopkins University Press.
- Constant, E.W. II (1987), "The Social Locus of Technological Practice : Community, System, or Organisation?", in Bijker, W.E. et al., (1987).
- Cooley, M. (1988), "From Brunelleschi to CAD/CAM", in Thackara, J. (ed), (1988), Design After Modernism, London : Thames and Hudson, pp197-207.
- Cooper, R. and Burrell, G. (1988), "Modernism, Postmodernism and Organisational Analysis : An Introduction", Organisation Studies, 9/1:91-112.
- Corrigan, A.J. (1944), A Printer and His World, Faber and Faber, London.
- Council for Science and Society (1989), Benefits and Risks of Knowledge-Based Systems, Oxford University Press, Oxford.
- Cousins, M. and Hussain, A. (1984), Michel Foucault, Macmillan, Basingstoke.
- Cowan, R. Schwarz, (1983), More Work for Mother : The Ironies of Household Technology from the Open Hearth to the Microwave, New York : Basic Books
- Crane, D. (1972), Invisible Colleges : Diffusion of Knowledge in Scientific Communities, University of Chicago Press, Chicago.
- Diaper, D. (ed), (1989), Knowledge Elicitation : Principles, Techniques and Applications, Chichester : Ellis Horwood.
- Diaper, D. (1989), "Designing expert systems : from Dan to Beersheba", in Diaper, D., 1989:17-46.
- Dosi, G., (1988), "The nature of the innovative process", in Dosi, G. et al (eds), Technical Change and Economic Theory, London : Pinter.
- Dosi, G. (1982), "Technological Paradigms and Technological Trajectories", Research Policy, pp.147 - 162, 11 (3).
- Douglas, M. (ed) (1973), Rules and Meanings : The Anthropology of Everyday Knowledge, Penguin Modern Sociology Readings, Penguin, Harmondsworth.
- Douglas, M. (ed) (1984), Essays in the Sociology of Perception, Routledge, London.
- Driver, S. and Gillespie, A. (1991), "Spreading the word ?

communications technologies and the geography of magazine print publishing", Newcastle PICT Working Paper Series, No. 1, CURDS, Newcastle.

Driver, S. and Gillespie, A. (1991), "The diffusion of digital technologies in magazine print publishing : organisational change and strategic choices", Newcastle PICT Working Paper Series, No. 2, CURDS, Newcastle.

Eagleton, T. (1991), Ideology : An Introduction, Verso, London.

Edge, D.O. (1974-75), "Technological Metaphor and Social Control", New Library History 6:136-47.

Edge, D. (1988), "The Social Shaping of Technology", PICT Working Paper Series, No. 1, University of Edinburgh, Edinburgh.

Eisenstein, E.L. (1979), The Printing Press as an Agent of Change, Vols. I and II, Cambridge University Press, Cambridge.

Faris, J.C. (1973), "'Occasions' and 'non-occasions'", in Douglas, M. (ed).

Faulkner, W. (1993), "Conceptualising knowledge used in innovation : a second look at the science-technology distinction and industrial innovation", PICT Working Paper Series, No. 43, University of Edinburgh,

Faulkner, W. (1992), "Understanding industry-academia research linkages : towards an appropriate conceptualisation and methodology", PICT Working Paper Series, No. 35, University of Edinburgh,

Ferguson, E.S. (1977), "The mind's eye : non-verbal thought in technology", Science, 26/8/77, Vol.197, No.4306:827-836.

Field, J.N. (ed.) (1980), Graphic Arts Manual, Arno Press, Musarts Publishing Corp., New York.

Fincham, R., Fleck, J., Procter, R., Scarbrough, H., Tierney, M. and Williams, R. (1994), Expertise and Innovation : Information Technology Strategies in the Financial Services Sector, Oxford University Press, Oxford.

Fleck, J. (1988), "Innofusion or Diffusation ? The Nature of Technological Development in Robotics", PICT Working Paper Series, No. 4, University of Edinburgh.

Fleck, J. (198?), "The development of information-integration : beyond CIM ?", PICT Working Paper Series, No. 9, University of Edinburgh.

Fleck, J. (1992), "Configuration : crystallising contingency", International Journal on Human Factors in Manufacturing,

- Fleck, J., (1992), "Expertise : knowledge, tradability and power". Paper presented to PICT Workshop on "Exploring Expertise", November.
- Fleck, J. and Tierney, M. (1991), "The management of expertise : knowledge, power and the economics of expert labour", PICT Working Paper Series, No. 29, University of Edinburgh, Edinburgh.
- Fleck, J., Webster, J. and Williams, R. (1989), "The Dynamics of IT Implementation : A Reassessment of Paradigms and Trajectories of Development", PICT Working Paper Series, No. 14, University of Edinburgh.
- Fleck, L. (1979), Genesis and Development of a Scientific Fact (1935), University of Chicago Press, Chicago.
- Foucault, M. (1967), Madness and Civilisation, Tavistock, London.
- Foucault, M. (1970), The Order of Things : An Archaeology of the Human Sciences, Tavistock/Routledge, London.
- Foucault, M. (1973), The Birth of the Clinic, Tavistock, London.
- Foucault, M. (1977), Discipline and Punish, trans. A. Sheridan, Penguin, Harmondsworth.
- Foucault, M. (1984) (ed. Gordon, C.), Power/Knowledge, Hemel Hempstead : Harvester Wheatsheaf.
- Friedman, A. with Cornford, D. (1989), Computer Systems Development : History, Organisation and Implementation, John Wiley and Sons, Chichester.
- Fyfe, G. and Law, J. (1988), "On the invisibility of the visual : editors' introduction" in Fyfe, G. and Law, J. (eds) (1988).
- Fyfe, G. and Law, J. (eds), (1988), Picturing Power : Visual Depiction and Social Relations, Sociological Review Monograph 35, Routledge, London.
- Galbraith, J.K. (1967), The New Industrial State, Pelican, London.
- Geertz, C. (1973), "Thick description : toward an interpretive theory of culture" in Geertz, C. (ed) The Interpretation of Cultures, Basic Books, New York.
- Georghiou, L. et al (1986), Post-Innovation Performance : Technological Development and Competition, Macmillan, Basingstoke.
- Glaser, B. and Strauss, A. (1967), The Discovery of Grounded Theory, Aldine Publishing Co., New York.
- Gordon, C. (1991), "Governmental rationality : an introduction", in Burchell et al.

- Goss, D. (1988), "Diversity, complexity and technological change : an empirical study of general printing", Sociology, Vol.22, No.3:417-431.
- Hammersley, M. (1990), "What's wrong with ethnography ?", Sociology, Vol. 24, No.4:597-615.
- Hammersley, M. (ed) (1993), Social Research : Philosophy, Politics and Practice, Sage Publications, London.
- Hammersley, M. and Atkinson, P. (1983), Ethnography : Principles in Practice, Tavistock Publications Ltd., London.
- Hardstone, G. (1991), "'A simple planning board and a jolly good memory" : time, work organisation and production management", No.4, PICT Student Paper Series, University of Edinburgh, Edinburgh.
- Harper, D., (1987), Working Knowledge : Skill and Community in a Small Shop, University of Chicago Press, Chicago.
- Harper, W.M. (1982), Cost and Management Accounting, Volume 1 : Cost Accounting, Macdonald and Evans Ltd., Plymouth.
- Harvey, D. (1989), The Condition of Postmodernity, Basil Blackwell, Oxford.
- Harvey, S. and Greenhalgh, E. (1988), Cultural Industries : Interim Report No.1 - A Report to Sheffield City Council from the Centre for Popular Culture, Sheffield City Polytechnic, Sheffield.
- Harvey, S. and Greenhalgh, E. (1988), Cultural Industries : Report No.2 - Final Report and Recommendations to Sheffield City Council from the Centre for Popular Culture, Sheffield City Polytechnic, Sheffield.
- Heidelberg UK (1987), Web-8 and Web-16 Press Manual.
- Hekman, S.J. (1990), Gender and Knowledge, Polity Press, Cambridge.
- Hindess, B. (1986), "Interests in Political Analysis", in Law, J. (ed)
- Hughes, T.P. (1983), Networks of Power : Electrification in Western Society 1880 - 1930, Baltimore MD : John Hopkins University Press.
- Hughes, T.P. (1986), "The seamless web : science, technology, etcetera, etcetera", Social Studies of Science, 16:281-292
- Hughes, T.P. (1987), "The Evolution of Large Technological Systems" (1987), in Bijker, W.E. et al, 1987:51-82.
- Hull, D.L. (1988), Science as a Process : An Evolutionary Account of the Social and Conceptual Development of Science, Chicago : University of Chicago Press.

- Juhola, H. et al. (1992), "CIM in printing", 1991 Conference Proceedings, Technical Association of the Graphic Arts (TAGA):508-518, Rochester, New York.
- Jupp, V. and Norris, C. (1993), "Traditions in documentary analysis", in Hammersley, M. (ed).
- Kaplinsky, R. (1984), Automation : The Technology and Society, Longman, London.
- Kidder, T. (1982), The Soul of a New Machine, Allen Lane, Penguin, London.
- Knorr-Cetina, K. (1981), The Manufacture of Knowledge, Pergamon Press, Oxford.
- Kraft, P. (1977), Programmers and Managers : The Routinisation of Computer Programming in the United States, New York : Springer Verlag.
- Kuhn, T.S. (1962), The Structure of Scientific Revolutions, University of Chicago Press, Chicago.
- Latour, B. (1987), Science in Action : How to Follow Scientists and Engineers Through Society, Open University Press, Milton Keynes.
- Latour, B. (1986), "Visualisation and cognition : thinking with eyes and hands", in Knowledge and Society : Studies in the Sociology of Culture Past and Present, Vol. 6:1-40
- Latour, B. (1986), "The powers of association", in Law, J. (ed), 1986.
- Latour, B. (1992), "Where are the missing masses ? The sociology of a few mundane artifacts", in Bijker, W.E. and Law, J. (1992) pp225-258
- Latour, B., and Woolgar, S. (1979), Laboratory Life : The Social Construction of Scientific Facts, Sage Publications, Beverley Hills
- Latour, B., and Woolgar, S. (1986), Laboratory Life : The Construction of Scientific Facts, Princeton University Press, Princeton, NJ.
- Laudan R. (ed) (1984), The Nature of Technological Knowledge : Are Models of Scientific Change Relevant ?, Dordrecht, Reidel.
- Law, J. (ed), (1986), Power, Action and Belief : A New Sociology of Knowledge, Sociological Review Monograph 32, Routledge, London.
- Law, J. (1986), "Editor's introduction : power/knowledge and the dissolution of sociology", in Law, J. (ed), (1986).
- Law, J. (1986), "On the method of long-distance control : vessels, navigation and the Portuguese route to India", in Law, J. (ed),

1986.

Law, J. (1987), "Technology and heterogeneous engineering : the case of Portuguese expansion" in Bijker, W.E. et al., 1987:111-134

Law, J. (1991), The Sociology of Monsters : Power, Domination and Technology, Sociological Review Monograph 38, Routledge, London.

Law, J. (1994), Organising Modernity, Blackwell, Oxford.

Law, J. and Callon, M. (1992), "The Life and Death of an Aircraft : A Network Analysis of Technological Change", in Bijker and Law, 1992:21-52.

Law, J. and Whittaker, J. (1988), "On the art of representation : notes on the politics of visualisation", in Fyfe, G. and Law, J. (eds): 160-183.

Lehtonen, T. et al. (1991), "On-press control of the newspaper print quality", 1990 Conference Proceedings, Technical Association of the Graphic Arts (TAGA):620-628, Rochester, New York.

Loft, A. (1990), "Every minute counts : a study of time in accounting", paper presented at the "History of the Accounting Present" conference, University of North Texas, November 15-17, 1990.

Lukes, S. (1974), Power : A Radical View, Macmillan, Basingstoke

Lupton, T. and Tanner, I. (1987), Achieving Change : A Systematic Approach, Gower Press, Aldershot.

Macdonald, S. (1983), "Technology beyond machines" in Macdonald, S., Lamberton, D.McL and Mandeville, T. (eds) (1983), The Trouble With Technology, London : Pinter.

Mackenzie, D. (1988), "Parallel Computing : Some Issues for Social Research", PICT Working Paper Series, No. 6, University of Edinburgh.

Mackenzie, D., (1988) "'Micro' versus 'macro' sociologies of technology", PICT Working Paper Series, No. 2, University of Edinburgh.

Mackenzie, D. (1990), "Economic and Sociological Explanations of Technical Change", PICT Working Paper Series, No. 27, University of Edinburgh, Edinburgh.

Mackenzie, D. (1992), "Negotiating arithmetic, constructing proof : the sociology of mathematics and information technology", PICT Working Paper Series, No. 38, University of Edinburgh, Edinburgh.

Mackenzie, D. and Wajcman, J. (eds) (1985), The Social Shaping of Technology, Open University Press, Milton Keynes.

- Mackenzie, D. and Wacjman, J. (1985), Introductory Essay : "The Social Shaping of Technology", in Mackenzie, D. and Wacjman, J. (eds), 1985.
- Mayntz, R. (1976), "Conceptual models of organisational decision-making and their application to the policy process", in Hofstede, G. and Kassem, M. (eds), European Contributions to Organization Theory, Van Gorcum, Amsterdam, in Cooper and Burrell, op.cit.
- McLuhan, M. (1962), The Gutenberg Galaxy : The Making of Typographical Man, Toronto.
- Mearns, I. (1981), Fundamentals of Cost and Management Accounting, Longman, London.
- Mendohlsen, E., Weingart, P., and Whitley, R. (eds) (1977), The Social Production of Scientific Knowledge, D. Reidel, Dordrecht.
- Meredith, J. (1993), "Theory Building through conceptual methods", International Journal of Operations and Production Management, Vol.13:5, 3-11.
- Morse, W.J., Davis, J.R. and Hartgraves, A.L. (1988), Management Accounting, Addison Wesley Publishing Company, Reading, Massachusetts.
- Muhlemann, A.P., Oakland, J.S. and Lockyer, K.G. (1992), Production and Operations Management, Pitman, London
- National Graphical Association (1982), London Region "Green Lists", 1985-1988.
- Nelson, R. and Winter, S. (1977), "In Search of a Useful Theory of Innovation", Research Policy, pp.36 - 77, 6 (1).
- Orr, J.E. (1986), "Narratives at work : story telling as corporate diagnostic activity", Proceedings of the Conference on Computer-Supported Work, December 3-5, 1986, Austin, Texas.
- Orr, J.E. (1987), "Talking about machines : social aspects of expertise", unpublished research report.
- Orr, J.E. (1990), "Sharing knowledge, celebrating identity : war stories and community memory among service technicians", in Middleton, D.S. and Edwards, D. (eds), Collective Remembering : Memory in Society, Sage Publications, London. (pp169-189)
- Pacey, A. (1983), The Culture of Technology, Basil Blackwell, Oxford.
- Pelaez, E. (1990), "From symbolic to numerical computing : the story of thinking machines", PICT Working Paper Series, No. 23, University of Edinburgh.
- Perez, C. (1983), "Structural Change and Assimilation of New

- Technologies in the Economic and Social Systems", Futures, pp.357 - 375, October.
- Perrow, C. (1970), Organisational Analysis : A Sociological View, Tavistock, London.
- Pinch, T. and Bijker, W. (1986), "Science, relativism, and the new sociology of technology : reply to Russell", Social Studies of Science, 16:347-360.
- Pinch, T. and Bijker, W. (1987), "The Social Construction of Facts and Artefacts Or How the Sociology of Science and the Sociology of Technology Might Benefit One Another", in Bijker et al. 1987:17-50.
- Polanyi, M., (1958), Personal Knowledge : Towards a Post-Critical Philosophy, Routledge and Kegan Paul, London.
- Polanyi, M. (1967), The Tacit Dimension, Routledge and Kegan Paul, London.
- Price, D.J. de Solla (1982), "The Parallel Structures of Science and Technology" in Barnes, B., and Edge, D. (eds).
- Price, D.J. de Solla (1984), "The Science-Technology Relationship, the Craft of Experimental Science, and Policy for the Improvement of High Technology Innovation", Research Policy, 13.
- Price, D.J. de Solla (1987), "Notes towards a philosophy of the science-technology interaction", in Laudan, R. (ed) (1987).
- Printing Industries Research Association (1992), UK Printing Industry Statistics 1992, PIRA, Leatherhead, Surrey.
- Rapoport, R.N. (1970), "Three dilemmas in action research", Human Relations, 9:1:499-513
- Ravetz, J.R. (1973), Scientific Knowledge and its Social Problems, Penguin, Harmondsworth
- Reynolds, S. (1989), Britannica's Typesetters : Women Compositors in Edwardian Edinburgh, Edinburgh University Press, Edinburgh.
- Rockwell International (1990), Press Manual for Goss Newspaper Presses in the UK.
- Rosen, P. (1993), "The social construction of mountain bikes : technology and postmodernity in the cycle industry", Social Studies of Science, Vol.23:479-513
- Rosenberg, N. (1982), Inside the Black Box : Technology and Economics, Cambridge : Cambridge University Press.
- Roth, J.A. (1973), "Benchmarks", in Douglas, M. (ed).
- Russell, S. (1986), "The social construction of artefacts : a

response to Pinch and Bijker", Social Studies of Science, 16:331-346.

Scapens, R.W. (1985), Management Accounting : A Review of Contemporary Developments, Macmillan, Basingstoke.

Schofield, J.W. (1993), "Increasing the generalizability of qualitative research", in Hammersley, M. (ed)

Schweisser, W. and Rettburg, A. (1990), "Computer integrated production in offset printing plants", 1989 Conference Proceedings, Technical Association of the Graphic Arts (TAGA):701-712, Rochester, New York.

Senker, J. (1992), "The contribution of tacit knowledge to innovation", paper presented at "Exploring Expertise" workshop, University of Edinburgh, November.

Sewell, G. and Wilkinson, B. (1992), "Someone to watch over me : surveillance, discipline and the just-in-time labour process", Sociology, 26:2, 279-282.

Silverman, D. (1985), Qualitative Methodology and Sociology, Gower, Aldershot.

Simon, H.A. (1962), Administrative Behaviour, Macmillan, New York.

Simon, H.A. (1965), The Shape of Automation for Men and Management, Harper and Row, New York.

Sizer, J. (1981), Perspectives in Management Accounting, William Heinemann, London.

Sorensen, K.H. (1993), "An anatomy of engineering knowledge", Social Studies of Science, Vol.23:373-77.

Sorensen, K. and Levold, N. (1992) "Tacit networks, heterogeneous engineers and embodied technology", Science, Technology and Human Values, Vol.17, No.1:13-35

Spradley, J.P. (1980), Participant Observation, Holt, Rinehart and Winston, London

Stewart, R. (1967), Managers and their Jobs, Macmillan, London.

Susman, G.I. and Evered, N.M. (1978), "An assessment of the scientific merits of action research", Administrative Science Quarterly, 23:4, 582-603

Thompson, E.P. (1967), "Time, Work Discipline and Industrial Capitalism", Past and Present.

Trimble, G. (1989), "Knowledge elicitation - some practical uses", in Diaper, D., 1989:223-234

- Turner, B.A. (1988), "Connoisseurship in the study of organisational cultures", in Bryman, A. (ed).
- Venables, D.R. and Clifford, R.E. (1973), "Academic Dress", in Douglas, M. (ed)
- Vincenti, W.G. (1990), What Engineers Know and How They Know It : Analytical Studies from Aeronautical History, Baltimore MD, John Hopkins University Press.
- Von Hippel, E.A. (1988), The Sources of Innovation, Oxford University Press, Oxford.
- Waddie and Co. (1960), One Hundred Years of Print : 1860-1960, Waddie and Co., Edinburgh.
- Weber, M. (1968), Economy and Society (1922), Bedminster Press, New York.
- Webster, J. (1990), "The shaping of software systems in manufacturing : issues in the generation and implementation of network technologies in British industries", No. 17, PICT Working Paper Series, University of Edinburgh, Edinburgh.
- Whitley, R., (1984), The Intellectual and Social Organisation of the Sciences, Clarendon Press, Oxford.
- Williams, R. and Edge, D. (1992), "Social shaping reviewed : research concepts and findings in the UK", No. 41, PICT Working Paper Series, University of Edinburgh, Edinburgh.
- Williams, R. and Russell, S. (1988), "Opening the Black Box and Closing it Behind You : On Microsociology in the Social Analysis of Technology", No. 3, PICT Working Paper Series, University of Edinburgh, Edinburgh.
- Williamson, O. (1980), "The organisation of work : a comparative institutional assessment", Journal of Economic Behaviour and Organisation, Vol.1:5-38.
- Wilson, R.M.S. and Chua, W.F. (1988), Managerial Accounting : Method and Meaning, Van Nostrand Reinhold, London.
- Winner, L. (1980), "Do Artifacts Have Politics ?", Daedalus, 109:121- 136
- Winograd, T. (1975), "Frame representations and the declarative-procedural controversy", in Bobrow, D. and Collins, A. (eds), 1975:185-210.
- Winter, S. (1987), "Knowledge and competence as strategic assets", in Teece, D. (ed), The Competitive Challenge : Strategies for Industrial Innovation and Renewal, Ballinger, Cambridge MS.
- Wittgenstein, L. (1973), "Wittgenstein's Tailor", in Douglas, M.

(ed).

Woodward, J. (1980), Industrial Organisation : Theory and Practice (2nd edition) , Oxford University Press, Oxford.

Yamauchi, R. (1988), "Status of Printing in Japan", IARIGAI 1987 Conference Proceedings, in Advances in Printing Science and Technology, Vol.19:366-398, ed. W.H. Banks, Pentech Press Ltd. London.

Yamauchi, R. (1992), "Considerations in the adoption of factory automation in print and post-processing", IARIGAI 1991 Conference Proceedings, in Advances in Printing Science and Technology, Vol.21, ed. W.H. Banks, Pentech Press Ltd. London.

Zuboff, S. (1988), In the Age of the Smart Machine, Basic Books, New York.

Beck, J. (1995), Informal information flow and the nature of expertise in financial services, (working paper, as yet unpublished)

NEWSPAPERS AND TRADE MAGAZINES

American Printer (AP) :

Feb 1992:80, Merit, D., "Production managers wear many hats".

British Printer (BP) :

Mar 1992:66-67, Holland, C., "The sleeping giant awakes"

Mar 1992:68, "Extra colours gain more work"

Apr 1992:3, Griffiths, S., "Opinion"

Apr 1992:12 Thatcher, M., "Green heaven"

Apr 1992:16, Holland, C., "Partners and choice"

May 1992:21-26, Holland, C., "Maturing MIS"

Jun 1992:17-22. "Making friends in adversity"

Nov 1992:31-34, Holland, C., "Second time around"

Dec 1992:5, "Printers' pessimism persists"

Jan 1993:24-27, Holland, C., "Imaging by both means"

Daily Telegraph (DT) :

25/11/91:30, "Fears for Print Jobs".

Guardian, The (G) :

Guardian 2, 4/3/93:17, Schofield, J., "CD-ROM Reviews".

Guardian 2, 4/3/93:19, Schofield, J., "The last word in discs"

LithoWeek (LW) :

20/12/89:?, Anon., "Technology and the next decade".

25/4/90:?, Marshall, C., "Meeting the press corps".

5/9/90, Anon, "Mauling the moneylender"

5/9/90, Holley, S., "Computers usage growing, finds BPIF".

22/5/91:5, Fairbrass, W., "In my view".

3/7/91:18-19, Lewis, C., "The shock of the new".

10/7/91:15, Holley, S., "Stalking your staff ?"

7/8/91:13, Buchanan, K., "Project MIS : a man's quest for knowledge"

21/8/91:10, Harrison, M., "The best things are worth waiting for"

3/9/91:22-27, Lewis, C., "MIS : getting it out of your system".

3/9/91:28-29, Sweet, F., "Printing : the public speaks"

17/9/91:3, Peach, M., "PIRA Sees light at the end of the tunnel"

17/9/91:17-19, "Feedback"

1/10/91:16, Editorial, "Awards show why British is the best"

15/10/91:16, Letters Page, "The customer comes first"

22/10/91:16, Caplin, A. "Comment".

29/10/91:16, Peach, M., "Communication breakdown"

5/11/91:14, Dixon, B., "Why desktop systems aren't always the answer to typesetting problems".

26/11/91:4, "Ease off our tax bill, BPIF tells Chancellor".

3/12/91:17, Hewitt, M., "MIS unclogs Holland's management".

2/9/92:18-20, Buchanan, K., "Is the price right ?"

20/10/92:19, "In at the deep end"

20/10/92:25-33, BPIF/LW, "Investment survey".

27/10/92:18, "Direct mail market contracting".

17/11/92:21-29, "Quick change".

5/1/93:10-11, "Printers prepare for a slow road to recovery"

12/1/93:18-20, Turner, L., "Making brain waves".

12/1/93:22, Turner, L., "Personnel services".

19/1/93:10, "Mr DTP holds on to tradition".
9/2/93:14-17, Birkenshaw, J., "The MISsing link ?".
16/2/93:8, "Web printers face bleak future, warn PIRA speakers".
16/2/93:14, Buchanan, K., "Survival plan for web printers".
16/2/93:33, "Toilet humour crops up during PIRA debate"
2/3/93:28, Coxhead, R., "Coxhead".
9/3/93:22, "Print profile - Ian Johnson, Group Production Director,
Hunters Armley".

New In Printing (NP) :

Jul/Aug 1990:42, "Don't blame the finisher".
Mar 1991:51, Buchanan, K., "Admin matters".
Mar 1991:53, "Union blues"

Newspaper Technology (NT) :

May 1992:4-11, Guth, R., "Computer-aided product planning and
production management".

Offset Print and Reproduction (OPR) :

Nov 1991:26-30, Price, G., "Future perfect"

Print and Converting Monthly (PCM) :

Feb 1992:6-8, "MIS start with estimating"
Aug 1992:20-25, "MIS : look for the real McCoy"

Print Impressions (PI) :

Jan 1992:60, Landau, R.M., "Experts watch printers' Ps and Qs"

Printing Industries (Pi) :

Feb 1993:16-23, "Hit with MIS".

Printing World (PW) :

19/2/92:18-20, Anghelides, B., "And computer shall speak peace unto
computer".
13/5/92:30-32, Thompson, D., "Big savings or Big Brother ?".
29/7/92:28-29, "Everybody should have one".
11/11/92:24-25, Anghelides, B., "MIS : Catching the small fry".

Screen Process (SP) :

Jan 1992:8-9, Sofidiya, S., "Management Information Systems".