



THE IMPACT OF NEW TECHNOLOGY IN THE CLOTHING INDUSTRY: OUTLOOK TO 2000

Chris Byrne

This paper was originally produced for the International Labour Office in Geneva. It has since been reprinted in modified form in Textile Outlook International

INTRODUCTION

The manufacture of clothing, along with the closely associated activities of fibre and textile production, continues to be one of the driving forces of industrialisation throughout the developing world. At the same time, the clothing industries of many developed consumer countries are fighting to maintain their share of the total value (as opposed to volume) which is created throughout the entire chain of apparel design, manufacturing and distribution.

Technology has always been key to this competitive struggle and is still largely controlled by the 'older' established industries of Japan, Europe and the USA. However, the ease and speed with which young industries have been able to absorb and master advances in machine and process technology throughout the 1980s have turned the attention of these industries to new modes of competition based on organisational know-how and systems as much as upon cost and productivity. Information technology in all its guises lies at the heart of much of the new thinking. An explosion of capabilities in that area is now shaping patterns of development through the 1990s and into the 2000s.

The application of these new technologies is having a profound social impact, not only upon the total numbers and location of those employed in clothing manufacture, but also upon the skills, training and management needs of organisations.

This paper sets out to describe the current state and major directions of research and technology development (R&TD) into clothing and to examine the social dimension of some of the changes that may result. It starts by comparing the driving forces of R&TD in the 1980s with those of the 1990s and beyond and looks at some of the results and impacts of developments to date.

It goes on to describe in greater detail the current state of the art in areas such as CAD/CAM, manufacturing, management, organisation and information technology systems, as well as the 'enabling' technologies which facilitate many of these changes. It also examines the extent to which manufacturing systems are likely to need, and be able, to respond to the demands of individual consumers as opposed to retailers and institutional customers. Finally, the human resource implications of these trends are considered.

CLOTHING INDUSTRY R&TD IN THE 1980s

The main commercial driving force behind clothing industry R&TD in the 1980s was the perceived need of industrialised countries to protect themselves against low cost competitors by improving labour productivity and reducing overall manufacturing costs. Towards the end of this decade, even the newly industrialised countries (NICs) responsible for much of the initial import penetration of Western markets (Hong Kong, South Korea and Taiwan) had started to find themselves being displaced by a further generation of developing countries. They were also beginning to suffer from internal labour shortages as their rapidly growing economies diversified into service, electronics and other consumer goods industries which offered more attractive working conditions.

The principal technical challenge to higher cost countries was seen to be the automation of clothing manufacture - ultimately, the achievement of the 'unmanned' factory. This aim was first identified and most clearly addressed in Japan. Not only were labour costs and exchange rates rising particularly fast there but Japanese clothing machinery manufacturers were riding the crest of a wave in supplying basic equipment to the rapidly growing Asian and Pacific market. They were even establishing a commanding position in Western machinery markets through exports and by acquiring local companies. A strong profit stream was available to support a major research programme with ambitious and far-reaching objectives.

The result was a joint R&TD initiative between industry and government (in the shape of the Ministry of International Trade and Industry, MITI). The TRAASS programme (Technology Research Association for Automated Sewing Systems) was established in 1982 with a budget of 13 billion yen (\$55 million) and involved a number of research organisations as well as 28 commercial companies. Its objective was to develop new technologies covering all aspects of the manufacturing chain, from fabric evaluation to finished garments. One important component was the design of sewing machinery in which a movable head could be programmed to work on fabric pieces draped over three-dimensional formers, thereby providing an extremely flexible method of adapting to changing styles, sizes and fabrics.

Although some important results have emerged (for example, further development of the Kawabata approach to fabric evaluation), major obstacles still surround automation of the manipulation and stitching of relatively limp and distortable fabrics. Satisfactory resolution of these problems still appears to be some 10-15 years away, even assuming that the commercial imperative for such research remained unchanged (which it has not).

Research in the USA and Europe was following very similar lines. In the USA, the textile and clothing industries together with the Federal Government provided \$25 million to set up the Draper Laboratories project in 1981. This was subsequently incorporated into "TC2" (the Textile and Clothing Technology Corporation) and eventually led to establishment of the National Apparel Technology Centre in Raleigh, North Carolina. An early objective was to use computers and robots to automate a relatively complex operation, the setting of a sleeve into a coat, but by 1988 this project had largely been abandoned in favour of simpler aims such as automatic seaming. In Europe, the "Flexible Materials" section of the BRITE programme committed millions of ECU to projects such as the automated sewing of underwear (Courtaulds and Pfaff).

In spite of all the resources poured into such programmes, particularly in Japan, automation of fabric handling and sewing operations has consistently proved to be very much more difficult than originally anticipated. Despite some useful spin-offs, the philosophy of total automation has now been shelved for the foreseeable future. However, this U-turn in philosophy has not been solely for technical and economic reasons but also because of changing market and industry priorities since the late 1980s. The search for enhanced competitiveness has increasingly turned to design, new fabrics, greater flexibility, quick response, quality and service as well as to new methods of motivating and involving employees.

Not all directions of research and development into clothing industry automation throughout the 1980s proved so fruitless. Considerable progress was made in the commercial development and application of computers and automatic systems to pattern grading and marker making, fabric cutting and materials transport between work stations. There was a rapid uptake of these new methods and a dramatic decrease in the price of entry level systems. CAD technology also started to receive a lot of attention as a creative design tool and by the end of the 1980s researchers were actively looking at ways to integrate this tool more directly into the fabric and garment manufacturing processes.

PRESSURES FOR INDUSTRY CONCENTRATION

Despite its falling cost and greater accessibility, there is considerable evidence that the overall impact of new clothing technology has been to strengthen the competitiveness of larger companies at the expense of smaller and medium sized firms. A 1991 study of the EC knitwear and clothing industries [1] showed that the average return on investment of small companies with a turnover of less than 700,000 ECUs was only 0.2% while that of companies with a turnover larger than 70 million ECUs was 15.0%. However, the economies of scale which contributed to this result were not primarily those of production but of other functional areas that added value and improved service to customers. In a similar vein, observers of some Asian clothing industries [2] have noted that it is difficult for companies employing fewer than 1000 people to sustain the development of more profitable "own brand" business, especially when supplying Western markets.

By the beginning of the 1990s, therefore, new technology had brought significant change and enhanced economies of scale to some of the preparatory stages of clothing manufacture and organisation of the overall supply chain but had not fundamentally affected the most labour intensive and quality sensitive areas of the manufacturing process on the sewing room floor. To an extent, this suited the evolving pattern of manufacturing in many higher volume areas of the industry. Design, marker making and cutting could be handled centrally with relatively intensive utilisation of the most modern capital equipment. 3-shift working by small teams of operators allowed faster response and better control of quality. In the case of knitted goods such as T-shirts, cutting could be directly integrated into the fabric quality control process.

Sewing and related assembly operations, on the other hand, could be farmed out to 'satellite' units wherever the availability and cost of labour was most favourable. Single shift working was still the norm. Trade regimes such as the former US "807" tariff schedule (now HTS9802) as well as various European outward processing (OPT) schedules facilitated this separation of the industry by including preferential provisions for re-import of garments made from domestically manufactured fabric and cut pieces.

CLOTHING INDUSTRY R&TD IN THE 1990s

Some of the market drivers of clothing industry technology in the 1990s and beyond have already been noted; they include greater emphasis upon design, innovative fabrics, flexibility, quick response, quality and service. Although these are not entirely new ideas to the industry, they have been given a fresh impetus and accent by some significant changes in the structure of retailing world-wide and by a new awareness of needs on the part of the eventual consumer.

Retailing is becoming more concentrated in many markets. Marks & Spencer in the UK has long had a powerful and formative influence upon the whole of its supply chain. In the USA, retailers such as Liz Claiborne, The Gap and, increasingly, mass merchandisers such as K-Mart, are extending their influence and relationships with suppliers right back to fabric, yarns and fibres. In Continental Europe, this process is still at an early stage but is poised to bring about a relatively rapid concentration in what have hitherto been highly fragmented clothing retail markets. In Asia, the trading house system already binds many stages of textile and clothing manufacturing together with retailing. Such companies are turning to electronic data interchange (EDI) as a core technology around which to build and manage their supply chains.

The growing number of new styles and collections required each year demands shorter lead times from design to sample, through manufacturing and delivery while protecting both manufacturers and retailers from the costs and risks associated with high stocks.

As far as the consumer is concerned, an increased awareness of and requirement for qualities such as individual sizing and fit, patterning and colouration, are beginning to appear alongside an established interest in new fabrics and garment styles. Evidence from a recent study on the colouration of garments near to the point of sale [3] suggests that existing dyeing, printing and finishing technology would be relatively straightforward to apply to much more 'bespoke' fabric and garment colouration but that significant advances in organisational systems and communications are required.

A NEW R&TD PERSPECTIVE

Such considerations have led to a retreat from the concept of highly capital intensive, fully robotised manufacturing centres in favour of the implementation of more flexible, modular, team-based approaches to the organisation and use of the new technologies. They also point to a future based on more customised, decentralised garment styling and making-up facilities closer to the point of eventual sale and to the customer. For example, a number of Japanese department stores are already installing small workshops to offer a customised garment service at a premium price and with a few days turnaround from order.

Automation still has a key role to play but it is now more concerned with enabling rapid adjustments of equipment from style to style, eliminating non-productive handling of fabrics and garments, and raising quality. Computers and microprocessor controls are central to this.

A considerable amount of research into the logistical and organisational implications of customised garment design

and manufacture has been undertaken at Chalmers University of Technology in Sweden over a period of several years. In particular, the role of advanced customer-oriented information technology techniques has been studied as an essential link in the chain between consumer and manufacturer.

Key to the integration of these technologies is the development of Integrated Service Digital Networks (ISDNs) based on fibre optic and satellite communications. These are essential to the exchange of considerable volumes of data, including images, along the whole supply chain from textile manufacturer to point of sale. They offer the possibility of extending the product visualisation and specification process right into the customer's own home through the future electronic equivalents of mail order and catalogue shopping.

This vision of the future is admittedly more relevant for the time being to relatively sophisticated and wealthy consumer markets. It does not, however, exclude supply chains being built upon more distant sources of labour and materials and therefore having a much more widespread social impact. Advances in communications, information technology and cheaper air transport all make the customisation and rapid supply of garments a feasible proposition from almost any location in the world.

Moreover, the newly industrialised economies of Asia and elsewhere are themselves becoming increasingly important consumers of clothing and other textile products. They are not yet as sophisticated as Western markets although appear to have a greater interest in new fibres and fabrics, particularly microfibres. Otherwise, garment styling and branding in these markets have so far tended to be imitative rather than innovative and original.

On a world scale, the social impact of new clothing technology in the NICs may ultimately be more important than in the West. However, there is relatively little research yet being conducted outside the established centres of Japan, Europe and the USA which looks likely to set new directions in the global clothing industry. This is not to minimise the importance of machinery industries within the NICs in transferring and adapting new technology to local needs but it is still far from clear which elements of more advanced 'Western' technology will be most relevant and quickly absorbed by these emerging industries.

CAD/CAM was the first area of impact of new generation clothing technology in advanced industrial countries and seems likely to repeat its success elsewhere. However, advances in computing power and communications technology should enable it to 'leap over' many of its previous limitations. This may prove to be the single most important tool in transforming developing clothing industries and their dependence hitherto upon contract manufacturing of clothing to the designs and specifications of others.

Existing and forthcoming advances in the basic manufacturing technologies of fabric preparation, cutting, fusing, sewing, pressing, garment dyeing and printing are all of considerable significance and potentially global application. However, it is likely to be the manner and extent of their linking together by Computer Integrated Manufacture (CIM) technology that becomes the key to their overall competitiveness and distinctive character in different world markets.

The implementation of systems for management, materials handling and team working is so far based more on know-how and organisational skills than upon technology. The extent to which current research may contribute to a better understanding of flexible manufacturing systems and their implementation through improved training, communications, information technology (IT) and expert systems is another important area in which to examine the potential social impact of technology. Underpinning many of these areas of change and enhanced competitiveness will be mastery and control of some key 'enabling' technologies. These include objective fabric measurement, anthropometrics, transport and packaging, as well as 'mechatronics'. Many of these will be tied to what is expected to be a key driving force of technology in the coming decade, growth in demand for semi-bespoke production techniques.

The impact and timing of all these technological and organisational changes and the scope for further R&TD will vary considerably from region to region and from market to market. The final section of this report summarises their likely implications for clothing and textile industry location, employment, working practices, skills, training and earning levels.

COMPUTER APPLICATIONS

Computer assisted design (CAD) and its direct linkage into the manufacturing process (CAM) has so far impacted

upon two (hitherto) distinct areas of the clothing industry, the grading, marking and cutting of patterns and fabrics prior to stitching, and creative fabric and garment design. Current R&TD focus is on the further integration of CAD and CAM techniques with other areas of computer use (accounting, order processing, payroll and management information systems) and their application to all areas of clothing manufacture (CIM).

COMPUTERS IN THE CUTTING ROOM

Applications of CAD/CAM made their first appearance in the cutting room in the 1970s. Led by Gerber in the USA, computer systems for grading patterns and producing markers developed rapidly and offered significant reduction in lead times and labour costs for generating and new styles, modifying existing ones and, above all, achieving significant reductions in fabric utilisation. By the early 1980s, half of all companies in the USA used CAD technology for this purpose. By now, the proportion is close to 100% across all advanced clothing industries. Developments in software, technology and intense competition have brought down the costs of a typical cutting room CAD system from around \$350,000 in the early 1980s to around \$50,000 at present, at which level many smaller firms can afford their own systems. Even for those very small firms without the in-house skills and resources to run their own system, networks of bureau services have appeared, as for example in the highly fragmented Italian clothing industry.

Automatic cutting offers many benefits in the form of reduced labour, stocks, space and fabric wastage but remains expensive, at up to several hundred thousand dollars per unit and therefore only accessible in the past to larger companies. While entry level costs can be expected to decline significantly, the potential for further development and sophistication of cutting room automation is such that large users will continue to enjoy an important competitive advantage.

COMPUTERS IN THE DESIGN PROCESS

The application of CAD to fabric and garment design and other related activities came somewhat later but has since had an equally far reaching impact upon techniques of creative design and product illustration, sample production and product costing. CAD is already a standard tool in many buyers' offices and manufacturers must ensure that their existing and new systems are fully compatible.

High resolution colour systems are already widely used for 2-D graphic design, with the ability to scan in images and manipulate them in many different ways. A key area of development is in 3-D/2-D mapping techniques which will eventually allow CAD technology to be used right from the creative design stage of 'three dimensional' sketching and styling through to preparation of markers and cutting instructions for two dimensional garment panels, trim etc. The current technology leader in this area is the US company, CDI Technologies Inc which has developed sophisticated techniques for three-dimensional design and representation of garments and is believed to be well advanced with software that will simulate realistic drape on computer generated images. CDI, in conjunction with North Carolina State College of Textiles, has also been developing draping algorithms which aim to interpret the properties of fabrics based on the Kawabata Evaluation System which is an accurate way of measuring and specifying the mechanical and surface properties of textiles.

In certain areas, CAD systems have started to make an appearance as merchandising tools for illustrating design ideas and products directly to final consumers. However, such systems are still primarily professional designers' tools, both because of their prices (\$50,000 up to \$200,000) and because of their relative complexity of use. Techniques already exist for mapping colours and printed designs on to drawings or photographs of models (or in the case of household textiles and floorcoverings, on to pieces of furniture and room sets). However, specifying the shape and texture of the areas to be illustrated and realistically simulating body contours and fabric drape remain largely manual tasks for a skilled operator and are not yet within the reach of, for example, a retail assistant or an untrained customer. A further stage, the use of moving computer-generated images to create a virtual reality 'electronic catwalk' for modelling of new garments and design ideas has also received a lot of attention but is still constrained by the current generation of computer processing power.

Progress in the development of modelling algorithms, improved human interfaces and the availability of ever greater computing power at lower cost can ultimately be expected to improve the scope for application of CAD into the retail and home shopping environments and thereby stimulate a market for bespoke and semi-bespoke manufactured products. The timescale for achieving on this on a reasonably high volume scale is difficult to forecast but could feasibly be within 10 years.

COMPUTER INTEGRATED MANUFACTURE

The penetration of microprocessor and computer measurement, control and information systems into almost every aspect of design, manufacturing and distribution poses an urgent need for their intercommunication and integration through both hardware and software links. Computer integrated manufacturing (CIM) provides a philosophy and pathway for moving beyond individual CAD and CAM applications by ensuring that all existing systems can talk to one another within both local and wider area networks and that future workstations and foreseeable information needs can be accommodated as they are developed or as a business grows.

Given that many of the physical standards and requirements of interfacing equipment and computers have now been resolved, much of the emphasis in CIM research now concerns software systems and human interfaces. Progress to date has been greatest in the area of fabric cutting where a number of leading systems and equipment suppliers have already co-operated to develop compatible systems. The next areas for attention will be those where there is already extensive use of computers, principally integration with company accounting, order processing and management information systems (MIS) as well as the creative design function, currently undertaken on a wide variety of proprietary systems, mostly workstation and microcomputer based. However, the sheer number and variety of existing systems in these areas may hinder progress towards their full integration or at least lead to the emergence of a number of competing approaches and 'standards'.

For example, systems are already available which allow the production of costings from databases of standard minutes, fabrics and trim but their widespread introduction has been slow. These will become increasingly essential to any full implementation of CIM but need to be developed further in order to provide more accurate and timely input to the earliest stages of the design process, including yarn and fabric design.

Computer modelling and simulation is an area which has progressed rapidly in recent years with the introduction of object-oriented programming and graphical interfacing techniques. Packages such as Taylor II now allow complex manufacturing environments to be varied, tested and evaluated without the need for expensive and disruptive workflow trials. At a more ambitious level, current US research is examining techniques for the modelling of entire industry and distribution networks using supercomputers.

MANUFACTURING TECHNOLOGIES

FABRIC PREPARATION

The preparation of fabrics for sewing includes final inspection for the elimination or minimisation of defects and the application of any finishes which will facilitate later operations, including cutting, fusing, sewing, pressing and garment colouration. As such, it is a critical area of interface between the textile and clothing industries and an area of opportunity for the development and enhancement of supply chain relationships and of integrated manufacturing systems.

The application of TQM principles to fabric and garment manufacturing is steadily leading to the reduction of multiple inspection at every stage from weaving, through finishing, to cutting. The processing and quality history of a roll of fabric will increasingly follow it (and be updated) at each process stage via EDI and bar coding. The protocols for this have already been largely developed but universal adoption of such practices is still at a very early stage. Automatic inspection is now increasingly feasible as the result of research into machine vision systems and to developments in real-time parallel processing of data.

Developments in fabric finishing and pre-finishing techniques are key to the development of much closer linkages within the supply chain. One area of very considerable potential is the 'pre-patterning' of undyed fabrics by selective application of dyeing 'accelerators' such as cationising agents to fibres, yarns and fabrics (by printing) and their subsequent 'development' by a final quick response garment dyeing operation. This is discussed further below.

Closely linked to this is the harnessing of new technologies to fabric and garment sampling. Ink jet technology is still some way from being an economic method for high volume printing of fabric and garments but has developed rapidly in recent years and is now a feasible method for producing sample lengths. The ability to link ink jet printing directly to CAD equipment allows the designer to experiment with endless pattern and colour variations. Ink jet technology even provides the capability to print a cutting outline directly onto a fabric for the purposes of bespoke

and sample garment production.

CUTTING

Cutting is the only garment manufacturing operation to have been fully automated, initially using the patented American Gerber System but subsequently developed by a number of competing companies among which European suppliers are strongly represented. Advanced robotics have also been increasingly introduced into this area for retrieving fabric from store, loading it onto the laying-up carriage, and removing cut material.

Virtually all cutters still use the knife system in spite of extensive research over the years with lasers, water and plasma jets. Lasers have found relatively limited application so far in bespoke tailoring and lace cutting. However, laser technology is likely to find more widespread use for fabric fault detection and management systems. These have only recently been developed but are beginning to be available from leading equipment suppliers; they operate during laying up and automatically instruct the robotic cutting head to avoid unnecessary waste, or alternatively to mark faulty panels for subsequent extraction.

Because of the considerable capital outlay involved, the cutting process is usually operated on at least a sixteen hour, 2-shift basis or more, often with a central cutting room serving satellite sewing units at different locations, sometimes hundreds of miles away.

Fabric cutting at the final stentering operation of the textile finishing process has attracted some interest recently. This would this by-pass several stages of intermediate materials handling and would have important consequences for existing boundaries between the textile and clothing manufacturing processes.

MATERIALS HANDLING

In order to reduce materials handling and speed the flow of work round a factory, various conveyor systems have been developed, ranging from relatively simple moving belts and manual push-pull rail systems to extremely sophisticated, computer-controlled automatic overhead conveyors. These are increasingly to be found in all areas of the factory, from cutting through sewing and finishing to warehousing and despatch. For example, one important area of current R&TD for materials handling in the cutting room is the robotic picking of cut pieces from the table and their placing onto automatic conveyor systems. Fully computer controlled transport and picking systems are already well established in modern garment warehouses.

In garment assembly, the most modern Unit Production System (UPS) provide the capability to locate and track individual pieces and orders around a factory as well as re-allocate work in the light of changing resources, styles and work contents. However, they can be expensive to install and operate and there have been some spectacular and costly failures arising from attempts to introduce inappropriate systems. Overhead systems generally have large space requirements and operators do not like the physical and visual isolation which result from widely spaced work stations surrounded by 'walls' of garments. Supervisors also find that the line balancing and 'debottlenecking' capabilities of such systems are often far from ideal although this problem may reduce with the further development and integration of comprehensive CIM systems. A growing trend towards team work organisation of sewing and related operations may cause some rethinking of current directions in the area of materials handling.

FUSING

For certain classes of garment, especially men's tailored garments, the processes of fusing an interlining to selected cut parts, and final pressing of the fully assembled garment, are as at least as important as the sewing operation itself for the production of good quality articles.

Fusing and pressing are both processes which depend on heat, pressure and moisture, and the reaction of different textile fibres and structures to a wide range of varying conditions. In particular, new generation fabrics such as those based on microfibres with sophisticated surface finishes such as 'peach skin' effects are especially sensitive to both temperature and pressure. Extreme care has to be taken to prevent irreversible damage whilst ensuring a satisfactory and even bond strength. This is a complex field of textile technology which has not yet received sufficient attention. Most development to date has focused on the use of programmable micro-processors for better

control, and workstation engineering to improve productivity.

One approach to improved regularity and versatility of fusing has been the development of flexible pneumatic roller systems which ensure completely even application of pressure across the whole fusing area, regardless of the thickness of the fabrics. Parts of different thicknesses can even be processed at the same time, including pre-stitched components.

Linked to this is the development of a much broader range of interlinings and adhesive systems. Interlinings are increasingly making use of the full range of new fibres and fabric forming techniques, including microfibres and specialised nonwovens. The precise selection and matching of interlinings to outer fabrics and to different applications and performance requirements is an obvious area for the application of objective testing methods and for use of expert systems.

SEWING

Various innovative methods of joining fabric and creating garment shapes have been researched in the past (e.g. radio frequency and ultrasonic welding, moulding and adhesives) but it is likely that, for the foreseeable future, clothing will continue to be assembled using sewing as the principal method of joining.

Nor is any major breakthrough in sewing technology likely. Developments here have tended to be incremental rather than fundamental and the basic sewing action seems likely to remain unchanged for the foreseeable future. These incremental developments fall broadly into two categories, in line with two main types of market requirement:

- Flexibility for quick response, with the ability to adapt to a succession of small orders in different styles involving changing stitch sequences and machine settings. To meet this need, a significant proportion of sewing machines are now pre-programmable, using microprocessors with push-button controls or, in special cases, responding to bar-code or "smart card" signals.
- Semi-automation for high productivity of a few basic or sub-assembly operations e.g. attaching pockets to jeans, stitching collars for shirts, hemming underwear and T-shirts. Most manufacturers have developed specially engineered workstations for very specific, basic sewing operations, often incorporating a degree of sensor technology and fabric manipulation, and enabling the operator to function more as a supervisor than a machinist.

The variety of competitive pressures and market opportunities ensures that both lines of development will continue. In particular:

- The facility to pre-programme individual sewing machines from a central computer will be incorporated into more ambitious systems of computer integrated manufacture (CIM). Ultimately, the capability will exist to programme machines with fabric-specific settings (based, for example, on Kawabata or FAST objective measurement data)
- Production engineering skills and developments in sensor and manipulative technology (often referred to as "pick-and-place" techniques) will lead to more obviously identifiable pockets of automation within the overall manufacturing sequence.

Sewing usually only accounts for some 10-30% of an operator's time. Handling and positioning of fabric pieces, which account for a much greater proportion of total time and effort, have therefore usually been the first areas to be tackled in the course of development of work aids and mechanisation. The conventional basic flat sewing table which still accounts for the vast majority of all workstations throughout the world has always been a machine support rather than an ideal ergonomic configuration for handling fabrics. Workstations of the future may need to incorporate adjustable surfaces which can be rapidly 'programmed' to suit constantly changing tasks and garment styles and will need to be better integrated with conveyor systems.

PRESSING, FINISHING

Pressing remains a labour intensive 'craft' skill in many areas of the clothing industry and yet has a critical impact upon the final quality and value of the garment. Current technology developments are aimed at reducing processing times while improving performance and consistency of this operation. Ergonomic redesign of workstations by

leading manufacturers is leading to the introduction of microprocessor controlled suction and central control units, variable height and table configuration mechanisms.

GARMENT DYEING

Garment dyeing techniques have been widely practised for a number of years. In Western Europe, Italy and the UK are leading producers, largely due to the influence of Benetton and Marks & Spencer and the importance of the knitwear industries of those countries. One estimate puts the total output of the garment dyeing sector at some 6% of all Western European apparel goods. The US market has traditionally lagged Europe in this field but is currently experiencing considerable growth.

Much of the recent boost in garment dyeing came from the fashion for a 'washed' look in denims and faded, creased cottons; before that, demand for fashion colouration of casual knitwear was one of the major driving forces of this technique. The garment dyeing sector is now contending with demands from other sectors of the apparel industry for rapid response service in higher quality and more technically demanding areas. There have recently been substantial improvements in the design and microprocessor control of machinery, fluid recirculation systems and the use of specialised dyestuffs and additives.

Colouration response times have been brought down from upwards of 10-12 weeks using the traditional fabric dyeing route to typically 2-3 weeks by garment dyeing. However, there is still a considerable gulf between the response capabilities and economic scale of operation of even the most versatile garment dyers and the provision of individual colour choice on single articles at or near the point of sale. Very little work has so far gone into the development of microbath dyeing technologies capable of processing single garments in the minimum of dye liquor or other solvent.

Patterning options at this stage are also very limited unless cross-dyeing techniques involving different fibres and dyestuffs can be employed. Qualitative developments are called for, not only in the technology of late colouration but in the whole organisation of materials sourcing, quality control and manufacture that precedes the garment dyeing operation. Difficulties still experienced in the provision of 'custom' garment dyeing services include:

- lack of specifically designed machinery
- limited scope for colour matching and quality control at local level
- limited operator skills and experience
- garments not properly prepared after sewing and handling operations
- limited scope for subsequent easy care finishing
- environmental limitations on water and air emissions.

Where patterned designs are to be applied to a fabric or garment other than by colour weaving, knitting or cross-dyeing techniques, most conventional printing technologies are limited in their application to flat surfaces. The only exceptions are where quasi-2-dimensional sections of made-up garments can be presented to a printing head for application of localised block, stencil, screen or transfer prints.

All of these techniques require substantial economies of scale for the basic creation, engraving and colour formulation of each design and can rarely be adapted for truly individual colouration. Such methods are also usually limited to simple unstructured garments such as T-shirts, sweat shirts, hosiery etc. An ideal new technology would facilitate creation of coloured patterns directly on complex 3-dimensional shapes.

Cationisation techniques are already attracting significant attention from garment dyers. They originated with attempts to improve the dyeability of cotton using anionic reactive dyes to impart a positive, cationic charge to the fibre surface and proved so effective that, under appropriate conditions, untreated areas of fabric could be left substantially uncoloured or at least, show marked two-tone effects. This provides a basis for producing 'colourless' prints which can subsequently be 'developed' to any colour by a relatively conventional dyeing process. Treatment of loose fibre or individual yarns to produce mixed colour yarns and yarn-dyed effects is also feasible. Piece dyed denim can be produced by this route.

In principle, this approach provides an attractive and flexible approach to garment dyers for the production of sophisticated, patterned goods with short lead times to final colouration (although not to choice of design). The technique is closely akin to cross-dyeing of fibre mixtures, except that only one fibre is involved, and is much more economic and effective than some of the dye resist techniques which have been attempted in the past. By

combining this method with other fibre and dye-specific treatments, it appears to be possible to obtain up to four-colour patterning effects from a single (multi-component) dyestuff application. The benzylation of certain fibres to improve their affinity to disperse dyes can be used in a similar fashion. Stumbling blocks to date have proved to be limited rub and light fastness, with some flattening of bright red colours but research into improved cationising agents is currently underway.

The most promising universal, digitally-generated, non-contact textile patterning technique yet available is considered by most observers to be ink-jet printing. The patent activity and development effort currently underway in this area are striking evidence of its prospects.

The ink-jet principle was first applied as far back as 1930. In a relatively low resolution form, it has already been successfully adapted to the printing of carpets and carpet tiles. The Milliken Millitron system is based on the deflection of a continuous stream of dye droplets by jets of pressurised air; an array of such jets can be several metres wide, with up to 40 nozzles per inch. Later methods have used micro-valves to control the flow of dye liquor directly.

In the search for higher resolution systems suitable for apparel and household textile printing as well as very high resolution systems suitable for reprographics applications, a number of different development approaches have emerged. These centre on the rival continuous flow and drop-on-demand technologies (DOD) but with a number of sub-variants. One leading system, the Stork X-cel, was originally developed for printing high resolution (250 drops/inch) colour images on packaging but has been adapted to the production of screen-based CAD textile print designs as direct strike-offs on to textiles. However, the technology may prove difficult to scale up and adapt to realistic rates for textile production. More work also needs to be done in order to develop suitable dyestuffs.

CHANGING BOUNDARIES BETWEEN THE TEXTILE, CLOTHING AND RETAILING INDUSTRIES

The structure of the supply chain for textiles and clothing has always had an important impact upon the technology focus of these industries. In the 1970s, the emphasis was on industrialising all levels of the supply chain in order to achieve economies of scale. In particular, the clothing industry developed production methods based on an extreme division of labour, with the fragmentation of the making-up process into many short, specialised operations in place of the make-through or semi-make-through methods which had previously prevailed. Product volumes were generally high, seasons were long and styles changed only slowly. Vertical linkages were often strong with companies such as Courtaulds in the UK involved in all activities from fibre to clothing manufacture.

In the 1980s, the focus turned to meeting the growing threat of low-cost imports from developing countries and to meeting a wave of consumer demand for greater product variety and quality. Time based competition and quick response were recognised as key strategies for survival and led to an upsurge in the development of technologies such as CAD/CAM, garment dyeing, EPOS (electronic point-of-sale), EDI etc., many of which are still only coming to fruition now. Past studies have indicated that quick response can save up to 25% of the retail price of some garments [4].

Important influences upon the clothing industry of the 1990s and beyond will include changing structures in retailing and a reshaping of established supply chain relationships. The retail industry is likely to undergo considerable concentration, especially in countries such as Italy where there are an estimated 170,000 independent clothing shops and the top ten retailers account for only 10% of sales. This compares with the UK which has one of the most concentrated retail industries and where the top ten retailers account for about 57% of sales.

Global sourcing will accelerate with this concentration of retail buying power. 'Strategic alliances' will be created in order to develop quick response supply chains and these will be based on fewer but larger suppliers. Stability of supply relationships has been demonstrated to lower overall costs more effectively than competitive multi-sourcing and this will create a better environment for the development of EPOS and EDI linkages. As the design process increasingly links and involves all parts of the supply chain, CAD technology will need to embrace retailers, buying agents and manufacturers' in-house design teams. Objective testing and evaluation methods for fabrics will also become central to the specification and communication process.

As the clothing industry becomes more attuned to operating quick response systems and as consumers' interest in new fabrics and finishes grows, it is likely that the textile industry will become more of a limiting factor within the

overall supply chain and therefore a prime focus for technology and service development. Future patterns of development in the world clothing industry could become increasingly dependent upon the sourcing and availability of new fibres, fabrics and finishing methods. The finishing sector will become a critical link in the chain from the point of view of clothing manufacturers and will need to be closely integrated into the CIM process by means of EDI and close strategic relationships. Minimum batch sizes and a typical 3-4 week lead time for colouration are still too high for many clothing manufacturers' requirements and will continue to focus attention on enhanced and novel methods of late colouration.

Location of production closer to final markets is a much-discussed strategic option but needs to be evaluated in the context of ever cheaper air transport and improved distribution logistics for relatively high value goods such as finished garments. Location of garment manufacturing closer to sources of finished fabric may, however, become a more important consideration and a key line of defence for many higher labour cost manufacturers. Developments such as direct fabric cutting off the stenter would further tie together the location of fabric finishing and garment manufacturing industries.

SYSTEMS

More sophisticated and highly developed systems have a key role to play in the integration and control of the various manufacturing technologies described above. Computer-based information technology lies at the heart of many of these systems but their scope is wider than just CIM; it includes new ways of doing business, of recognizing and measuring costs and value, of organising and motivating human resources, and above all of improving decision making in a much more complex and rapidly changing environment.

MANAGEMENT SYSTEMS

Quick Response (QR) has come to be regarded as a core defensive strategy for protection of home markets in high cost countries. It encompasses a range of techniques to shorten lead times in the manufacture and supply of goods at all stages of the production chain, to keep intermediate and final stock levels low, and to ensure precise and timely compliance with the eventual customer's individual needs.

Vertical partnership strategies between textile suppliers, clothing manufacturers and retailers are usually essential to the effective implementation of QR but experience so far is that retailers are usually the driving force of such relationships. They are also often the best placed to benefit from QR. One US retailer, JC Penney, has reported a 60% increase in sales, 20% reduction in stocks and a 90% increase in stock turnover from introduction of QR systems to certain of its stores. In other instances, however, the best attempts of a number of textile and clothing manufacturers to implement QR have foundered on the inability of their retail customers to adapt to and make full use of the capabilities offered. Upstream suppliers in a QR chain often complain that they bear many of the investment and organisational costs of QR but receive few of the benefits other than maintaining business with their customers.

Activity Based Management (ABM) techniques offer more flexible and meaningful approaches to the tasks of accounting and cost control in manufacturing environments where there is considerable product variety and continual change. ABM recognises that traditional methods of distinguishing variable and fixed costs and of absorbing overheads are inadequate to cope with situations where short run working is the norm, combined with the varying order sizes, delivery schedules, global distribution arrangements and marketing overheads which have to be borne by each product line. Because of the importance of labour (usually over 50% of total costs), the clothing industry has traditionally been able to rely on traditional work measurement and standard minute costing systems. Increasing reliance on high value capital equipment and time-based value-adding strategies requires a much more fundamental and detailed analysis of the various elements of finished product value. ABM techniques can be closely integrated with the product and resource allocation databases that are increasingly available through the introduction of CIM technology.

Business Process Re-Engineering is another developing systems technique that appears well suited to the clothing manufacturing industry. BPR aims to analyse and restructure businesses in terms of fundamental processes rather than conventional functions. Thus, the 'order fulfillment process' crosses the boundaries of order taking, production planning, manufacturing, quality control and warehousing. The new approach involves turning organisations through 90 degrees and analysing what the key processes are and how the available human resources, technology and systems support them.

MRP II (Manufacturing Resource Planning) is a well-established management tool that has been developed outside the clothing industry but is finding growing application to complex quick response environments. The availability of relatively low cost data collection terminals which can be installed at each workstation and materials control point can now provide a central computer with a complete real time picture of current operator and machine allocations, track specific work pieces through the production cycle, dynamically rebalance lines and teams, and replan production in response to changing customer demand. Modern methods of materials handling such as automatic overhead conveyor systems are well suited to the introduction of MRP. However, current moves towards team working may require some rethinking and re-evaluation of its application.

EPOS, EDI

EPOS (Electronic Point-Of-Sale systems) and EDI (Electronic Data Interchange) are integral elements in the implementation of Quick Response (QR) and Just In Time (JIT) manufacturing and distribution strategies, by speeding up the flow of information between suppliers and customers and allowing each to keep inventory levels to a minimum.

The collection of up-to-date information about current sales levels and patterns directly from retail outlets (EPOS) has typically been the first link in this chain to be established, often privately within major retailing groups and sometimes using purely proprietary coding and data transmission standards. Its more widespread and generalised introduction has since been facilitated by the development of a common bar-code standard, the Universal Product Code, and by 'open' EDI standards and protocols throughout the textile and clothing industries.

EDI is defined⁵ as the transfer of structured data by agreed message standards, from one computer to another by electronic means. Current interest is in extending the use of EDI throughout the entire chain from textile production, making-up/conversion, distribution to retailing. Full implementation of EDI requires the development of standards and systems for communication and data transfer between all partners in the chain, including:

- selection of appropriate standards
- data exchange systems
- integrated planning systems
- development of a basic communication system.

Information is required to:

- facilitate quick response
- track the process history of materials/products with particular reference to possible quality and environmental interactions
- track the materials history of a product in order to facilitate recycling e.g. polymer content, yarn blends, use of adhesives and finishes.

The United Nations introduced EDIFACT as an international standard in 1987. Under this umbrella, each industry sector is able to develop industry-specific sub-set message formats. Some industries had already started to implement their own systems e.g. TRADACOMS, used by major UK retailers.

In the USA, the Fabric and Suppliers Linkage Council (FASLINC) has been set up to develop and promote standards for information flow and exchange. Its voluntary guidelines so far cover:

- forecasting guidelines for exchange of product and market information
- Package Labelling and Identification (PLI) standards: development of bar codes and alphanumeric codes for each packaged shipped
- transportation standards
- cotton fibres; standards covering label identification, quality, transportation, and data transmission
- EDI; voluntary conventions conforming to ANSI X12 standards for documents, data segments and data elements for transmission
- quality characteristics; standards for information to improve product quality and eliminate redundant testing and other costs.

In Europe, EDITEX was set up in December 1990 as the equivalent organisation for the textile and clothing industry. Three countries were involved initially but the number now stands at 14. This organisation's mission includes:

- general promotion and training
- the creation and maintenance of message formats written in EDIFACT language to cover orders, order confirmations, invoicing, credit and debit advice, and delivery notes
- support for pilot projects.

EDITEX has so far only developed message guidelines for commercial tasks e.g. orders, order change requests, order responses and invoices, including product specific information such as style, colour and size. Work is under way on guidelines for despatch advice. Future guidelines planned include: delivery schedules, product information, sales status, price lists/conditions of sale, quality data and remittance.

A technical committee is working on message formats for specific tasks such as dye instructions and future areas for EDI may include transfer of CAD data. However, the European fibre industry has set up its own group to develop standards, including bar codes similar to those used in the distribution sector. It intends to align itself with the US FASLINC standards as well as those of the European Chemical Industry Council, CEFIC, which already uses EDIFACT standards. This seems likely to force the pace for EDITEX.

TEAM WORKING

With the retreat from attempts at its complete automation, garment making is likely to remain an essentially labour intensive operation. Systems for developing and harnessing the human resources of the industry to their maximum potential are therefore crucial.

For many years, the management of human resources in the sewing industry has been based upon Taylorian 'scientific' principles of work measurement and methods engineering. These have led to a general deskilling and specialisation of labour, and to a separation of production from control, with planning and monitoring imposed from above. The result has been a relentless search for automation regardless of the cost in terms of job satisfaction, labour turnover, and the absence of adequate experience and skills at just those moments when they are most critically required.

In terms of equipment design, this approach has led to a focus on specialised purpose machines suited to highly repetitious, short cycle operation and to computerised conveyor systems which are intended to reduce materials handling and improve line balancing. The importance of workflow control and of monitoring individual operator performance has also led to a recent growth in microprocessor-based workstation data collection systems.

The demands of QR and more frequent style changes have now provoked the industry to become much more flexible on the subject of working practices and there has been a considerable growth of interest in teamworking (also referred to as "modular manufacturing"). Already well established in Japan (from which most of the new systems have emerged), teamworking is now practised by some 10% of US clothing companies and is rapidly gaining ground in Europe.

Instead of individuals being stationed on a conventional production line, all teamworking systems base themselves on compact teams (usually 7-9 people) of multiskilled operatives who have the freedom to move between different tasks and work centres. In probably the best known system, TSS (the Toyota Sewing System, developed on the basis of that company's experience in automotive assembly), operators stand to work and carry their garment pieces around a U-shaped group of machines. Similar systems have been developed by Brother Industries and Juki of Japan and by Pfaff of Germany; the latter provides for small buffer tables between workstations in order to reduce the need for complete synchronisation and balancing of operations but still applies firm Kanban principles to prevent build up of stocks and to trigger re-allocation of operators to other tasks. The ratio of machines to operators in any teamworking system can be as high as 3 or 4:1 although there is a recent change in thinking towards smaller ratios based on more flexible and instantly re-programmable machines.

One of the most powerful justifications for the move to teamworking comes from the changed relationships within the production unit. The teams take much more responsibility for their own planning and implementation of tasks, as well as for the quality and quantity of their output. Supervisors and managers move to a more facilitative and co-ordinating role. Advocates of teamworking claim that it is applicable to all types of work and almost invariably

results in higher productivity and quality after an initial period of introduction. Critics argue that it places too much responsibility on operators for making key decisions and can be, at worst, another means of work intensification.

Continuing education and training are essential components of any teamworking strategy and technology has an important role to play here, from simple video and cable-based distance learning to full implementation of multi-media structured learning methods. With a reduced need for individual performance monitoring, information systems within the teamworking environment perform a very different role. Current research is aimed at improved methods of data collection and presentation, human interfacing, and assisting with delocalised decision making through use of, for example, expert systems.

Future directions in the development of automatic conveyor systems are also called into question by the spread of teamworking although they would still seem to have an important role in the overall flow of materials to and from the cutting room and subsequently to finished garment warehousing and distribution.

Despite this greater emphasis on human factors at the expense of complete automation, the development of advanced sewing workstations and supporting technologies still poses a need for more intensive utilisation of increasingly expensive equipment and systems. Traditionally, garment making has been based on the single shift working day but is now clear that, compared with other industries, this practice has stood in the way of developing and exploiting advanced technology to its fullest potential.

The two-shift automated cutting room has demonstrated that this need not be so in the future and new "green field" garment operations are increasingly being established on a similar basis. This logic could ultimately lead to 24 hour per day, 7 days per week working as a norm in many clothing industries.

MULTIMEDIA

Multimedia technology is a rapidly developing field which embraces many different techniques for manipulating, transmitting and using visual images, sound and data. Particular areas of interest for the clothing industry at present are improving communications between creative designers at remote locations and the introduction of new distance learning techniques for both managers and operators. As multimedia techniques progressively invade the domestic market, they will also provide new channels for retailing garments and for market research.

EXPERT SYSTEMS

Expert systems supplement human judgement and specialised knowledge in areas of complex decision making. They have important potential in several roles within the textile and clothing industries:

- selecting raw materials
- product design and application
- process optimisation
- production planning and control
- quality assurance
- environmental impact monitoring and control
- health and safety
- financial analysis and control.

'Artificial intelligence' (AI) techniques have a further role to play in supplanting human intervention entirely and allowing the automation of complex on-line inspection, machine and process control tasks.

AI can also assist with the modelling of complex organisational and management problem systems and the development of optimum strategies for quick response, etc.

Examples of current areas of focus in expert system and AI development include:

- short term production planning and control
- setting of process parameters, machine settings and operator assignments
- handling techniques for non-rigid materials based on objective measurement data

- redesign and optimisation of manufacturing procedures to meet health, safety and environmental requirements
- on-line analysis and interpretation of visual images (product quality control, process control etc.).

ENABLING TECHNOLOGIES

A few key technologies have emerged from outside of the clothing industry which seem likely to have an important impact upon future directions of clothing R&TD, industry organization and competition . Apart from electronics and computing, these include fields as diverse as objective measurement, anthropometrics, transport, packaging, anti-counterfeiting measures and mechatronics.

OBJECTIVE MEASUREMENT

Reliable methods for measuring and characterising the physical properties of fabrics such as 'stiffness' and 'smoothness' (i.e. handle) and relating these to the sewing and end-use behaviour of garments were first investigated as part of attempts to automate the sewing process. Now they are increasingly being recognised as ways of scientifically matching the fabric design process, including fibres, coatings, yarns and fabric constructions, to eventual consumer needs for comfort and performance as well as tactile and visual aesthetics. Such 'objective measurement' is relevant for:

- Evaluating the sewing characteristics of different fabrics and finishes, and using the information for sewing machine settings, including pre-programmable micro-processor controls.
- Evaluating 'tailorability' characteristics in a similar way, including the fusing and final pressing operations for tailored garments.
- Further development of computer aided design, by numerically specifying fabric drape and folding characteristics for incorporation into more sophisticated computer graphics.
- Communication of required standards, e.g. by garment maker to fabric supplier, or retailer to garment maker, to specify handle.

Objective measurement of textiles aims to characterise their mechanical behaviour under conditions approximating to those found in processing and wear rather than at the limits of failure, as most traditional testing methods do. New developments in this field pose two basic questions; what to measure and how to interpret the results.

Kawabata (Japan) originally set out to measure as many different factors as possible and developed the KES-FB system based on at least 16 different parameters grouped into 6 basic types (bending, surface, tensile, shearing, compression and thickness/weight). The equipment and procedures for these tests are now widely established but remain expensive and time-consuming. The alternative FAST technology developed in Australia reduces time and cost by measuring fewer parameters but is still regarded as too expensive for many industrial testing labs.

Alternative approaches have focused on evaluating only those parameters whose correlation with subjective evaluations of fabric hand were above some critical threshold but these are not universally acceptable. Recent developments have been aimed at simplifying and standardising the tests further, based for example on the use of a single widely available instrument (e.g. an Instron tensile tester) together with appropriate attachments. Such studies have also shown that, because of the interdependency of many fabric properties, as few as nine parameters may be needed for fully objective comparison of fabrics.

Attempts are also being made to further automate the testing procedures [6] while new techniques are being developed and assessed for presentation and interpretation of test results, including their graphical representation as 'fabric fingerprints'.

ANTHROPOMETRICS

Research work on the volumetric shape of the human body has developed in a number of directions. Consumers have become more interested in garment fit and comfort but there is a lack of reliable data about varying body shapes and about different markets. Much available anthropometric data is seriously out of date and often only reflects very narrow cross-sections of the population, for example, members of the armed forces. Average body dimensions are changing particularly quickly in some regions of the world, especially Asia, as nutritional standards

improve and basic eating patterns and diets change. Populations in many leading consumer countries are ageing and with them, there is a shift in spending power reflecting different priorities with regard to fashion, fit and functionality of clothing.

There is a considerable growth of interest in being able to measure and use more individual consumer data, either for garment selection at the point of sale or for feed-back to bespoke manufacturing systems. Current research work in Japan and the UK has therefore focused on the development of equipment for volumetric body measurement using lasers and image analysis techniques. Anthropometrics also has a contribution to make to work on the perfection of CAD systems which link 3-D volumetric shapes with 2-D pattern shapes.

TRANSPORT AND PACKAGING

The growth of global sourcing has led to a revolution in the use of air transport for speedy delivery of relatively high value garments from virtually any location in the world. Further reductions in the cost of air transport (with a new generation of massive jumbo jets already on the drawing board) and in the economies of scale associated with this method seem likely to make it an almost universal means of distribution for all but the most basic products in future. An essential requirement for reducing long distance freight costs and for ensuring the delivery of goods in optimum condition is further progress in packaging and storage technologies such as vacuum packing.

Packaging is also a key issue of environmental concern, with increasing pressures on suppliers to take full responsibility for its return and disposal after use. Germany already has stringent laws to this effect. Elsewhere, major retailers such as Marks & Spencer have become sensitive to these issues and have encouraged the development and use of packaging that can be recycled.

Local transport and distribution services for garments have become increasingly sophisticated and a number of specialist companies in the major consumer markets now provide comprehensive 'logistical' support in the form of customised vehicles, fully computerised warehousing facilities and full EDI linkage with both suppliers and customers. An increasing number of garment manufacturers are beginning to dispense with their own warehousing facilities and rely on these specialist companies, some of whom have established large international networks and are even beginning to offer garment re-finishing services immediately prior to delivery to retail outlets.

ANTI-COUNTERFEITING

Protection of intellectual property rights and measures to combat counterfeiting of brands have become a cornerstone of international trade liberalisation and are particularly relevant to the clothing industry. Increasing R&TD emphasis is expected to centre on such issues. Researchers in the USA are already looking at ways of transferring polymer micro-dispersion technology developed for tagging of nuclear missiles during the recent round of disarmament negotiations to anti-counterfeiting applications in fibres, textiles and clothing. Elsewhere, DNA profiling and other micro-biological techniques are being developed for unambiguous identification of natural fibres and their origins. In a similar vein, the need to protect retail goods from shoplifting has stimulated research into new methods of tagging goods other than by bulky and disfiguring external devices. Such techniques may also prove useful to inventory control and tracking of individual orders through manufacture.

MECHATRONICS

Mechatronics is a relatively recently coined term which describes the multi-disciplinary application of mechanical, electronic, optical and computer engineering science to machinery design and process feed-back control. It is not a new branch of engineering in itself but represents a developing recognition of the need for intensive interaction between the established branches of engineering science and technology.

The term was originally coined in Japan and a key factor is the integration of microelectronics and information technology into mechanical systems, leading to reduced mechanical complexity, combined with greater operational precision and controllability. Mechatronics also emphasises the development of machinery and processes around the principles of systems thinking, flexibility, versatility, economy, intelligence, safety, reliability, modularity, quick changeability, self adjustment etc. for applications which include:

- automated testing and quality control

- machine monitoring and process control
- operator-friendly machine changing
- production of small batches
- multi-purpose machinery
- textile and fabric formation to shape (weaving, knitting, braiding etc.).

Key technology issues include development of:

- a more fundamental understanding of complete textile systems, properties and processes and of control principles for textile machinery and processes
- reliable and economical sensors
- information processing software and hardware suitable for real-time operation.

Important new directions for the clothing industry emerging from current mechatronics R&TD include:

- machine vision for e.g. robotic manipulation of fabric plies
- application of robotics in testing
- automated garment handling and assembly
- fabric/garment visualisation

SEMI-BESPOKE SYSTEMS

Quick response has hitherto been viewed primarily as a competitive strategy for the textile and garment supply industries to minimise inventory and stock-out costs and to cope with a greater number of buying seasons. It has so far not been particularly concerned with responding to the needs of individual consumers for customised styling, fit and colouration. This has traditionally been the province of the bespoke tailor or dressmaker, a craft-based trade which still plays an important role in many parts of the world but has generally declined in the face of industrialised ready-for-wear garment manufacture in most major markets.

Recent research into consumer needs [7] suggests that the young 'fast fashion' market is not a primary target for bespoke apparel. Older and more affluent age groups, on the other hand, are concerned with issues such as fit and with matching colouration to existing wardrobes and accessories rather than following the dictates of the current fashion colour consensus. The same research showed that, rather than having wholly unrealistic expectations of 'instant' customisation, a delivery period of around 1 week was entirely acceptable to these consumers.

Harnessing the various elements of technology described above through a completely integrated design, manufacturing, transport and distribution system would appear to offer realistic opportunities of achieving such a goal within a relatively few years and at reasonable levels of cost. However, it is likely to be larger companies and vertical partnerships which first develop the necessary organisational and technological capabilities in the same way that Benetton revolutionised the European clothing and retail market in the 1980s with a combination of state-of-the-art warehousing and distribution, late colouration technology and novel retailing methods.

LIKELY SOCIAL IMPACTS

AREAS OF IMPACT

A technological and market environment has been described above in which the global apparel industry is increasingly likely to be dominated by large companies and in which well established strategic supply chain relationships will come to predominate over completely free market patterns of manufacture and trade.

Within the apparel manufacturing process, however, an increasing distinction is emerging between operations such as design, fabric cutting and distribution where large economies of scale can prevail and where use can be made of highly capital intensive technology, and of the basic sewing and assembly operations which seem set to remain essentially labour intensive activities, albeit supported by much more sophisticated, flexible and integrated technology. The introduction of team working practices, of Unit Production Systems and of more extensive CIM technology will do much to transform the organisation, skills and training needs of the sewing room but will not fundamentally alter this overall trend. Lower labour costs will continue to be an important goal for those seeking to

establish global supply chains.

A scenario can therefore be developed of a growing physical separation between centralised cutting operations and garment assembly. The organisation of outward processing by Germany is already a good example of this. Leading companies there now have fully automated design, planning and cutting departments which despatch cut parts to low cost sewing facilities in Eastern Europe. Made-up garments are returned to the computerised warehouses of the German companies or of specialist sub-contractors where they are sorted and prepared for delivery to retailers. These storage and distribution centres also often have facilities for final pressing and finishing of the garments.

Similar patterns could become established in other leading garment centres with, for example, US companies organising outward processing in the Caribbean or in Mexico. Even traditional commodity garment producers such as Taiwan are now moving towards a 'regional operations centre' philosophy in which their relatively vertical textile industry and larger companies within the existing garment sector feed assembly work to low-cost making-up centres in China, Vietnam and Thailand.

More extensive shift working is another inevitable consequence of the increasing capital intensity of clothing manufacture. This will be particularly evident in the most highly automated areas (design, cutting and distribution) but will also begin to affect sewing units. Teamworking methods, which seem to be the predominant pattern for the future, call for relatively high ratios of increasingly sophisticated machinery to be made available to each team member. Greater utilisation of the increased capital investment as well as fulfillment of quick response objectives can only be achieved by more continuous working practices.

Training in the use and maintenance of microprocessor and computer-based systems will become increasingly essential in all areas of clothing manufacture. Standalone CAD systems and microprocessor controlled machinery are currently the fastest growing areas of application for the new generation of information technology but integrated CIM networks and decision making processes based on expert systems will increasingly affect all levels of organisations and their employees.

Training of managers, supervisors, technicians and operators will also have to reflect new systems and concepts of business organisation, including QR, JIT, TQM, multi-skilling and team working. Maintenance will become a particularly important function as shortened supply lines and reduced inventories increase the costs of breakdowns. Suppliers to the automotive industry, including textiles and made-up products such as seating, are already accustomed to operating in JIT environments where heavy cost penalties can be incurred for any disruption of the production lines.

Earnings levels in the clothing industry need to rise to be at least on a par with other competing industries. They are typically 10-20% lower than the averages for manufacturing industry in many countries. Labour shortages are already a problem in many countries, including Taiwan and South Korea. Working conditions also need to be improved by attention to ergonomic design of machinery, materials transport equipment and work areas. Repetitive strain injury (RSI) is increasingly being recognised as a phenomenon associated with the over-engineered and specialised division of labour in industries such as clothing.

IMPACTS ON DIFFERENT TYPES OF COUNTRY

In line with the growing technological differentiation between design, cutting and distribution activities and garment sewing and assembly postulated above, there is also likely to be a continuing geographical division of labour and responsibilities within the overall clothing supply chain.

The advanced manufacturing and consumer countries are belatedly attempting to reverse the long term decline of their textile and clothing industries, aware that these remain major sources of employment and wealth generation with a strong multiplier effect on industrial sectors as diverse as engineering, polymers, chemicals and dyestuffs and information technology. The US textile and clothing industries still consist of more than 26,000 companies representing 2 million jobs, 12 % of the entire manufacturing work force. Annual sales are more than \$200 billion and contribute \$53 billion to the GDP. The recently announced AMTEX initiative (see Appendix) aims to arrest the loss of up to 350,000 jobs in the industry over five years and even to create 200,000 new jobs within 5-10 years, including the manufacture of textile and apparel machinery and equipment.

Western Europe and Japan seem less concerned with re-establishing the textile and clothing industries as major

new forces for employment as with asserting greater control over global supply chains and strengthening key sectors (fibres, machinery, design and distribution) that will create and extract maximum value within this overall process. Development of outward processing relationships with Eastern Europe, North African and Asian low cost suppliers will continue to dominate the agenda while, domestically, restructuring of the textile, clothing and retail industries is likely to result in a smaller number of larger and better integrated groups.

Eastern Europe is likely to attract very substantial amounts of investment over the next few years. It offers at present, and somewhat anomalously, reasonably well trained and educated workforces that are receptive to new technology and methods but at wage levels far below those of many developing countries. Transport, communication and cultural links are ideal for them ultimately to be absorbed into a European trading block.

The future commercial and industrial organisation of clothing manufacture in Asia will be almost entirely dominated by the emergence of China as a major manufacturing and trading power as well as an important market in its own right. China's share of world clothing exports more than doubled from 4% in 1980 to 8.5% in 1990. Its total value of exported textiles and garments rose by 2.6 times to some \$25 billion between 1987 and 1992 alone and is planned to exceed \$40 billion by 2000 [8]. The proportion of made-up clothing within this total has already reached 63% (39% in 1987) and is set to increase in place of basic textiles. One feature of China's rapid growth is that there is expected to be very little scrapping of old capacity and technology as new investment continues. There are also very few signs of the introduction and use of modern information technology in that clothing industry yet.

Instead, a number of established textile economies in the region are competing fiercely to establish themselves as 'Regional Operations Centres' in order to organise and channel this massive productive potential. Hong Kong has hitherto seemed best placed to perform this role but South Korea and Taiwan are strong contenders, along with smaller centres such as Singapore. Along with China, these 'ROCs' are extending their influence and direct investment in the emerging clothing industries of Vietnam, Thailand and Malaysia. Meanwhile, Japan continues to build a pivotal position as major technology provider to the entire region as well as a direct investor in all of these countries together with Indonesia and the Philippines.

The future of these ROCs is, in many ways, the most interesting and important from the point of view of the impact of advanced clothing industry technologies and information systems throughout the Asian region. South Korea and Taiwan already have strong textile industries but are experiencing sharply rising labour costs. They are therefore seeking to develop outward processing relationships with lower cost countries in the region. The challenge to these countries is to wrest overall control of the supply chains for higher value goods (and therefore a higher proportion of the total value added) from developed countries by investing in design and distribution technologies, systems and training. The continuing transfer and embodiment of 'Western' know-how into freely accessible technology is ultimately in their long term interest.

APPENDIX: MAJOR CENTRES OF CLOTHING RESEARCH

Although most countries with significant clothing industries have their own R&TD centres which are engaged upon a wide variety of incremental and more fundamental research activities, the USA and Japan still provide the best examples of concerted programmes between industry, academic organisations and government guided by a vision of a radically different long-term future for the textile and clothing industries and the changing nature of consumer needs.

US CLOTHING RESEARCH

The US Government has recently (March 1993) set up the AMTEX Partnership, an R&D collaboration between the US Department of Energy (DoE), selected universities and the industry. It covers fibres, textiles, apparel and other fabricated products. The aim is to create a role model for collaboration between Government and industry outside of the military arena. Four critical industries were initially identified; textiles, transportation, machine tools and electronics. Textiles was chosen from these for the first collaborative programme because of the number of relatively well organised and coherent research programmes already in place.

The mission of the Partnership is to involve Federal research laboratories in technology transfer to the US textile industry in order to increase its competitiveness. Eight of the DoE's nine national laboratories will be involved, including, Argonne, Brookhaven, Lawrence Berkeley, Livermore, Los Alamos, Oak Ridge, Pacific Northwest and Sandia. The research organisations involved in the Partnership are:

- Institute of Textile Technology (R&D budget \$6.0 million): 32 members representing 400 manufacturing locations and one third of total US textile manufacturing capability: its mission is to operate a manufacturing focused research and educational degree programme for development of new textile technologies
- Textile/Clothing Technology Corporation [TC]2 (\$7 million): members include most fibre producers and large textile and apparel companies: its mission is to develop and train industry in state-of-the-art apparel manufacturing, automation and work practices
- Textile Research Institute, Princeton (\$2.5 million): members include about 75 companies in fibres and textiles, including chemicals and consumer products: its mission is to conduct research in fibre and textile science and specialised testing and measurement methods
- Cotton Incorporated (\$42 million): represents US cotton growers: its mission is to provide research, development and technical services in support of the use of US cotton throughout the world
- National Textile Centre (North Carolina State, Auburn, Clemson Universities and Georgia Tech (\$8 million): its mission is to provide a shared academic base for the entire textile industry.

The overall vision is of creating an integrated industry that will become a dominant global force in providing high value products to the world market in an environment of industry growth, environmental responsibility, profitability and worker satisfaction. The industry seeks to lead the world in technical innovation, quality, value and rapid responsiveness to customer needs. Although the programme will be 'industry driven', it will emphasise the exploitation of 'spin-offs' from prior government investments in science and technology. Shared government and industry expenditure will amount to some \$400-500 million over the next five years. The Energy Research and Defense Programs offices planned to allocate \$15 million in initial funds for 1993, with a five year DoE budget of \$100-200 million. Industry was also expected to contribute \$15 million in 1993, reaching \$100-200 million over five years, including staff costs and other in-kind facilities e.g. use of production lines, materials etc. Strong measures will be taken to keep all resulting technologies within the USA for at least five years. Directly clothing-related projects include:

Simulation and computer integration leading to 'Demand Activated Manufacturing'

The aim is to create a communications and computer network which will analyse consumer trends, allowing all phases of the textile industry to meet consumer demands better and resulting in a process that will allow consumers to get specially tailored items in a very short period of time and allow industry to maximise its ability to react to consumer demand. The primary industry partner will be the Textile/Clothing Technology Corp. Use will be made of supercomputers and initiatives are anticipated in:

- Textile industry information architecture
- Textile industry communications infrastructure
- Business and product analysis tools
- Dynamic simulation of the textile and clothing industry.

Apparel automation

The aim is to improve the competitiveness of all aspects of the apparel and fabricated products industry by developing sensors, methods and equipment to increase the productivity of fabrication methods and workers while also creating revolutionary new methods that will be the foundation of the integrated textile industry in the 21st century. Primary industrial partners are the Textile/Clothing Technology Corp. and the National Textile Center. Potential initiatives include:

- Apparel anti-counterfeiting tagging
- Sensors for cutting and sewing technologies
- 3-Dimensional weaving and sewing

Improved materials and processes

The aim is to develop and implement the next generation of materials, sensors, machinery and processing technologies to improve manufacturing quality and efficiency. Primary industrial partners are the Institute of Textile Technology and the National Textile Center. Potential initiatives include:

- Automated textile inspection
- Waterless dyeing
- Intelligent processing sensors
- Expert control systems.

Apart from the AMTEX initiative, the major US clothing research centres have their own government and industry funded R&TD programmes. These include:

Apparel Manufacturing Technology Center, Georgia Tech Research Institute

Study of apparel manufacturing processes and systems, including:

- flexible manufacturing systems
- machine vision and robotics
- product quality control
- MRP and MRPII applications
- non-traditional capital investment strategies
- plant modelling
- integration of Quick Response strategies and systems.

Textile/Clothing Technology Corporation National Apparel Technology Center, Raleigh, NC

The National Apparel Technology Center is a demonstration and education facility featuring state-of-the-art equipment, software and time-based management methodologies. \$3 million of equipment operating in a real-time manufacturing environment is available for viewing and for demonstration of flexible, empowered-team manufacturing techniques, ergonomic technology, computer simulation and modelling, and quick response technologies. This is claimed to be the first cross-industry, large scale demonstration of QR using flexible manufacturing. Demonstration facilities include:

- Apparel on Demand, a process that combines non-contact body measurement, as a driver of advanced manufacturing technologies
- conversion of body measurement data into a digitised pattern by CAD - conversion of an electronic pattern into cut parts by transmitting the data via cable to a high speed, low ply cutting system
- production of a ready-to-wear T-shirt in 3 minutes using a team of cross-trained specialists using flexible manufacturing techniques
- use of a Unit Production System to reduce in-process inventory and throughput time
- the world's only sewn products computer simulation service to help management make more effective and cost-efficient decisions by modelling proposed changes to their current or planned manufacturing systems
- demonstration of [TC]2 sewn products Interactive Training Systems
- demonstration of the role of ergonomics in the design of [TC]2 work stations and attempts to educate industry about cumulative trauma disorders using inventions such as the Pocket Ergometer, the Nervepace and adjustable workstations.

The corporation is funded by major garment and primary textile producers, plus some government financing. Sponsors include Levi Strauss, Milliken, Cone Mills, and Swift Textiles (Dominion Textile). The main thrust of the Corporation's research and development is directed to automating various sewing operations. The intention is to ultimately develop an integrated flexible manufacturing process for complete garment production.

JAPANESE CLOTHING RESEARCH

The structure and funding of R&TD in Japan is somewhat different from the USA. Most public sector research is undertaken by local government (mostly prefectural)-funded bodies and there is little or no direct funding by the Ministry of International Trade and Industry (MITI) to public sector organisations in the area of fibres, textiles and clothing. Overall, large companies, particularly the fibre manufacturers, continue to dominate the RTD sector in Japan. Any research funding from MITI tends to be channelled through them.

Every five years since 1973, MITI has undertaken a major review of its vision for textiles and clothing through its two

advisory councils, the Industrial Structure Council and the Textile Industry Council with the aim of providing a way forward and a strategic policy for the industry. This resulted in a number of 'National Big Projects'. For example, from 1981 through 1988, MITI entrusted the development of automatic sewing systems to a research partnership established by various interested manufacturers. Some 10 billion yen of trust money was paid to this partnership over a 7 year period. However, much of that programme has now been discontinued.

The 1993 study started in December 1992 and an interim report was produced in June 1993; a final report was due to be submitted to MITI in November. As in past years, it is expected that new legislation will be enacted as necessary as result of these 'visions'. This time, the new vision has focussed upon the following issues:

- the future vision of the textile industry over the next 10-20 years
- the positive steps that need to be taken to accommodate future change
- rationalisation of distribution channels in apparel
- evaluation of, and a new vision for overseas activities
- improvements in quality and in business transactions.

Future investment in R&TD will concentrate on:

- Restructuring from "Product-out" (production oriented system) to "Market-in" (market oriented system). Market needs must come first, followed by planning, production and selling to construct a supply system dealing with actual demand. Quick response systems and the modernisation of distribution channels must be based on this concept.
- Promotion of structural improvements which encourage "creation" of new concepts. The textile and clothing industry is fashion-driven and is regarded as a "Life-Culture-Creative Industry" which detects the potential needs of consumers in advance and proposes new life styles to them. Industry structures must not hinder the freedom for creativity.
- Global strategy. Locations for designing, production and marketing should be considered on a global basis.
- Promotion of LPU (Linkage Production Units) which assist the flow of information between linked production units and the effective production of highly segmented, small-lot products.

REFERENCES

1 Kurt Salmon Associates

2 ATA Journal Dec '92/Jan '93 p 24

3 David Rigby Associates, private study for UK Dept. of Trade and Industry

4 Kurt Salmon Associates, EC Commission Report 1991

5 International Data Exchange Association (IDEA)

6 UMIST. Prof I Porat

7 David Rigby Associates, ibid

8 G Ji, "The Development of China's Textile Industry and its Reform and Opening", Asia and World Textiles Textile Institute World Conference, Hong Kong, 1993 Notes