CHAPTER II
The objective of this study being to assist hosiery firms to make rational production decisions, it requires the use of several concepts involved in optimal decision making. The definition of concepts formulation of models and few empirical evidences on the problem focus are helped by a review of past studies related to the subject. Therefore, an attempt was made to review available literature and a brief account of the review is presented below under the following headings

1. Hosiery Industry
2. Quality Standards
3. Policy
4. Simulation
5. Optimizing models - Goal Programming

Hosiery industry

In this section, a profile of Indian hosiery industry is presented on the basis of review of literature and data.

Knitting surely is almost as old as civilization. In fact, it was from India that the art of knitting spread to the rest of the world. But, in historical times, the first
knitting machine was invented by William Lee of Britain about five centuries ago. Though crude and cumbersome, Lee's "folly" was the progenitor of the sophisticated and computerized machines of today. The machines that are now in use in India are mostly from the European community or from Korea and Taiwan. India too is also an exporter of relatively low-cost machines for knitted fabrics and socks.

A century ago, the country was wholly dependent not only politically but also technologically on Britain. In 1893, few spirited Swadeshi gentlemen of Calcutta started a hosiery unit in Kidderpore with machines from England. Then, the British controlled all the market outlets for hosiery products as they did for others, and the early Swadeshi entrepreneur had an extremely difficult time in fighting hurdles set up by the commercial houses. However, by the fourth decade of the 20th century Swadeshi hosiery won the struggle, and established strong roots in Bengal and in the South. Till about the sixties Bengal produced 80% of the country's hosiery output. Lately, the picture has been reversed with the South, especially Tiruppur, coming into the lead. The other important centres of hosiery production are Delhi and Bombay for socks, Ludhiana for woollens, Kanpur, Banaras and Ahmedabad for cotton knitwears.
In its journey of 100 years, Hosiery industry in India had its ups and down. In initial period it was not recognised as an independent industry but with the advent of circular knitting machines and products research and development, it gradually gained recognition. Today, it’s a major consumer of cotton and Synthetic, Woollen and acrylic yarns¹.

Despite being the pioneer, Calcutta’s share of total domestic market is dropping sharply, making way for newly born Tiruppur which nowadays, control 80% of cotton Hosiery Export market in addition to substantial percentage of domestic market. It is their credit that despite Calcutta being nearer to Bangladesh (largest importer), exporters prefer to get their orders completed there. It is a certainty that, had there been a planned development in Calcutta like Tiruppur, India’s Export could have been more than doubled.

Most of the knitwear industry is in small scale sector and is concentrated in Tiruppur, Calcutta, Ludhiana, Bombay and Delhi. While the cotton hosiery is mostly concentrated in Tiruppur and Calcutta, the woollen is thriving in Ludhiana and Silk Hosiery industry is concentrated in Bombay and Delhi.

Hosiery manufacturing business has suffered a great setback during the last couple of years (1995-97). The price of cotton yarn constituting 70 percent of the cost of finished products was progressively escalated, prices of other essential raw material and labour wages considerably gone up, resulting in adverse effect on working of small entrepreneurs. These small entrepreneurs do not dare to increase the selling price to fully offset the increased cost and had to absorb the same against their net profit.

Facilities for advanced research and education in knitting technology have to be made available to the young entrepreneurs so that they may find prospective career in the knitting industry. In this regard, the financial as well as organisational aid from the Government is erstwhile requisite. It may be observed here that though IDBI launched a modernisation programme, the industry could hardly take advantage of the benefits because of complex procedures and formalities. Modernised Training Centres should be made available immediately to provide more skilled workers in this industry.

Tiruppur blossomed into an important manufacturing centre for a variety of hosiery garments such as cardigans, jerseys, pullovers, ladies blouses and skirts, sportswear, trousers and T-shirts besides the traditional inner garments.

As per the information available at the District Industries Centre, Coimbatore', in 1995, there are about 6,500 knitting and stitching units, 250 dyeing, bleaching and calendaring units, 200 printing units and about 100 embroidery units. Ancillary industrial units engaged in activities of manufacturing elastic tapes, packing materials, labels, polythene bags, button and button hole stitching derived their business from the hosiery goods manufacturing units.

International Federation of Knitting Technologies with its headquarters in Switzerland is the only worldwide body which could claim representation of knitting industry from all over the world. Its membership extends to all the six continents. In seventies, India became the member (IFKT). In 1978, Shri Rikhab Chand Jain' represented India in the conference of the International Federation at Troyes, France.

There are nine large and medium scale industries in Tiruppur and all of them are textile oriented. They meet only the domestic demand but also substantial exports earning valuable foreign exchange to the nation.


According to the Hosiery Manufacturer's Association (HMA), the hosiery is contributing one third of the textile made ups exported by India. Before the start of its second century, the hosiery industry is poised for take-off into even higher horizons. Throughout the world, a revolution in fashions of dress is taking place. Now, knitted slacks and shirts make rainbows of colours as much in the office as in the park or the beach.

Tiruppur has the basic infrastructure facilities like transport, communication and water supply, conducive to a sustained future growth. The entrepreneurs here are generally modernising their units, though the pace of modernisation definitely need to be speeded up. There are following industrial estates in and around Tiruppur:

1. SIDCO Industrial Estate : 40 sheds
2. Private Industrial Estate : 150 sheds
3. Industrial Estate, Ganapathypalayam : 30 construction are over and yet to start functioning

"Annual Report of the General Manager, ibid."
4. Industrial Estate: Chettipalayam

Chettipalayam are over and yet to start functioning.

Tiruppur Exporters Association (TEA)\(^6\) also plays a very vital role in assisting exports and for the general growth of knitwear industry in Tiruppur. With these excellent infrastructural facilities available, with the supporting institutions, Tiruppur can further grow into a giant in the field of knitwear manufacturing and also in export as it has tremendous potential.

An estimate by TEA, shows that in the next five years, a growth rate of 10% per annum on the number of knitwear units is possible with corresponding increase in production capacity. However, a steady growth of hosiery industry, which has a good potential for export requires special attention to quality of the products.

**Quality**

As defined by ISO 8402 (BS 4778)\(^7\) quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs of the

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users of the product. Within this definition one can identify concepts of (a) fitness for purpose, (b) value for money, (c) reliability, (d) customer satisfaction and (e) conformance to requirements of quality control standards. These concepts of quality are not new, nor are they restricted to any age or culture. Traditionally however industrial houses have viewed functions related to quality as assessment of product followed by return of what is defective and suggestions for rectification. For many years, this iterative process of make, inspect, accept or rectify has been the basis of manufacturing industry and it is only recently that the more effective concept "getting it right first time - every time" has started to replace it. This came forth in the first edition of BS 5750 in 1979.

Factors critical for quality

Long term success in knitted fabric manufacture necessitates production of fabrics of a high grade of fibre, colour and made-up quality and, above all, distinguished by dimensional stability. Therefore, the high quality knitted fabric manufacturers should not attempt to handle a very wide range of knitted fabric qualities but limit themselves to a few special varieties of knit goods. These days knitted fabric finishers and dyers are confronted with such a great variety of fibres and fibre blends and such an abundance of processes, installations, machines and units that one expert
alone cannot possibly command the entire field of knowledge surrounding knitted fabrics. There have never been and never will be alround dyers who are capable of dyeing any kind of textile fibre, such as pure silk, pure wool, wool blends, pure cotton and cotton blends, man made or synthetic fibres. In addition to the various types of fibres, there is the question of right choice of dyestuff groups and classes of fastness, the processes and application of the diversified and often contrary types of equipment, machines and installations. This statement made by Banerjee\(^8\) for dyeing apply qualitatively also for knitting, finishing and printing.

**Factors critical for success**

For a new entrepreneur, it would be possibly desirable, to first get a good and clear idea of the target market and possibility to get into a tie-up. The choice of product range and hence the machines, etc., follow. The whole house needs to be guided by the motto that good quality pays only in the long run. The in-house testing facility for random testing of raw materials and intermediate products would be of great assistance in this regard. Colour matching systems, to name one, is an indispensable facility to satisfy the customer. This process is used fairly widely in Indian mills and hence

\(^8\)P.K. Banerjee, ibid.
even a new entrepreneur could safely invest in this. However, sophisticated machineries incorporating on line control systems are available and also cost effective if well maintained. There is the problem of frequent breakdown. So they need to be viewed carefully from the angle of breakdown problems. Only if proper servicing facilities exist in the neighbourhood, would one be advised to go for the sophistication.

There appears to have been a little or no research into the competitive factors which bring each of the main classes of textile fabrics (non-woven, woven, warp knitted and weft knitted) into prominence and often dominance in certain end-use areas.

Export

The knitwears, sector being predominantly small scale, information available to them about the export market is inadequate. The fact that even sophisticated markets like those of USA, Germany and UK, have accepted the Indian made cotton knitwears proves great future potentiality for export of knitwear products. So, the crux of the matter is requirement of advanced know-how modern machineries and research institutions.

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10 A note in ITB Yarn and Fabric Farming. 3/97. p.6
Exports of knitted garments from India have been growing significantly. Apart from growth in volume and value terms, the share of knitwear in total exports of garments has also been growing steadily. The annual growth rate in year 1990 and 1989 over the previous year was more than 30 percent, however, in 1991 over 1990, it was just about 6 percent. This decline in the growth rate in the year 1991 is due to several disturbances, in the communist block consequent to the collapse of erstwhile USSR and recession in USA and EEC countries especially Germany. India's basic fabric base is of cotton and hence out of the knitwear exported from India, a huge share is from cotton fabrics, followed by synthetic and woollen. During 1991, for example, the cotton knitwear exports had a share of 97.28 percent in total knitwear exports.

Indian knitwears find wide acceptability in highly sophisticated markets in Western world like U.S.A., Canada, Germany, France and Italy. In terms of their total share in our readymade garments exports of India they account for 38 percent in quantity and 23 percent in terms of value. The major items exported during recent years in cotton knitwear are T-shirts, Jerseys, Slipovers, Cardigans, Ladies’ Dresses, Jackets and Blazers. There is further scope for increasing exports of high value added knitwear.

Looking at countrywise exports of Indian knitted garments, it is seen that in value terms, Germany is the biggest market with a share of 16.5 percent followed by U.K. with 14 percent and France with 10.1 percent. USA is in the fourth position with a share of 7.5 percent share closely followed by Italy.

The Tiruppur Exporters Association and Apparel Export Promotion Council had jointly organised the 4th India Knit Fair displaying Autumn / Winter Collection '98 from 27th November to 29th November, 1997 at Tiruppur.

The Director, AEPC, Reddy, said “all is not lost” and added that by making necessary changes to suit the market preferences, Tiruppur could bounce back with vengeance. “Tiruppur exporters are gearing up for making winter garments though on a limited scale and this should mark the beginning of a new era”, he said.

Policy

India’s recent policy of economic restructuring is the first determined effort to bring market orientation in the economy and to give a boost to the export sector. This should be vigorously followed. A single shot effort will not bring the desired result.

There is a need for export consciousness all over the country. West Bengal which is still a major centre for production of cotton knitwear items, is indifferent to the aspect of exports. As a result, the State is missing the opportunity despite its big export potential. Delhi, by virtue of being the national capital has built up an export culture. Entrepreneurs in Tiruppur in Tamil Nadu have set up an example as to how entrepreneurship through proper utilisation of human resources can achieve the desired objective despite many difficulties.

The new EXIM policy of India has practically freed her foreign trade from the shackles of controls and regulations. But, the accumulated inefficiency built over the years should be removed. The country needs a radical change in environment which is conducive to exports. The infrastructure facilities - power, transport, telecommunication, port operations, etc., must be adequately improved. Efforts should be made to improve quality of products and to bring down cost of production. Delivery schedules must be maintained and commitments should be honoured.

Discipline should be ensured at all levels. A culture of productivity and work ethos must be inculcated amongst the workforce. Finally, India must not ignore the emergence of new economic blocs, such as European Economic Community, North
American Free Trade Agreement and East Asian Economic Consensus led by Japan. The countries which are not part of any of these economic blocs will find it extremely difficult to maintain their exports. India must therefore have strategic alliance with these groups. In formulating the foreign policy, the country’s economic interests must get adequate importance. Dogmatism should be replaced by pragmatism.

**Sales tax on hosiery goods**

The Government of Tamil Nadu announced that even the one percent sales tax on hosiery goods would be removed (TEA). As a result of this announcement hosiery goods produced in Tamil Nadu now enjoy complete exemption from sales tax. Even though exports are already exempted from sales tax, the complete exemption for local sales, has eliminated the problems, harassments and unnecessary payment of penalties faced by exporters while moving export goods for shipment and subsequently at the time of assessment.

It is a felt need that job work billing should be done on Grey Weight of fabric. Grey weight or dyed weight should be mentioned on the challan. The disputes will be minimised by using a singular system of billing on Grey weight. This

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Century old practice is popular earlier in Delhi, Ludhiana and Tiruppur. After detailed discussions, it was unanimously adopted that all processors would be billing on Grey Weight of fabric.

Shortage by weight during processing will be calculated on actual basis, which may be two percent to 10 percent or more depending upon factors like quality of yarn, moisture content in fabric, colour, type of processing and method of drying involved. Some rejection percentage should be allowed with processing charges for dyeing of knitted fabrics, because, some rejection in dyeing is bound to happen.

A committee has been formed to look into the matters of default on payments (Hosiery Reports Weekly)\(^\text{15}\). Any member having problem in this regard could bring his case to the committee in writing with documentary proof. The committee will study the case and discuss with processor and in case, the Committee feels it necessary, it will discuss with customer and thereafter necessary action could be decided. Any customer having any kind of problem where association can help him, can also approach the committee. To minimize disputes with the Customers it is suggested that purchase/processing Order (P.O.) should be signed and accepted well before execution of order by the authorised person with all terms and conditions.

\(^{15}\)Hosiery Reports, ibid
A strong research effort will solve many of the technical and operational problems.

**Modelling**

Kohler describes the modelling of a specific production line making children's briefs under the bundle method of manufacture. The model considers the introduction of a new materials handling system to increase capacity utilisation. Batch methods of experimentation are employed but little detail is given on any statistical analysis used. Other papers have continued from this research and identified the following factors as significant to production:\(^16\).

* The hourly production rate of each operator
* The average breakdown rate of each type of sewing machine
* The average sewing machine repair time and mechanics arrival time
* The availability of spare sewing machine
* The incidence of absenteeism
* The proportion of faulty garments recirculated.

A model of both the present system and the proposed system is developed and validated using face validation. Student's 't' test was used to compare long term averages of performance. His main conclusions relate to the insight gained through modelling and the data collection phase of model building.

He discusses the analysis of sewing machine breakdown using both simulation and queuing theory. The factory studied in this case has around 30 production lines producing underwear (men's briefs). A small spectrum of machine types is encountered providing forty five days of data on repair dockets.

The data obtained from therapies dockets have revealed some trends that suggested deviations from the assumptions of queuing theory. The data indicates that a priority system of repair is in operation and that the queue priority is not always first in first out. Breakdowns are found to be Poisson rate but a test for homogenous data reveals differences between machine groups.

Analysis of repairs reveals that a breakdown requiring more than one mechanic is rare and that there is little specialisation of a mechanic to a particular type of repair. The distribution of repair times has the shape of the negative exponential distribution although there is not sufficient
evidence to support this statistically. There is no evidence to suggest significant difference in the repair times between machine types or between mechanics.

The same data on breakdown rate and repair are used in both analytical queuing model and a simulation model to optimise the number of mechanics. The simulation results demonstrate little difference with the optimum for two machines as shown by the queuing theory analysis. However, he points out that there is no evidence to suggest that the simple queuing theory approach may be generally appropriate.

Simulation

He concludes that the computer simulation developed is more powerful than the theory as it permits experimentation along the lines of introducing spare sewing machines to lower cost of lost production, dealing with a situation involving small numbers of machines with vastly different breakdown and repertoires, and introducing different priority schemes.

There is considerable pressure on the clothing industry to remain competitive in the face of foreign competition.
Faced with these problems there are broadly two lines of action available to the industry: radical changes in the system of production or improvements within the present systems.

The scope for the radical changes via automation is limited at present despite many advances. The problems of automatically assembling garment pieces are substantial. Automation of material handling has not produced systems that are more flexible. Extensions of the Flexible Manufacturing System concepts have been suggested but as yet this concept has not been realised.

It is clear that the requirement to successfully manage manual labour will continue for the foreseeable future. Managements are naturally reluctant to remove financial incentives to the operators, and particularly the incentives to piece work labour. Changes to group working requires new incentives and there is some hesitancy on the part of the managements in moving over to these methods.
In 1979, the Kurt Salmon Associates (KSA) were commissioned by the E.E.C. to conduct a study of the state of the art of assembly of apparel products and to make recommendations for future developments. The KSA report makes a recommendation for developments in simulation.

Although simulation has been shown to be a powerful problem solving tool within many manufacturing industries, its suitability to tackle the problems of garment manufacture cannot be implied. Simulation has origin in hard systems engineering, wherein, the problems and the objectives are well defined. Its success in what can generally be termed 'machine dominated' industry is therefore expected: The tradition of the systems engineering approach coupled with systems that are relatively well defined ensures some success. It suggests the need for modelling.

Model

The term "model" may be applied to any of the real world and the philosophies behind these representations. Models are used to promote knowledge and understanding of the real world.

17Kurt Salmmon Associates, ibid.
At a very broad level, the adoption of the philosophy of science has been found to be a successful approach to developing models of reality. However, advocates of Systems Thinking argue that the methodology of pure science involving reductionism, and refutation are not sufficient to describe many complex situations. Checkland\(^1\) describes the systems discipline as:

"It is the concept of organised complexity which becomes the subject matter of the new discipline 'systems'; and the general model of organised complexity is that there exists a hierarchy of levels of organisation, each more complex than the one below, a level being characterised by emergent properties which do not exist at the lower level".

**SYSTEMS**

The subject 'systems' may be divided into the theory of systems (system thinking) and the application of the systems theory to real world problems (systems practice). Systems thinking is holistic thinking that relies on two pairs of ideas: (a) emergence and hierarchy, (b) communication and control. The application of system thinking as a meta discipline in problem solving constitutes taking a 'system approach'.

Optner shows that the classic systems approach is that of the system analyser systems engineer\textsuperscript{19}.

The approach involves a formal definition of a problem by a problem owner whose needs are given, and set as objectives to be achieved. The systems engineer then tackles the problem of how these specific needs can be accomplished.

He describes the inadequacy of the hard systems engineering approach to tackle many real world problems in which humans have a significant role (human activity systems). With these systems the definition of the problem is itself problematic because it is dependent on the large part, the perception of the workers.

"The concept of human activity system is crucially different from the concepts of natural and designed systems. Once they are manifest, the latter 'could not be other than they are' but human activity systems can be manifest only as perceptions by

human actors who are free to attribute meaning to what they perceive. There will thus never be a single (testable) account of a human activity system, only a set of possible accounts all valid according to a particular perception.

The soft systems methodology can be summarised as taking into account finding out about a problem as well as taking action about a problem. Its early stages are concerned with developing a number of, 'root definitions' that state what the system is without imposing any problem structure. After this stage it is quite possible for a hard systems approach to emerge as a valid course of action. To this extent the hard systems engineering approach is a subset of the soft systems methodology. The use of systems thinking and 'scientific' methods of problem solving within manufacturing and service industry comes under the general title of operation research (OR). In OR, these technics are applied to operating systems and are defined as "a configuration of resources combined for the function of manufacture, transport, supply or service".
Parnaby\textsuperscript{20} notes that there is no single concept of a manufacturing system covering all the industries in every detail, he attempts a general definition:

"In general terms, a manufacturing system is one in which raw materials are processed from one form into another, known as a product, gaining a higher or added value in the process".

In attempting to take a broad systems view, Parnaby's definition is almost devoid of meaning because of its lack of specificity. To provide more content it is common to view the activities involved in manufacture as a hierarchy of sub systems that contribute to the 'global company strategy'. These are the activities of production and operations management, observed Heizer and Render\textsuperscript{21}.

"Production and operations management (P/OM) are activities that relate to the creation of goods and services through the transformation of inputs into outputs".


\textsuperscript{21}J. Heizner and B. Render. "Production and Operations Management : Strategies and Tactics". (Allyn and Bacon, Inc. 1988.)
A P/OM strategy involves all the activities of general management viz., planning, organising, staffing, directing and controlling. P/OM strategy must be consistent with the global strategy of the company and with factors relating to the interaction of the manufacturing system with its environment. Examples include environmental constraints, competition and the product life cycle. The principal problems of P/OM can be seen in three main interrelated areas:

* Capacity management is concerned with the determination and adjustment of manufacturing capacity to meet demand.

* Inventory management involves planning and control of physical stocks and the location of inventories in the layout.

* Activity scheduling is concerned with the specification of the timing of events within the system, such as the input of raw materials and the meeting of order 'due dates'.

By taking a systems view it is possible to describe specific aspects of clothing manufacture.
Methods employed in the industries of U.K. industry are described by Carr\textsuperscript{22}, Chuter\textsuperscript{23} and Johnson-Hill\textsuperscript{24}.

**Cloth manufacture**

Manufacturing has been defined as the 'transformation of raw materials into a product. The nature of the product can be used to classify the manufacturing system: in garment manufacture the product is discrete and comprises a number of sub-components made from fabric. Garment manufacture is therefore, a type of assembly manufacture for discrete products.

Manufacturing systems making discrete products can be classified according to the volume of identical components that are made. The process of manufacture

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may differ considerably because of the impact of economics of scale and the need for flexibility with low volume runs. The classification is as follows

* **Highly repetitive mass production** - Dedicated flow line systems are often characterised by limited flexibility and dedicated machinery. They work under a product layout which is a fixed sequence of activities required to make the product. If largely manual skills are employed the system is referred to as an 'assembly line'.

* **Medium volume batch production** - The volume of product is too small to justify high specialisation and there is generally a need for flexibility to make a number of 'different' products in the same plant. Process layouts are used with flexible routing for different product categories.

* **Small batch of jobbing shop** - The volume of identical product is further reduced. The method is often characterised by multi-skilled labour, flexible machining cells and flexible routing.
The clothing industry has both a mass market for which flow line methods of manufacture are appropriate and also specialist 'high style' markets for which batch or jobbing shop systems are appropriate.

**Product strategy**

A product strategy encompasses the selection, definition and design of a product. It is recognised that product strategy contributes a high proportion of the total cost of manufacturing by determining the range of alternatives in other areas of P/OM. Hoffman and Rush sum up the activities of product engineering in the clothing industry as:

"The activities involved are data intensive and require a high degree of skill both in creative and engineering terms. Inputs to the design phase include information on the past performance of product lines, fashion trends, market surveys, consumer expenditure patterns, customer requirements and deadlines, fabric types and styles available from the textile manufacturers, and of course, the creative input of the designer."

Generally there are three main outputs from product engineering that have a bearing on the production of the garment:

* A **master pattern** that is graded to produce garments of different sizes and then used as a guide to cutting garment components from the fabrics.

* A **set of assembly instructions** to tell the operator how to put the garment together. Working from general guidelines, the techniques are used to refine the method.

* **Guidelines** for how the assembly process should be organised, encompassing the process and layout strategy.

Within the clothing industry it is common to divide the time required to produce a garment into the basic element and the excess element. The basic element is the inherent work content in a garment as a function of product engineering and process strategy.
used. The excess element is the difference between the actual time to produce a garment and the basic element. Often the managerial excess component is identified and it reflects the competence of the management in administering production.

The managerial excess component is that part of the production time that reflects such things as how the production of work is planned and loaded (work scheduling), the skills of line supervisors to balance the production line, and effective motivation and incentive schemes for operators. Some elements of the excess components may be identified through performance indicators for the production line.

Process layout strategies: Heizer and Render\textsuperscript{26} defined a process strategy as the method by which inputs are transformed into products. Closely linked to the process strategy is the layout strategy that

\textsuperscript{26}Heizer and Render, ibid.
determines the spatial relationships between the components of the manufacturing systems and in turn directly affects materials handling methods. Within clothing manufacture there is a high dependence on manual skills for sewing activities due to the complexity of automating the assembly process, as shown by Nilsson\textsuperscript{27}.

* The garment pieces are irregular and often three-dimensional in shape. It creates some problems in integrated CAD/CAM processing systems. Fabrics are also of a porous, soft and limp material, which presents a major obstacle to automated positioning.

Concentrating on manual skills there are a variety of process strategies in use in the garment industry of which the following are the most common in present use:

* **Makethrough or semi-sectional:** Here a single operator carries out nearly all operations on each garment from start to finish. The method is analogous to the jobbing shop. Certain operations such as hard work (thread trimming etc.) and pressing are carried out separately.

* **Progressive bundle:** is used for medium to high volume production under a product laycut. Storage buffers are provided between operations so that a practice initial balance of the line is not required. Line balance is achieved dynamically during production through the intervention of the line supervisor. The level of work in progress allows each operator to be in control of their individual production, maximising the potential of production incentives.

* **Small group method:** This production method relies on group incentives for its success, and the development of "team spirit" amongst a group of workers. It is most often used when changes in product are large and frequent. Machinists need
to be experienced, flexible and versatile, probably make through machinists in their own right. Work is shared out between the members of the team who work as a team and are paid as such. The group is left to develop its own control. Slow operators tend to be actively encouraged by other members of the group.

Carr\textsuperscript{28} categorizes materials handling methods used in the garment industry by the nature of the handling unit, the power source and the routing of the handling units.

**Tied bundles** keep similar garments and garment components together in order to shorten handling times. The size of a bundle may vary from one garment upwards, commonly in one dozen increments, to a limit determined by the physical size of the garments. For example, bundles of 48 are common in

\textsuperscript{28}Carr, ibid.
the manufacture of underwear and lingerie, a size of 12 or less is common for larger items such as outerwear.

A large portion of materials handling systems utilises the operator as the power source. Operators may move individual bundles or boxes of bundles, they may push garments on hangers along rails (the manual work). In some systems the rails are arranged so that work will flow under the influence of gravity removing some of the manual effort.

Unit production systems are a more recent approach to materials handling that employ a high degree of automation. Operator utilisation, in terms of time spent actually sewing, is low under the manual methods of materials handling previously described. Shirley observed that sewing time constitutes about 20% of the operator's time. Unit production system is an attempt to reduce materials handling time to automation of handling between work places.

In a unit production system the bundle is removed and single garments are attached to carrier units on some form of automated rail. Operators at a work station have control over a very small buffer at their station so that a single garment may be transported to the operator, worked on (commonly while still attached to the carrier), and then sent on to the next operation. Unit production systems are most suited to high volume or mass production.

**Human Resource Use**

Human resource strategy aims to get the best return to the business from staff under the constraints of other strategies and provide a good working environment. It is one of the key areas in production management of clothing and has the following distinct areas.

* Man power planning to deal with work schedules.
* Job design to specify the task for each person.
* Establishing man power requirements in capacity planning.
The management of the human resource in the garment industry usually centres on the techniques of work measurement and method study. These two techniques come under the generic name of work study.

The technique of work measurement arises from behavioural studies of workers. There is a tendency to create work to do if proper targets were not set. Work measurement is defined by the standards set by BSI\textsuperscript{30}.

"Work measurement is the application of techniques designed to establish a time for a qualified worker to carry out a specified job at a defined level of performance."

The objectives of work measurements in the garment industry as defined by Carr\textsuperscript{31} are:

* To provide a "Standard time" for each operation.

By providing a numerical value for the time taken to perform a task. The work study


\textsuperscript{31}Carr, ibid.
encourages a formal numerical analysis of the planning of production.

* A standard time allows different work methods to be compared. Excess work content in each method may be identified. This analysis of method is called method study.

* The standard time provides a mechanism for cost controls. Each operator's production may be compared to that expected for the operation, based on the operation standard time. A measure of operator performance is thus developed, as given in the equation below:

\[
\text{Performance} = \left( \frac{\text{ST}}{\text{OT}} \right) \times 100
\]

Where:

\( \text{ST} \) = Standard time for job

\( \text{OT} \) = Operator's time to complete the job.

* Work measurement provides information for making investment decisions, such as pay back analysis for a new machine.

* Work measurements provides a basis for the operator incentive payment schemes. The standard time combined with operator performance allows
different operators on the same operations to be compared.

**Concept of Standard Time**

A 'standard time' is often referred to as a standard minute value or SMV. It is generally developed using one of the two methods. One method, called **time study**, utilises the skills of a time study practitioner to calculate the SMV. Another method is to use some form of pre determined motion-time system (PMTS).

As pointed by Chuter\textsuperscript{32}, rating within time study essentially relies on the judgement of the time study practitioner.

The stages involved are as follows:

* Define the job to be timed by identifying the best method of assembly. The job is then broken down to small elements that can be timed easily.

* Each element is timed for one particular operator that is assumed to be typical of all operators performing the task.

\textsuperscript{32}Chuter, ibid.
* The operator is 'rated' during timing. Individuals will vary in ability and subjective assessment must be made of their performance. Rating is used to normalise the absorbed time by converting them into basic times at defined levels of performance. There are a number of different rating scales of which the B.S.I (0-100) scale is the commonest in the U.K. industry.

* Establish the basic time which is given by the equation.

Basic time = (OT*OR)/SR.

Where:

OT = Operators time to complete the job.

OR = Operator's subjective rating

SR = Standard rating (100 on B.S.I 0-100 scale)

* Include allowances in the basic time for relaxation, contingencies and machine adjustments etc. Allowance vary according to the environment and working conditions.
PMTS circumvents subjectivity of time study. A PMTS allows any complex human motion to be analysed as a sequential series of small motion steps of stated time duration. It is noted that a PMTS "...may be regarded as forming a sub division of synthesis, because the standard elements which comprise the system are used to build up a basic time for the job being studied".

The elements of a PMTS are assigned codes with a corresponding time and time scales vary according to the 'level' of the system. Usually smaller units than S.I units such as the TMU (time measurement unit) are used. It corresponds approximately to one twenty eighth of a second. PMTS vary according to the scale of movement accommodated at the lowest level and thus in the number of codes the system uses.

Maynard et al. argue that the best known PMTS is MTM or Methods Time Measurement\(^3\). The system uses 350 motion codes many of which are below seven TMUs each.

Consequently the system requires a considerable amount of work to calculate an SMV. Robinson describes the evolution of MTM into an alternative called MTM Core Data, on which the major clothing PMTS is based.

The principle on which Core Data is founded is that there exist one motion category with a known TMU value and variance which can be applied simply by counting of the number of movements. If the resultant accuracy is insufficient than the motion categories, cases and/or distances are successively subdivided until a satisfactory level of accuracy is achieved.

MTM core data can thus be entered at any level of the pyramid, providing TMU values from a single value at the apex to around 700 at the base. The base level corresponds roughly to MTM-1.

The main PMTS in the clothing industry is General Sewing Data are (GSD) was developed from MTM.

core data. It is the most widely used PMTS in the U.K clothing industry. Mercer35 shows that GSD involves the description of the sewing process into a sequence of general events. These are getting parts and matching, presenting parts to the machine frame, sewing with realignment, trimming of threads and putting parts aside. GSD consists of 25 codes from the general level which may be supplemented by GET and PUT data and selected MTM codes to give a wide coverage.

A comparison of GSD to output standards set by time study and MTN-2 is given by Gershoni36 who notes a high correlation between these techniques. Gershoni also identifies discrepancy between the time standards actually adopted in the companies analysed (the so called “company time standard”) and the values produced by GSTR proper time study. Company


standards were consistently high, the reason being the method years old and out of date. In conclusion Gershoni states “that until the time of these test no-one had seriously questioned the accuracy of the company standards”.

The type of production now demanded of the U.K. clothing industry, requiring masser styles and shorter production runs places greater demand on work study personnel. He emphasises the need for dedicated PMTS systems (such as GST) to reduce the work of the determining new rates, and to allow work study personnel time for methods analysis and improvements. He points out areas of disagreement between company time standards and those determined by a PMTS, as follows:

* Small contracts constrain the implementation of time study for rating. After style change a period of operator performance improvements
occurs, and during this phase operators cannot attain an acceptable pattern of work which can be measured and taken as a standard.

* With larger contracts, problems with time study still occur. In many cases time study is merely used for negotiating a rate for payment and does not involve methods analysis.

Capacity Planning

Work study is the major element in capacity planning. Historic records of operator's performance are used to calculate the operator's potential contribution to productions in a new job for which the standard minute value has been derived. For the progressive bundle method of manufacture an approximate line balance is calculated in the following stages:

* The production target in dozens per day has been specified and the aim is to achieve a rate of production at each operation that is as close as
The standard minute values for each operation is found using time study or a PMTS. This gives data about the time in minutes for a standard operator to complete one dozen garments.

Based on the standard minute values, the capacity at each operation (in standard operators) can be calculated from the equation

\[ \text{Standard operators required} = \frac{T \times SMV}{CLK} \]

Where:

\( T \) - Production target in dozens
\( SMV \) - Standard minute value for one dozen
\( CLK \) - Total clock minute in the day.

Using the skill of the supervisor and historic performance records, operators are assigned to jobs. The actual performance of operators represents the proportion of a standard operator that day they can contribute to the job. By summing these proportions as operators are assigned, an approximate balance of operators to required capacity can be achieved.
Capacity management in clothing production is an uncertain process, because:

* The static capacity planning model creates only an estimate of initial line balance since the true performance of each operator on the new job is not known until they start the job.

* There are complications if the standard time used in the model is not accurately derived or is based on inaccurate company time standards.

* At the time of style start-up there is likely to be a substantial falling performance from the projected value, followed by a period of performance improvements.

* Due to performance variability and the process strategy, dynamic rebalancing is a frequent necessity.
Tactical decisions

Tactical decisions are short term decisions made in the day to day operation of production systems. They are the fine control of a system that has its major characteristics defined by the strategic decisions made at the design stage such as process design and layout. Tactical decisions involve levels of inventory, scheduling tactics, quality control and reliability.

It is difficult to discuss tactical decisions in strict isolation from each other and from the strategic decisions made in manufacturing. For example, the strategy known generally as "just in time" (JIT) recognises the cost of large volumes of inventory held at the input, inter-process, and output storage areas of a manufacturing system. In conventional systems these buffers are there to protect the system from unpredictable factors (Orders, machine break downs, delivery of raw materials, etc.) and they cannot be simply removed. The adoption of
JIT demands improved communication both within the system, and between the manufacturing organisation and the external world.

Within clothing production systems the management of capacity is very much a tactical decision making process due to factors identified. Consequently the just-in-case rather than the just-in-time approach to inventorial management prevails to protect output in the event of uncertainty. Under the Commonest method of manufacture, that of progressive bundle, upto one day's work for a number of operators may be held each buffer. This feature marks the main deviation of the progressive bundle method from the traditional flow line.

In conventional flow lines under a product layout line balance is less dynamic. For transfer lines a fixed cycle time is used to establish the balance. For assembly lines, pacing is commonly used to impose
a fixed cycle time with the consequence of system losses. Under the progressive bundle method, pacing goes against the philosophy of piece work incentives, pacing is not used and cycle times are highly valuable.

It is noted that the highly variable cycle time go against the main treatments on scheduling of flow lines that assumes a fixed cycle time (Baker\textsuperscript{17}; Conway\textsuperscript{18} et al.). In addition to the factory operator performance variability, Tyler\textsuperscript{19} notes that Zoning constraints preclude the design of the line to a fixed cycle time. Work elements are chosen to facilitate job specialisation under piece work and their combination to achieve a fixed cycle is not practical. In addition, developments in automated


machinery are at the whole operation level so little control of cycle length is possible.

Simulation

The systems approach to modelling is generally accepted (Fishman⁴⁰; Law and Kelton⁴¹; Pidd⁴²; Shannon⁴³). By building on the concepts of general system theory (Boulding⁴⁴), a theory of the modelling process itself may be developed. Once system theoretic concepts have been adopted, the concepts of modelling may be defined in systems language. Mitrani⁴⁵ used an opposite definition:


* To model a system is to replace it by something which is (a) simpler and/or easier to study, and (b) equivalent to the original in all important respects.

**Performance evaluation of the production system**

For example, assessing the effects of changing levels of work-in-progress on operator utilisation and calculating the corresponding changes in throughout time. The extent to which reduction in inventory can be achieved is essentially a function of variability within the line and control. If the model can produce the dynamics of the line then the extent to which WIP can be reduced may be properly assessed.

* The ramifications of absenteeism should be portrayed by the model. Although absence is often viewed as an uncontrollable variable, within clothing manufacture it is generally perceived that there is a considerable amount of absence that can be reduced through incentive schemes. It should be possible to investigate the merit of such schemes.
Machine breakdown has complex effects on the production line since the amount of downtime is a function of mechanic staffing levels, repair time, repair priorities and the level of machinery. The model should be able to investigate controllable variables in the downtime function such as the availability of spare machinery and mechanic staffing levels.

The areas of application indicated that the model should have some degree of general applicability within the clothing industry. In other words the model should have 'generic properties' to progressive bundle lines. The extent to which this can be achieved must be considered by the research, but it is appropriate to indicate why such a model is necessary and exactly what constitutes a generic model.

A progressive bundle line may be considered to be a collection of resources within a factory (machines, operators, supervisors, etc.) that are
brought together to achieve a goal of producing garments at a certain target rate. Capacity planning is concerned with assigning these resources from the complement within the factory to achieve this goal. The unit is dynamic in that allocation of operators changes to achieve a line balance and, in addition, each new style requires a new capacity plan and operation layout.

A general model of garment production is defined by the author as follows:

"A framework into which the major resources of garment production may be placed to produce a specific style, and within which resources may be moved to achieve line balancing during the production of a single product. The framework should be easily reconfigurable to reflect the production of alternative styles with a different combination of production resources".

Intuitively there are likely to be many factors that may limit the generic properties of the model. It is hoped that some of these have been made apparent by this research.
Fozzard\textsuperscript{46}, has recently been involved in similar research related to the manufacture of garments from woven fabrics.

Russell\textsuperscript{47} has carried out research with the International Wool Secretariat on novel yarn developments and on aspects of woollen carding.

In this context, mathematical programming has appeal for its simplicity, yet wide spectrum of application. It is especially desired where information available is very limited and only static solutions are desired.

While simulation is used extensively in complex situation requiring experimentation normative analysis for decision making by firms finds use of mathematical programming. Application of simple linear programming is very extensive where the \textsuperscript{48}C.F.

\textsuperscript{46}Fozzard, Hollings Faculty Manchester Polytechnic. 1994.

decision maker has a unique well defined objective. However, in the real world conditions, firms function with multiple objectives and a set of constraints. For them Goal Programming finds application.

Goal Programming

Flinn et al. incorporate the multiple goals of a household into the analysis of farming systems using linear goal programming (L.G.P.). From this approach the set of plans which are as close as possible to achieve a set of designed goals under conditions of land and cash scarcity were derived for a Filipino tenant farmer. They concluded that L.G.P. provided an intuitively appealing way to investigate resource allocation problems characterised by multiple goals and multiple constraints.

Romero et al. showed how multiple objective programming, compromise programming and filtering technique could be used to take the problems in agricultural planning. A real case involving the establishment of workers co-operatives within an agrarian reform program in Andalasia (Spain) was studied. Agarwal et al., employed lexicographic goal programming.

Problem was to find a compromise between objectives ie. employment, seasonal labour and business probability. The multiple objective programming was used after filtering procedure to find the efficient set among these objectives. A compromise between the objectives was established based on the compromise programming approach.

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Agarwal et al., employed lexicographic goal programming (L.G.P.) model for a planning problem of an industrial firm which aimed to achieve four goals. They opined that G.P. solution is certainly better than L.P. solution since it allowed a simultaneous solution of a system of complimentary and conflicting objectives rather than a single objective. Further more than one project could be included in the final programme of choosing projects.

Zekhri and Romero present a simple weighted goal programming model which can be used to predict the current allocation of agricultural enterprises in a particular geographical area. They also show how the approach proposed can be integrated into a multiobjective framework to measure the opportunity cost of maintaining the current situation in terms of several criteria which are relevant from a private and a public perspective. They assess the

51Agarwal et al., ibid.

opportunity cost of sustaining the current allocation of agricultural enterprises in the irrigated lands of Tauste (Spain) in terms of gross margin, employment, seasonal labour and water consumption.

Sandiford53 illustrates the application of multiobjective analytical model for decision making in fisheries management in Scottish inshore fishery. A hybrid modelling approach is used to analyse fisheries management objectives. Regression based model of the fishing process are used to provide input for the linear and goal programming models. Optimisation of the goal programming model resulted in an optimal pattern of resource allocation for the Scottish inshore fishery.

Berbel54 models decision making processes and the conflicts between profit maximisation, risk

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minimisation, leisure and seasonal labour as decision makers' objectives in a labour managed horticultural firm in South Eastern Spain. Multiobjective technique was used to analyse and incorporate risk into programming. He concluded that the compromise solution described reality better than an income maximising or risk minimising solution.

Reddy\textsuperscript{55} used multiobjective programming and compromise programming techniques to get best compromise solution for sericulture farmers in Bangalore and Kolar districts of Karnataka to achieve short term farming objectives. He considered the linkages between farm and farm family and also the production environment in which farmers were operating the farm business to sustain the farming system. The results envisaged higher farm returns to family owned resources. Farmers preference for multibivoltine over bivoltine was economically rational within the context of their goals realising regular and relatively stable income.

Stovall\textsuperscript{56} illustrates some implications of enterprise selection on total return and variance in farm planning after obtaining a variance function, the contribution of each enterprise to the total variance is derived. The researcher gave a theoretical model formulation with only two real activities to handle such situations without any numerical illustrations.

**Multi objective programming**

Multiobjective programming (MOP) or vector optimisation technique tackles simultaneous optimisation of several objectives subject to a set of constraints usually linear. As an optimum solution cannot be defined for several objectives, MOP obtains the set of feasible solutions which are efficient (pareto optimal) solutions rather than to locate the single optimum solution. The elements of this efficient set are feasible solution such that there are no other feasible solutions that can achieve the same or better performance for all the objectives and strictly better for at least one objective.

The efficient set is partitioned into two disjoint subsets, i.e., the subset feasible and non-efficient solutions and the subset of feasible and efficient solutions.

For the requirements of this study, the lexicographic goal programming is found appropriate because, the aim is to help decision making of firms in hosiery industry that have multiple objectives and they are able to order this priority. Therefore, it is used and further review of literature on goal programming is presented in the next chapter for convenient reference.