PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

High Volume Component Manufacture [and Discussion]

B. E. Stokes, M. Seaman, H. L. Muller, Crookall and G. M. Fazakerley

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High volume component manufacture

By B. E. Stokes
Automotive Products Ltd, Leamington Spa

We attempt to forecast the future in order to ensure that today's decisions and the actions which follow will continue to be relevant as the future becomes the present.

Historically, forecasts of the kind and direction of technological development have consistently been better than forecasts of the timing, application and impact of such developments. The latter, however, are the more important when assessing what changes are likely to be significant. The paper examines both technical and environmental factors which make this sort of forecasting difficult and considers their relevance to the particular circumstances posed by high volume component manufacture.

Against this general background, the paper speculates on the future role of such companies, the development of techniques and technologies to maintain their competitive position and the adjustments necessary to meet changes in both social and trading environments.

Professor Galbraith, when introducing the first of his Reith Lectures, made the comment that lectures, unlike novels, are often more satisfactory if the plot is revealed at the outset. In this particular meeting for discussion the comment is apt, since any attempt to predict what will happen in the 1980s provides unlimited scope for the exercise of imaginative speculation. Moreover, prophesy is an art form rich in temptation for the prophet. He can range at will over matters requiring attention, without the tedium of defining a solution and can draw conclusions sufficiently subjective to make any form of proof both impossible and unnecessary. Finally, the further removed the events foreseen, the less the chance of discovery should the prophet happen to be wrong.

I have not entirely resisted temptation, since I do raise some issues for which I cannot provide any general solution. I have, nevertheless, chosen to reveal the plot, so that my approach to both the subject-matter and the 1980s is clear from the outset. Before doing this, however, I should add that, although I have gleaned ideas and comments from many sources, the views that I present are my own and do not represent those either of my company or of the Institution of Production Engineers.

The scope of the paper (the plot)

Manufacturing technology is essentially a practical technology in that it is valuable only if it works, if it performs some real task. My approach is consequently practical and deals with a number of real issues which I consider important.

High-volume component manufacture is, by and large, a particular kind of batch manufacturing activity with the occasional flowline thrown in for good measure. The techniques likely to influence its operation and development have already had a good airing at this discussion meeting and will be rounded off in Mr Iredale's paper which follows. I have, therefore, chosen to look at some aspects of the industrial context within which the techniques will need to be applied. High-volume component manufacture lends itself to this treatment, since it has a degree of industrial identity.

In a thematic sense the paper is divided into three parts which tend to coalesce from time to time.

First, I explore briefly the forecasting process and comment upon experience of the process to date and the probable relevance of this experience for the future.

Secondly, I examine what high-volume component manufacture is about in order to identify issues which I believe will be relevant to the 1980s.

Thirdly, in the light of the foregoing, I speculate on the future development of high-volume component manufacture, including the role of specialist companies involved and its implications, particularly for the engineers and managers involved.

The forecasting process

Between any idea and its realization there is a gap; sometimes a very large one, such as when wishing to transmute lead into gold.

When a designer has an idea about a new product, manufacturing technology provides the resources which bridge this gap. Ideally, the life of the product and the life of the resources and the progressive improvements in both, should correspond, so that changes in product can be matched with the latest and most appropriate resources. This is one of the production engineers' principal problems; that his decisions on potentially long-life resources will continue to be relevant as the future becomes the present. As the cost of mistakes rises, so does the pressure for some arrangement which will predict the future.

Without some knowledge or assessment of what is ahead, we are in a similar predicament to that of the driver leaving Damascus for Baghdad before the construction of the metalled road. He was enjoined to 'choose his rut with care, since he could be in it for several hundred miles and arrive some place else'.

This illustrates a basic rule for all who make predictions or forecasts. We should be ruthlessly objective in assessing whether we can indeed forecast and with what degree of accuracy. As the probable accuracy reduces, so the need for manoeuvring room increases. When uncertainty is very high, be prepared, but 'don't shoot until you see the whites of their eyes'. It is in this light that I look at experience to date.

The aim of the forecast is to assist us to stay in business. In broad terms the scope of the forecast should embrace changes in product, in technology and in the environment within and without the workplace.

In specific terms, few of us have yet had much experience of forecasting developments in manufacturing technology and such experience that we have is relatively recent. From such attempts as have been made, I would hazard a few conclusions.

Historically, it seems that the probable trends in technological development and its organization have often been established well in advance of the ability to apply such development. Babbages *Economy of manufacture* published in 1832 is a good case in point. It is surprisingly relevant in 1972. In a more general way, Leonardo da Vinci was also pretty far-sighted.

It is clearly, however, much more difficult to define the probable timing and impact of these trends which are much more important, since as I have said, manufacturing technology does not count until it works. Babbage again provides an interesting example. His concept of a calculating engine arose about 150 years ago and it has taken pretty well the whole of the intervening period to bring its entire concept to fruition. This illustrates an important factor in any development that frequently one technological conception can only be realized when several others have also been developed adequately. To take this a stage further, it became clear around 1950 that all the related developments involved in producing a computer of considerable power were 'gelling' successfully. This led to a great deal of very exciting speculation about the opportunities which this new breed of machines would open up.

Twenty years later these opportunities are still largely unrealized. This point is one to which I will return later.

One other, somewhat more mundane, illustration of another factor influencing impact and timing of development. Frequently the emergence of new ideas creates renewed interest in the effective use of existing facilities, which retards the impact of the former and provides a new lease of life for the latter. The bar-fed automatic lathe is a case in point. Production engineers have been forecasting its demise for the past 20 years, with the growth of new or improved chipless forming processes. The challenge of these processes improved the auto breed, but more important, created renewed interest in the reduction of down time and the organization of the 'auto shop', which reduced cost and in some instances actually increased the range of components which could be manufactured economically. I should add that the development of chipless forming processes also ran into Babbage's stumbling block of related developments. I do not think, incidentally, that we have learned this lesson anything like well enough when I look around at the work being done to improve the manufacturing process.

To conclude my comments on impact and timing, past experience shows that the margin of error in forecasting can be pretty big, presently as big in fact as the lead time in our attempted forecasts for the 1980s.

Finally, what of the changes in environment within which technology must operate and particularly in the environment created by human attitudes. The latter has been the subject of much forecasting and speculation and long before technology became important. Attempts to assess the mutual impact of people and technology seem to me to have been hazy, misleading and sometimes contradictory. One historical point, possibly peculiar to Britain is that on the whole the general environment within which industry has operated has at best been neutral and more often has been hostile.

I would suggest that experience to date does not demonstrate a particularly high confidence level in forecasting though events conspire to increase its importance nevertheless. I take this as reinforcing my view that it is as worth looking at ideas, which are important to the development of manufacturing technology, as it is looking at the techniques as such.

With this background in mind, I want now to examine:

What high-volume component manufacture is about

The component manufacturer sells a combination of specialist product and process skills, which then form part of someone else's finished product. He stays in business only so long as he can demonstrate superiority in these skills.

Components range between very simple and very complex, from fasteners to complete braking systems. The component industry has reached one of its most highly developed stages within the vehicle industry of the Western World. It is highly competitive and must increasingly operate internationally, since both its customers and its competition are international.

So that we can consider the issues likely to be relevant to the 1980s, I have set out broadly the areas influencing decisions which effect the development and deployment of manufacturing resources within the component industry. In addition, since my own company is an appropriate example of the more complex part of the industry, I have set out some illustrations of its operation which will help demonstrate these influences in a practical and quantitative sense. The component manufacturer's product development may spring from:

(*a*) Invention.

(*b*) Innovation to meet an anticipated need to improve safety or performance, for example, anti-skid control is a case in point, which has been available for some years.

(*c*) The need to meet competition and to retain and expand markets.

(*d*) The need to meet a customer's specific requirement.

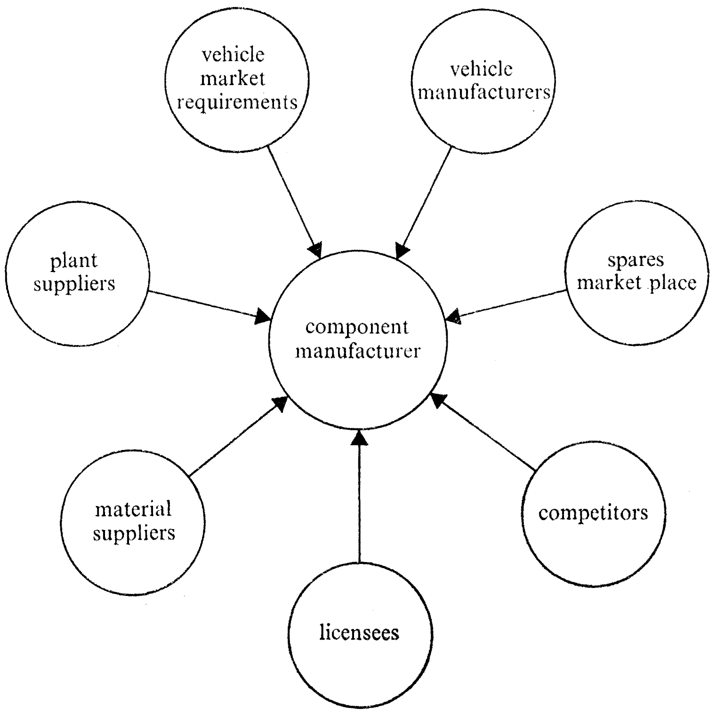

FIGURE 1. This shows the external spheres of influence within which the component manufacturer must operate in serving the motor industry.

Major influence on manufacturing technology is periodic and influenced by customer acceptance, which is in turn influenced by the customer's own cycle of product change. For example, the move from drum brakes to disk brakes completely changed manufacturing techniques. Disk brake development to reduce weight and improve performance has provoked several breeds in the last 10 years. Recent legislation is provoking further changes.

In parallel with changes arising from product development, continual pressure to reduce cost, or these days attempt to contain inflation, provokes continual methods improvement in all areas of activity. This is largely centred on improved use of existing techniques. From time to time, however, a change in process may also have a significant effect. For example, cold extrusions replace turned parts. This can react on the customers' product cycle, particularly if the component and the product involves lengthy testing, which is required with life-and-death products.

A great deal of process development which influences the component supplier has historically been undertaken by the suppliers of the plant and/or material involved in cooperation with the component manufacturer. While this has produced results, it is, nevertheless, an increasingly inadequate approach for a number of reasons. First, development has been of an evolutionary character and has consequently frequently lacked measurement of cause and effect, thus limiting the number of useful applications.

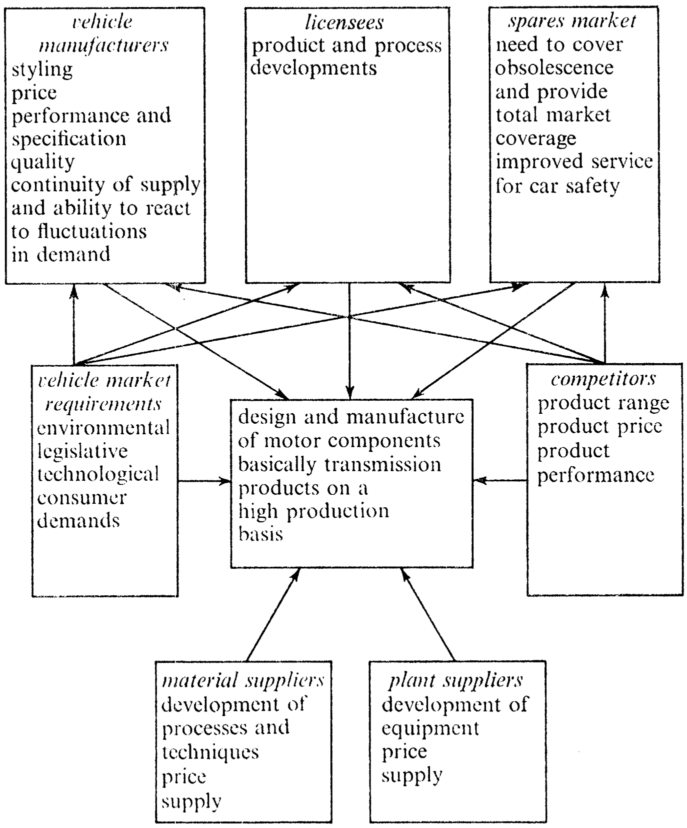

FIGURE 2. This looks at this situation in some more detail, defining the matrix of relationships and related decisions, and about which the following comments are pertinent.

Secondly, and consequent upon the foregoing, development has been carried out largely as an adjunct to production and frequently on actual production plant. Consequently, such development has not been seen as a requirement in its own right.

Thirdly, the development has largely taken place within the 'single operation' concept, about which I have more to say later in the paper.

Relevant factors demonstrating the range and variety of a typical component manufacturing company in the automotive industry are:

(i) 160 original-equipment customers.

(ii) Parts distribution throughout 150 countries.

(iii) 37 licensees operating 50 licenses throughout 14 countries.

(iv) 500 different products, with production volume from 5/week to 5000/week.

(v) 630 material and component suppliers providing 40 different types of material in many shapes and sizes.

(vii) 9000 different components in manufacture at any given time.

(viii) In the main manufacturing complex, 4000 machine tools from single spindle drills to large multi-station transfer machines and 3500 items of process plant.

It will be seen that the development of component manufacturing technology is a highly dependent variable, influenced by many external factors. It must at least match market and customer demands, meet or better competitors' technology and prices, develop in concert with and provoke the developments of the technologies of both the suppliers of material and plant, and continue to be effective despite changes in product and changes in working environment arising from changes in worker attitudes, taxation, legislation and so forth.

In operational terms, the high volume is generally accompanied by high variety, there are, for example, a large number of different kinds of vehicles on which one can apply braking techniques. Generally, the components themselves are becoming more complex; for example, braking systems which can now incorporate power operation, anti-skid, load sensing and so on. These factors tend to intensify the complex of dependent relationships with suppliers and customers.

Looking to the 1980s

In looking to the 1980s, the most obvious first consideration is what is likely to happen to product variety and complexity. I believe both are likely to increase. The industries which the component manufacturers serve, and particularly the vehicle industry, are generally improving product performance, and with increasing emphasis on safety for example, will increase their demands. Furthermore, with emerging industries, the component manufacturer has additional opportunities to sell his expertise in wider markets and countries.

It seems to me that complexity and uncertainty will continue to bedevil the scene, and that the extent to which we bend our energy towards coping with this situation will be a significant factor in staying in business. This will need a major change in strategy, but in order to explain why, I must bring a number of threads together. These are concerned with the way the production engineer has operated and the consequent development of manufacturing technology, the requirements of the workplace and the nature of the component industry and the advent of the computer.

For the most part, and until quite recently, the development of manufacturing technology was directed towards the improvement of a particular process, operation or technique, to its limit. This is reflected in the development of machine tools and in related research which has concentrated on the mechanics of drilling, cutting, grinding and the like. Not surprisingly, the production engineer's method of approach is similarly single-operation orientated. Every job must first be broken down into its individual operational elements, each defined on a planning sheet with tooling and inspection details and only then combined with related elements in order to provide a complete description of the cycle of operations for the manufacture of the component and product.

The single-mindedness of this approach has generally paid off in development terms, its less fortunate other consequences have only recently become significant.

Within this framework, the production engineer has sought further improvements through standardization and simplification, countering the growth of variety, an activity in which he frequently seems to have to run harder in order to stay still and continually seeking ways to improve the use of manufacturing resources.

In general, the worker has been expected to fit the technique, sometimes in a literal sense, as Corlett has shown in his comments on the ergonomics of the capstan lathe. At the workplace the single-operation approach has generally been reinforced. By training which emphasizes specific operational content (this applies to workers and management alike), by concentration on utilization and the consequent grouping of like facilities and by the dependence of one operation upon another for the successful completion of any component or product.

From what I have said earlier, it could now be observed that while the single-operation approach has effectively developed certain techniques, it is in some respects at odds with the market circumstances to be met by the component manufacturer. The complex relationships of interdependent operations, the dependence upon suppliers and the frequent variation in customer requirements, all conspire against the orderly deployment of resources neatly docketed in operational formation. A vast, and often seemingly very untidy, coordinating job is necessary to keep the wheels turning. It was not surprising that back in the early 1950s, many people saw the computer and its associated developments as manna from heaven. Coordination involves data, its storage and manipulation, what therefore more desirable than a machine which deals with data, its storage and manipulation all at an extraordinary speed? What indeed!

There were, and to some extent still are, two snags in this proposition:

First, no one yet completely understands just how the coordinating process actually works, except that it involves people. It does seem that the manager and his working group, who are clear on the extent to which they can freely operate tactically (which implies some appreciation of strategy) continually manoeuvres and adjusts to accommodate the unexpected in somewhat the same way as an army patrol will re-organize to meet an enemy threat, or a group of players rearrange their positions and effort in accordance with the state of play. It is an interesting thought that whereas the two latter groups spend more time in practice and training than for real, the working group plays for real all the time and its formal training, when there is any, is individual and rarely includes the team as a whole. I should perhaps also add that the knowledge of strategy and tactics apparent within the successful working group has not necessarily been acquired formally. The group learns from experience.

The second snag stems from the first. The attempt to use the computer in controlling situations just described proved to be acutely embarrassing, though this was not necessarily admitted. Its role of benign aid proved to be a disguise, behind which sat a judge who proceeded to put management on trial.

We were now asked to describe in clear, exact, unambiguous terms exactly what goes on; a quite impossible task. Systems engineers to whom life was a precise orderly process mapped out in stages, which went through and/or gates, had no computer vocabulary to cope with feel, intuition, bloodymindedness, drive, thoughtfulness, concern and all the other real means of dealing with, and getting results within, imprecise, ambiguous and indescribable situations.

At this point it might be useful to recap.

I have suggested that the single operation approach has had some success in the development of techniques, but has had other less fortunate consequences, one of which was that it took a fragmentary (if not myopic) view of manufacturing activity as a whole. Further, the nature of the component industry tends to reinforce this view, because interdependent operational performance on time, is so critical to its production performance. Perhaps I should also add here that to 'stop the line' is a cardinal crime. In turn, I have suggested that the computer, with its apparent capacity for dealing with the many relationships which make up manufacturing activity as a whole, was first seen (and not infrequently sold) as a means for coordinating and controlling this activity. It failed to live up to expectations because of the overriding importance of day-to-day tactical decisions which are either not yet describable in precise unambiguous quantitative terms or because the rules change too frequently.

This is a juxtaposition of events which, while perhaps unfortunate, is also revealing. It is unfortunate because the component industry already has an adequate supply of cynicism, although it is usually healthy and often hilariously funny. (For those of you whose views of the component industry have been influenced by Keith Richardson's book *Do it the hard way*, I should mention that there is much more humour around than you may have gathered from the book.)

It is revealing, in that it illustrates a typical dilemma which has to be resolved. Past success in the industry has, in no small way, sprung from a subtle consistency of management style and the manner in which manufacturing technology has developed. The success has, in turn, generated complexity, for which neither the style nor technology are really suitable. But, handling complexity can be, and often is, hideously expensive, and the ability to deal with it successfully will become a potent ingredient in successfully competing in the 1980s.

At this point, I feel that the novel has a decided advantage over the lecture. The novelist can invent ways of overcoming obstacles and resolving dilemmas. Sometimes, the more bizarre the invention, the greater the reader's enjoyment. I am not able to do this.

I can only say the situation is hopeful, the dilemma is increasingly recognized and it is being worked on.

All of this you may feel is a lengthy preamble to actually getting around to the 1980s as such. But as many of us have discovered, the first difficult task in the forecasting process is that of establishing honestly and objectively just where we stand.

Further into the 1980s

I have approached a number of factors obliquely, shown issues as incomplete and fragmentary and stemming from a concentration on improving the performance of individual tasks, because this is representative of things as they are, both within industry and in much research. The great opportunity of the 1980s arises from the juxtaposition of related developments which enable us to look at manufacturing technology systematically as a whole. To take advantage of this opportunity we have to create an environment in which the new concepts of information handling, related control potential and the ability to explore alternatives without physical involvement can be applied to the manufacturing system as a whole.

I see this as a process of technological evolution rather than revolution, spurred by internal discontent and external pressure.

As a first step, we need a clear concept of strategy at a corporate level, within which comprehensible units can control their own tactics. This will provoke a reversal of much of the existing computer application philosophy, which is aimed at exploiting bigger and faster. The computer power must be at the elbow of the people who are in the thick of it. When the day-by-day pressure ceases to exercise so much management energy and time, a release of new energy can be deployed on further improving the system. In future the worker will expect the order of things to be changed, that manufacturing technology and techniques will fit him.

Whatever changes in general structure this may provoke, its real importance lies at the workplace. Improvement in performance is always the sum of many contributions, comprehensible units provide the maximum opportunity for the maximum contribution. For these reasons the cell system will, in my view, become increasingly important.

I have already declared my hand in so far as the future of high volume component manufacture is concerned. I believe that it will continue as an identifiable activity because there is merit in centres of innovation which provide for a logical development of technology and skill: this apart from fiscal pressures which tend to encourage innovation within existing units. I believe that product range and complexity are likely to increase for the more sophisticated markets and that this will be accompanied by an increasingly international supply pattern. The pressure for local contribution in countries building up consumer durables could well provoke more partnership operations and licenses and an increase in barter arrangements, whereby individual countries each concentrate on specific parts of a product which they each assemble. Such an arrangement could reduce the range of facilities required and reduce the learning curve, whilst retaining the benefits of simple specialization.

I do not share the views of Aldous Huxley's *Brave new world* or George Orwell's 1984, portraying technological advance as a gradual enslavement of man by machines. More important is that some developments do increase opportunities for man's inhumanity to man in more subtle ways, such as invasion of privacy, record falsification and so on.

Let Babbage have the last word:

'A most erroneous and unfortunate opinion prevails amongst workmen in many manufacturing countries, that their own interest and that of their employers are at variance...

'Convinced as I am, from my own observation, that the prosperity and success of the master manufacturer is essential to the welfare of the workman, I am yet compelled to admit that this connexion is, in many cases, too remote to be always understood by the latter: and whilst it is perfectly true that workmen, as a class, derive advantage from the prosperity of their employers, I do not think that each individual partakes of that advantage exactly in proportion to the extent to which he contributes towards it; nor do I perceive that the resulting advantage is as immediate as it might become under a different system.'

Discussion

Professor M. Seaman (*University of Technology, Loughborough, Leicestershire*) suggested that corporate organizations needed to reconsider their approach to financial matters. The present accounting method merely values dead assets and a certain changing credit ratio which is evaluated outside the technological area; the calculus of investment is illogical. He asked whether Mr Stokes agreed that there is a need in corporate planning, both on a national and a company level, to include an evaluation of systems development and educational development.

Mr Stokes agreed that such a change was necessary. He added that the structure of a company often tends to reflect a set of circumstances which are no longer applicable. An engineer will describe a company by drawing some rectangular boxes, which is as useful as describing a game of football by showing how the players line up before the kick-off. There is little consideration of how things work in practice, and it is here that an application of intellect is required. The Training Boards are entirely wrongly constituted for this purpose and he looked forward to other people's views on this problem.

Professor Muller thought that there were two aspects of the problem of corporate planning, management of the firm's present operation and management for long-term strategy. There should be two systems to deal with these separate aspects.

Mr Stokes agreed that often these were integrated at too early a stage so that tactics for the moment and strategy for the future were confused. He believed that problems should be divided into comprehensible areas which can be dealt with tactically, by bringing in a computer if necessary, within a strategy that does not have to be changed because of tactical considerations. This problem particularly affects the component manufacturer who is working under constant pressure. He has to keep abreast of every modern development and to work with more exotic materials, knowing that if he fails to do this his business will collapse.

Mr Crookall (*Imperial College, London*) referred to Mr Stokes's point that if schemes are to be implemented, they must be comprehensible. He asked, with reference to the computer industry, if there were any developments, such as interactive modes, which could make computers more accessible and more comprehensible to people who would benefit from using them.

Mr Stokes replied that comprehensibility is still absolutely critical and for this reason it is pointless to try to produce a system dealing with an entire company which no one single person can comprehend. He thought that we would only start to use the computer successfully when we could 'fire' all the systems engineers and programmers and leave decisions to the person actually facing the problem.

Mrs G. M. Fazakerley (*Institute of Advanced Studies, Manchester Polytechnic*) said that she was concerned with the social implications of group technology, with the interaction of technology and the social environment, with the attitudes that people bring from outside to their place of employment and the way in which they see their employment as serving their broader social values. Systems analysis has emphasized boundaries between areas, but of greater importance was the interaction between them.

Mr Stokes said that this was an immensely difficult problem, and one to which academic sociologists, a description which appeared to him a contradiction in terms, had really failed up to now to apply themselves. Social relationships at work are clearly important, but equally important is a sense of privacy and a desire not to be overwhelmed by size. So far we have exploited the operator to fit the technology, and he wondered if we would be as successful in making the technology fit the operator.

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