An Investigation into Indian Apparel and Textile Supply Chain Networks

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Copyright Statement

Abstract

The activities of the Indian clothing industry supplying Western markets have been investigated, with particular reference to identifying where improvements could be made to supply chain management. Focus group discussions, case studies and questionnaire analysis established that long lead-times in pre-production areas were of great concern. However Indian apparel manufacturers were found to be more cost conscious and rather less conscious about the value of time in pre-production areas.

It was found that pre-production activities constituted 73% of total manufacturing lead time and have high positive correlation (0.96) with total manufacturing lead time. Pre-production activities in India mainly consist of prototype making and pre-production sample development; of which approval processes were found to have a high correlation (0.63) with pre-production. A significant (more than 50%) time of all activities consist of waiting time, which has positive influence on total lead time (0.86).

Improvements to sample approval processes such as streamlining iterations and bottlenecks could eliminate some non-value added activities and reduce total manufacturing lead times by as much as 12 per cent. The average loss of time due to intermittent work interruptions in skill-based activities such as grading ranged from 15% to 24%; this could be saved by prioritising workload distribution to resources. Implementation of critical chain methodology compressed the pre-production time by 40%, resulting overall improvement of lead time by 29%.

A skewed distribution of workload on resources in the pre-production chain tended to result in unbalanced planning and inefficiencies. A multi-project Gantt chart when implemented through software could help rationalise the distribution of resources, levelling the workload with better prioritising of activities, thus leading to better management of bottleneck resources.

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List of Abbreviations

AEPC	Apparel Export Promotion Council
ALAP	As late As Possible
AOA	Activity on Arrow
AON	Activity on Node
ASAP	As Soon As Possible
CPD	Collaborative and concurrent product development
CPM	Critical path method
IIFT	Indian Institute of Foreign Trade
INR	Indian Rupees
IT	Information Technology
JIT	Just In Time
MRP	Material Resource Planning
NCR	Northern Capital Region
NIFT	National Institute of Fashion Technology
NNVA	Necessary Non Value Added
NPD	New Product Development
NVA	Non Value Added
PD	Product Development
PERT	Programme (Project) Evaluation and Review Technique
PLM	Product Lifecycle Management
PPC	Production Planning and Control
QR	Quick Response
SCM	Supply Chain Management
SEZ	Special Economic Zone
SME	Small and Medium Enterprise
SSI	Small Scale Industry
TNA	Time aNd Action
UVR	Unit Value Realisation
VMI	Vendor Managed Inventory
VSM	Value Stream Mapping

List of Published Works

Jana, P. and Bheda, R., 2001, *Supply Chain Dynamics in Indian Apparel Export Manufacturing: How Well Do We understand?* Clothesline, pp 24-28

Jana, P. and Bheda, R., 2001, *Supply Chain Dynamics in Indian Apparel Export Manufacturing: How Well Do We understand?* Apparel, pp 71-75

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Jana, P., Knox, A. and Narag, A., 2004, *Role of Intermediaries in Apparel Supply Chain*, International Conference HPTEX, KCT, Coimbatore, India, 7-9 July.

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Chapter One

1. Introduction

A supply chain, in a generalised statement, can be said to be the interaction between, or a system of, people, activity, technology, information, resources, infrastructure and organisations involved in moving a product or service from supplier to customer. Studies have shown that in the area of production and inventory management, 'Supply Chain Management' (SCM) has become the most talked about phrase during the last two decades.

A web search of the phrase 'Supply Chain Management' delivered 12.3 million hits on Google (Google 2008) and 6.1 million hits on Cuil (Cuil 2008). The acronym SCM has the most widespread reach among manufacturing and retail industries (Gattorna 1998a), and has been one of the most popular research topics among business and technology schools in the world. The growing popularity of SCM among researchers is clear from the following figures from Emerald (Emerald 2008): Of articles published between 1995-2000, 615 had the phrase 'supply chain management' in the title. The number grew to 1584 between 2000-2005 and there were as many as 1649 articles between 2005-2008. The Information Technology (IT) integration of the topic and widespread support from both the print and electronic media is exemplified from the following statistics: A web search (Google 2008) on 'software solutions for supply chain management' resulted in 1660 hits, whereas 4030 hits were counted on 'seminar/conference on supply chain management'. SCM is no longer confined to operation and functional areas of a firm; today it is a strategic issue demanding attention from top level management in all sectors of industry.

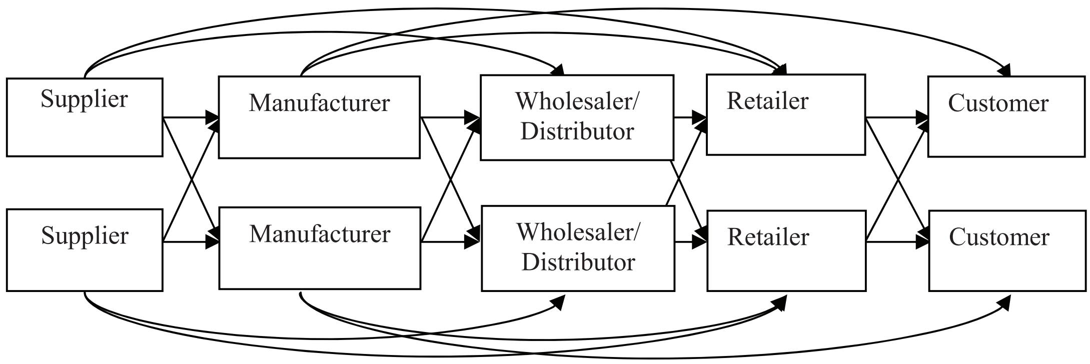
The apparel and textile industry is such a sector: it can be regarded as a series of interrelated activities which originates with the cultivation and/or manufacture of fibre and culminates in the delivery of a garment to an end user, viz, the consumer. The industry caters to one of the basic human needs— clothing— being present in almost every country in the world and plays a very crucial role in supporting and sustaining human life. With the terms 'apparel' and 'textile' being very much linked with 'fashion' (Jones 2006a), the industry has a vested interest in developing new products at the expense of existing items; i.e. planned obsolescence (Easey 1995).

India, with a centuries-old rich heritage in textiles is a strong force to reckon with in the global apparel and textile trade (WTO 2007). Applying one of the most dynamic management concepts, i.e. SCM, to the fashion industry in an emerging economy such as India, is indeed a challenging task. This research involves the latest thinking on management of the apparel supply chain with specific application to case studies from India.

1.1. Understanding the Supply Chain

A supply chain is the global network used to deliver products and services from raw materials (i.e. upstream) to consumers (i.e. downstream) through an engineered flow of information, physical distribution, and cash (Alber and Walker 1998). Christopher (2006a) defined a supply chain as a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate customers. A typical supply chain may involve a variety of stages like customers, retailers, wholesalers/distributors, manufacturers and component/raw material suppliers. Figure 1.1 represents the various stages of a simple supply chain.

Figure 1.1 Typical Supply Chain



Source: Chopra and Meindl 2005a

The primary objective of SCM is the integration and control of the normal flow of materials across multiple members of the system, involving multiple ties among suppliers and customers (Monczka *et al.* 1998). The material flows down stream with value added in each process and cash flows upstream, while information flows in either direction. The aim is to improve efficiency, reduce or eliminate waste and save direct resources. In effect, it is to ensure 'right product at right place at right time'. Each link (echelon) has input-process-output; the flow can be push or pull between each couple of activities in the chain.

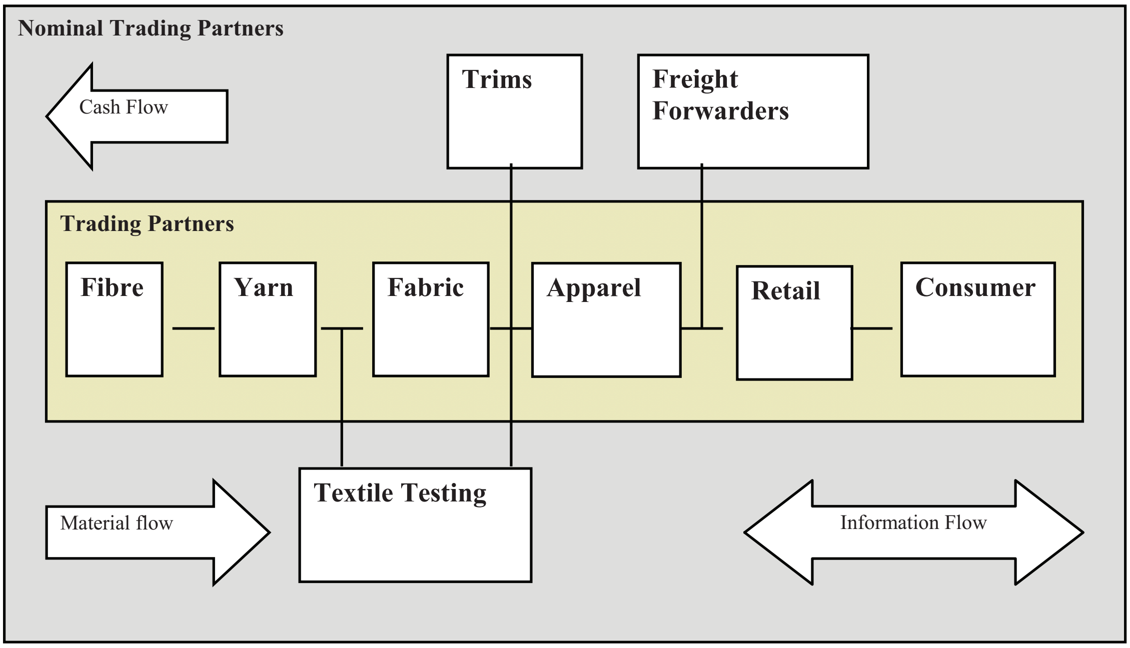
The material decoupling point is the position in the material pipeline where the product flow changes from push to pull and the information decoupling point is the point in the information pipeline where forecast driven and market driven information flows meet each other (Mason-Jones and Towill 1999a). According to them the position of the material decoupling point has a significant impact on inventory levels in the supply chain and responsiveness to demand and postponement of material conversion moves the decoupling point downstream (Mason-Jones and Towill 1999b)., thereby enabling smooth upstream planning.

The total time taken by the material from upstream to downstream is called supply lead-time. SCM could be seen as a management philosophy, implementation of management philosophy, or a set of management processes (Mentzer *et al.* 2001). In SCM, the philosophy of supply chains extends the concept of partnerships into a multi-platform effort to manage the total flow of goods from the supplier to the ultimate customers (Ellram, 1990; Jones and Riley, 1985). The non-value added activities in the supply chain could be more than 90 percent of the supply lead-time (Christopher 2006b) and need to be minimised. Inventory reduction and improved logistics (Christopher 1998), Collaborative Product Development (Womack and Jones 1996) and partnership sourcing (Macbeth and Ferguson 1994) are some of the methods to reduce lead-time and improve supply chain efficiency.

1.2 Global Apparel and Textile Supply Chain

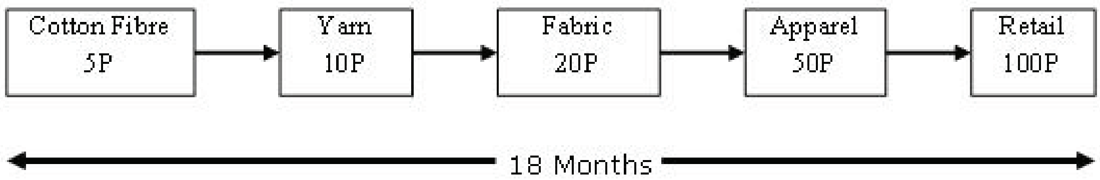
A typical apparel and textile supply chain would have trading partners from fibre producer upstream to retail consumer downstream. Some of the nominal trading partners would include trims and accessories suppliers, textile and apparel testing agencies, and freight forwarders. Figure 1.2 represents a typical apparel and textile supply chain.

Figure 1.2 Apparel and Textile supply Chain



Global apparel and textile industry is characterised by product variety, fashion content and seasonality. Though there are less than 20 significant textile fibre types, the variety in the final product (the garment) is infinite. As material flows downstream from fibre to retail, the fashion content in the product increases; thus stock keeping unit (SKU) diversity also increases phenomenally (Massey 2000). The fashion content of apparel makes it a perishable commodity over time, resulting in markdowns and discounts (Oxborrow and Massey 2000) and so the objective of every player in the chain is to move the goods from design to consumer in the fastest possible time. In a car industry, new product development used to take 4-5 years (Womack *et al.* 1990), whereas in the apparel industry, new product introduction every 4-6 weeks has become common in the so called 'fast fashion' (Oxborrow and Massey 2000, Mintel 2007). The following example of cotton brief (figure 1.3) gives an idea about value addition and lead time in a traditional apparel and textile supply chain (Knox and Newton1998).

Figure 1.3 Typical Value Addition and Lead-Time for a Cotton Brief (in Apparel and Textile Supply Chain)



Being highly labour-intensive, the apparel manufacturing activity has migrated to lower labour cost countries over time, resulting in global supply chains. Now, with fibre grown or manufactured in one country, fabric could well be in another and apparel in a third country. To manage this global supply, intermediate agents like the buyer, contractor, importer, wholesaler and distributor might be added to the basic network (fig 1.2). With the traditional two seasons per year (Autumn/Winter and Spring/Summer) or with commodity clothing, such extended supply chains were not a major problem.

During the 1990s, there had been a paradigm shift from cost-based to time and value based competition in global sourcing of merchandise (AAMA 1995), resulting in an ever-increasing and irreversible global trend towards 'speed and replenishment sourcing of merchandise' (Oxborrow and Massey 2000), (Abernathy *et al.* 1999a). Increasing importance was given to design innovation capabilities of the manufacturer (Kerr 1999) and shifting of product development functions from retailer to manufacturer for an effective supply chain (Watson 2002).

The time taken from an order being placed on an apparel manufacturer till the complete order being shipped to retailer is called 'manufacturing lead time' or 'manufacturing cycle time'. The average lead time is approximately 167 days (JBA 1998); lead time may vary from 117 to 172 calendar days depending on the level of adoption of technology (Abernathy *et al.* 1999b). Given that the labour cost of a garment is generally much less than one hour (The Binran, 1990), it is apparent that typically 95 percent of all lead time in manufacturing is non-value added activities (CMTC, 2003).

1.3 Indian Apparel and Textile Industry

The Indian textile and apparel industry, with a turnover of $ 15.4 billion in 2005-06 (Annual Report 2001-2008) is one of the largest segments of India's economy, accounting for 15 percent of total industrial production and slightly more than 17 percent of total export earnings. It is also the largest employer in the manufacturing sector with a workforce of some 35-38 million people (Chandra 2006, Annual Report 2007-2008). India is the third-largest producer of cotton in the world with annual production of some three million tonnes, fifth largest producers of manmade fibres and filament yarns with an annual output of 1.7 million tonnes and second-leading producer of silk, with annual output of nearly 15 million kilograms. India's textile sector has the second highest installed spindles capacity and the highest number of looms installed in the world. Due to the Small Scale Industry (SSI) investment ceiling imposed by the government, India's apparel sector was highly fragmented, comprising about 30,000 units and employing some three million people during 1997 (AEPC 1998). However, due to the recent relaxation of investment limit and consolidation, the industry now consists of around 100 plus large players with a turnover of more than ₤15.13 million and around 2000 smaller players, who specialise in either niche products or small quantities (ApparelOnline 2006). Factories with turnover of more than ₤6 million are regularly monitored for compliance and account for more than 75 percent of India's exports. Till Sept. 2005 there were 58 WRAP certifications, 111 SA 8000 and more than 125 AVE audited factories (Trend Fusion 2006). Government initiative includes a Technology Upgradation Fund scheme a with loan of INR 92,700 million, 100 percent FDI allowance in manufacturing, setting up 42 new Special Economic Zones (SEZs), etc., (Trend Fusion 2005).

Apparel exports from India started mainly with low-value low-quality products with the objective of using an inexpensive workforce (Koshy and Jana 2000). While the majority of developing (apparel exporting) countries are engaged in contract manufacturing, India is mainly engaged in fully factored manufacturing (Koshy 1997a). As a global sourcing destination, India's core competencies are innovative and value added merchandise with flexibility in production volume. Improvement of product development and design capability (Dhingra 2004) by utilising the inspirational fabric base (Chandra 2005) for Indian apparel manufacturers was highlighted repeatedly for gaining competitive advantage in exports. Problems plaguing Indian export are mainly inconsistent quality and delivery and higher lead time (Koshy and Jana 2000).

With the ‘low-value low-quality’ concept, not much importance was given to strengthen production facilities. Industry structure can be characterised by largely proprietorship or partnership firms without any joint ventures, technical collaborations, strategic alliances or subsidiary operations (Koshy 1997b). The crucial value chain is missing due to the absence of a world-class domestic market (Prahlad 1993) and (Porter and Ghemwat 1994). Even though technology had improved world-wide for apparel manufacturing, Indian clothing industry mainly used outdated machines due to prohibitive duty on imported machines and investment restrictions due to garment manufacturing being reserved for the small scale sector (Jana 1999).

Typical strengths of the Indian apparel industry are strong raw material base, fully factored manufacturing, ability to execute small and large order quantity, value added merchandise, design and product development capability. An English speaking population and political and economical stability and ethical manufacturing practice add to the confidence of overseas retailers. The weaknesses are inconsistent quality (Bheda *et al.* 2003), poor delivery (Chandra 2006, Koshy and Jana 2000), long lead time (Pandey 2002, Dhingra 2004, Chandra 2006, Karandikar 2005), low productivity (Bheda *et al.* 2003, Dhingra 2004), and poor support infrastructure (Dhingra 2004). India has clear geographical specialisations, like NCR (Northern Capital Regions) for fashion; Chennai for shirts; Bangalore for structured garments/trousers; Tirupur for knitwear; Ludhiana for sweaters and Panipat, Karur and Cannanore for home furnishing (Trend Fusion 2005).

A traditional fully factored manufacturing base, India’s (unit value realisation) UVR increased from € 13.73 per kg. to 15.11 per kg. during 2005 in Europe while average import UVR for Europe reduced by 2 percent (Trend Fusion 2007). The design and development capability is increasing and getting global recognition as design outsourcing hub. Munch Design Studio, Grace Group and Bricolage are pioneers in this segment (Trend Fusion 2007). Flexibility (Jana 2000), ability to execute small order quantity, and an English speaking population (Trend Fusion 2006) give additional advantage over neighbours. With such a diverse yet challenging market, there are ample opportunities for improvement.

The structure of the Indian garment industry is complex as much as it is diverse, it is highly fragmented and a large part of it is unorganised (Krishnan 2001). In tune with the global paradigm shift towards speed and replenishment sourcing of merchandise (Oxborrow and Massey 2000), (Abernathy *et al.* 1999a), India is facing pressure from EU and US retailers to execute orders in faster lead times (ApparelOnline 2000), (Dhingra 2004), (Trend Fusion 2005). Indian export remains cotton-based, value addition remains low, as the processing sector is a weak link (Subbu 2003). Also in tune with increasing importance being given to design innovation capabilities of the manufacturer (Kerr 1999) and the shifting of product development functions from retailer to manufacturer (Watson 2002), Indian apparel manufacturers —specially in NCR— are required to develop and exhibit their own product development capability as order winning criteria (ApparelOnline 2003, 2008). This combination of factors creates the base of this investigation.

1.4 Aim of Investigation

The aim of this investigation is to identify the critical issues concerning production lead time for contract apparel manufacturing supply chain, analyse the reasons behind delay in lead time, evaluate different improvement options, and suggest easy to use rationale-driven practical solutions.

1.5 Principal Objectives of the Research

In overall furtherance of achieving the stated aim, this paper has been subdivided into several sections. The objectives assigned devolve from the overall aim, as mandated by the splitting up of the subject into segments. These are as listed infra:

1. To develop a full understanding of the Indian apparel export manufacturing industry and its supply chain network.
2. To analyse the variability of processes within the network and develop best practice methods.

3. To evaluate and measure delay-contributing activities in manufacturing cycles, analyse the reasons behind such delay and suggest means of reducing it.
4. To identify and evaluate value-added and non-value-added activities in the manufacturing cycle.
5. To evaluate the applicability of different optimisation techniques to reduce lead time in the manufacturing supply chain.

1.6 Rationale and Scope

While some applied research had taken place in Europe (Apparel & Textile Challenge 1997, JBA 1998) and USA (JBA 1998) in demand-supply performance measures in the chain, such as Demand Activated Manufacturing Architecture (Chapman *et al.* 2000), the core manufacturing and related areas remained largely unexplored. Research in the Indian apparel and textile supply chain is still at a nascent stage. With the Indian apparel and textile industry constituting about 15 percent of industrial production, four percent of the GDP and 17 percent of the country's export earnings, this research has tremendous importance in the emerging Indian economy.

Previous research in Europe and US tended to be either from a retailer's perspective, wherein manufacturing functions were generally executed somewhere in developing countries (Asia, Eastern Europe, Africa or the Caribbean Islands), (Kapuge and Smith 2007), or from a large manufacturer's perspective, wherein the manufacturer actually acted as an importer for offshore manufactured goods (Bragger 2004), (Abernathy *et al.* 1999a), (Forza and Vinelli 2000), (Popp 2000). In both cases, details of manufacturing activities were missing. While product development activity is explored and analysed in retail and design perspectives (e.g. Collaborative Planning Forecasting & Replenishment Initiative), the prototyping and approval aspect was completely missed. A lot of emphasis was placed on correct prediction of demand by analysing and sharing point of sale data. Lead time reduction was limited up to product development in the upstream functions and visited from non-technical approaches like trust and partnership, the core activities in a fully factored or cut-make-trim manufacturing environment were largely missing.

The current research is focussed on the activities of the Indian apparel manufacturer exporter engaged in cut-make-trim or fully factored manufacturing. Though the specifics pertain to the Indian apparel manufacturer exporter, it is expected that the generic principle would be applicable for any apparel manufacturer exporter in South Asian countries where circumstances in the field of apparel are similar.

The scope of research is the manufacturing domain, primarily because very little work has been done globally on the manufacturing area of apparel supply chain and virtually no work is being done on the pre-production area of the Indian apparel manufacturing industry. In the outsourced manufacturing scenario in apparel, the total supply chain is decoupled and may be divided into three sections: first, design and concept development; second, sourcing and manufacturing and third, shipping, warehousing and retailing. Geographically, the first and third sections are still being done in the importing country (typically developed countries) and the second section, i.e., sourcing and manufacturing is done in the exporting country (typically underdeveloped or developing countries). Extant literature tends to emphasise the first and third sections, whereas negligible insight is available to sourcing and manufacturing by contract manufacturers. From the contract manufacturers' perspective, they have direct control over activities after a confirmed/ prospective order is received till the merchandise is shipped out of the factory. To impart value to the output of this research insofar as contract manufacturers are concerned, it is essential to study the second section (sourcing and manufacturing) in depth and explore opportunities to reduce manufacturing lead time.

After the abolition of WTO's Agreement on Textiles and Clothing (ATC) with effect from 01 January 2005, categorisation of the Indian apparel industry into domestic and export became insignificant. Now there are many cases of the same organisation producing for the domestic as well as export market. Indian retailers like Big Bazaar, Westside, Lifestyle, and brands like Blackberrys are already sourcing merchandise from countries like Bangladesh and China. Such phenomena will compel Indian organisations to increase their supply chain efficiency by reducing lead time to compete with global brands. Research in apparel and textile supply chain focussing on reduction of lead time and improving overall operational efficiency by reduction of non-value added time and finally, benchmarking against global competition holds out the promise of tremendous benefits for domestic as well as export apparel manufacturing organisations in India.

1.7 Research Design

1.7.1 Literature Survey (Secondary Data)

The evolution of supply chain as a concept has been studied by contemporary researchers like Forrester, Burbidge, Towill and others, while background research on concepts and different supply chain models that are prevalent in apparel and textile and other industries has been addressed by leading researchers like Macbeth, Christopher, Porter, Harland, Schonberger, Gattorna, Womack, Jones and others (see bibliography). Global apparel trade was studied from Gereffi, Dickerson, Jones and agency websites like ITC, Geneva, UNIDO, WTO, Indian and US Govt. websites and magazines like Textile Outlook International, etc.

The Indian apparel industry, its development and characteristics was studied from Khanna, Koshy, Raman, several organisations or institutions like Apparel Export Promotion council (AEPC), Indian Institute of Foreign Trade (IIFT), and National Institute of Fashion Technology (NIFT), reports and leading trade magazines like ApparelOnline.

Current research in apparel and supply chain management areas was studied from journals like Journal of Fashion Marketing and Management, International Journal of Operation and Production Management, Supply Chain Management: An International Journal, International Journal of Clothing Science and Technology, International Journal of Logistics Management, International Journal of Physical Distribution and Logistics Management, International Journal of Logistics Management. Reports from Apparel and Textile Challenge, Industry Forum (UK), Sandia National Laboratories (US), Kurt Salmon Associates, $[TC]^2$, Council of Logistics Management, etc. Conference papers from Textile Institute (UK), dissertations at Nottingham Trent University (NTU), (Indian Institute of Technology (IIT), and National Institute of Fashion Technology (NIFT) as well as internship reports at the last named Institute.

Current market development on the ibid subjects is available from e-journals like Just-Style (www.just-style.com), Supply Chain Council (www.supply-chain.org), APICS.org (www.apics.org), Techexchange (www.techexchange.com), and Journal of Textile and Apparel, Technology and Management (www.tx.ncsu.edu/jtatm/). Market research organisations like Karabas Management System, David Rigby Associates, Mintel, World Trade Organisation were studied to understand the retail scenario and current developmental trends. Catalogues, brochures and white papers from software solutions providers like SAP, i2 Technologies, Justwin, Manugistics, JD Edwards, Lawson, Geac etc. were read. Research databases like Emerald, Ebsco, Google Scholar and Google e-book were used extensively to refer to books and peer reviewed articles.

Besides background knowledge from literature, there was innate awareness stemming from involvement with the Indian clothing industry as a Professor of Garment Manufacturing Technology department at National Institute of Fashion Technology (NIFT), India. Background knowledge also allowed for additional research sources to be applied during this research through the means of internship and industry-linked assignment. Current knowledge was also gathered through the alumni circle in India and South East Asian countries.

1.7.2 Primary Data

Initial cross sectional researches were conducted through questionnaires, case studies and focus group reviews. This helped to clarify research issues, cross check different views and acted as a prelude to focussed longitudinal research. Longitudinal study was carried out to identify and measure value added and non-value added time in pre-production activities, and to study the applicability of different optimisation techniques to reduce lead time from the manufacturing cycle. As the researcher had easy and fruitful access to Indian apparel manufacturers, focus groups were used frequently to understand the key issues from senior executives; case studies were used under full management support to test-pilot new concepts and also share results with other manufacturers for critical review. As the researcher was an instructor in NIFT, students were assigned to monitor and follow up some cases at an organisation's site, thereby enabling better breadth and depth and the facility to carry out experiments on multiple samples during the research.

1.8 Research Publications

Some of the work included in this thesis has already been published during the extended period of the research.

- In 2001, an article titled 'Supply Chain Dynamics in Indian Apparel Export Manufacturing: How Much Do We Understand?' based on case studies was published in two different trade journals in India, namely Clothesline and Apparel.
- During 2001-02, an article titled 'Supply Chain Dynamics in Indian Apparel Export Manufacturing: Collaborative Product Development' based on a case study was published in three different journals; Clothesline, a print journal in India, Just Style (www.Just-Style.com), an international e-journal from the U.K. and Techexchange (www.techexchange.com), an international e-journal from the U.S.
- During 2002-03, an article titled 'Vendor Managed Inventory in Apparel Manufacturing" based on a case study was published in two different journals; Clothesline, a print journal in India and Just Style (www.Just-Style.com), an international e-journal from the U.K.
- A case study on critical chain implementation was the first time ever in the global apparel industry that such a theory saw application. One article titled 'The Critical Chain Approach to Apparel Production' was published in two international e-journals, Just Style (www.Just-Style.com) and Techexchange (www.techexchange.com) and Clothesline. Complimentary reviews and appreciation were received from industries in Turkey, Hong Kong, New York, among others.
- Role of Intermediaries in Apparel Supply Chain, at International Conference HPTEX 2004 on 7-9 July 2004 at KCT, Coimbatore, India.
- Papers were presented in an international conference on 'Innovative Approach in Apparel Manufacturing: Critical Chain' at North India Section of Textile Institute (NISTI) conference, New Delhi, India, in December 2004.
- The outcome of longitudinal research on supply chain measurement metrics was well accepted by industry and is currently being used by several organisations for testing its utility. A two part article titled 'Measuring Efficiency of a Supply Chain' was published

in Techexchange (www.techexchange.com), and one article in a print journal from India, StitchWorld (www.stitchworld.net), during 2007.

- One paper was also selected for presentation in the 1st Indian Supply Chain Summit in New Delhi, organised by India Supply Chain Council (http://www.supplychains.in/) on March 01, 2007.
- Another Paper, titled 'Integrated TNA in Apparel Merchandising' was presented in the 4th International Conference on Apparel & Home Textiles, ICAHT – 08, held in New Delhi between 26 - 27 September 2008.

1.9 Summary

As a global sourcing destination, India's core competencies are innovative and value-added merchandise with flexibility in production volume. Apart from being a contract manufacturer, India is trying to establish itself as full-service manufacturer. problems plaguing Indian export were mainly quality and delivery time related, out of tune with the global paradigm shift towards speed and replenishment sourcing of merchandise, leading to pressure from overseas retailers to execute orders in faster lead times, if it wanted to remain a global player in this field. While previous research primarily aimed from retailer's perspective, a research is need of the day for assessing supply chain requirements from a contract manufacturer's point of view to meet the increasing demand of quicker delivery from retailers. Research should address small and medium enterprises (SME) towards identifying a generic solution, implementable across organisations with minimal investment.

Chapter Two:

2.0 Literature Review

Literature from secondary sources are studied and analysed in this chapter in the context of research objectives. Material and information flow, different trading partners and different product development processes in apparel as well as other industries were studied. Different techniques available for identification of delays in a supply chain and different optimisation techniques available for lead time reduction were also studied and analysed in detail to select the appropriate research design and methodology.

2.1 Defining Supply Chain

Defining Supply Chain Management is a rather daunting task due to its dynamic nature and continuous evolution over the years. There appears to be little consensus on the definition of the term ‘supply chain management’ (New, 1997; Lummus *et al.* 2001; Mentzer *et al.* 2001; Kauffman, 2002). There is also a high degree of variability in people’s minds about what it meant (Kathawala and Abdou 2003). There are three almost similar terminologies: first, supply chain; second, supply chain orientation and third, supply chain management (SCM); the last one being most commonly used, extensively studied and referenced by researchers. Mentzer *et al.* (2001) called this a ‘phenomenon’ that exists in a business environment. In other words, a supply chain may exist, but may not necessarily be managed. For clearer understanding, a ‘supply chain’ will be defined first, followed by what supply chain orientation is and then what supply chain management is.

Supply Chain has been defined as an interconnected set of business processes and trading partners that manages the flow of goods and information from the point of design to the delivery of the product or service to the end customers (Kinaxis 1999). Another interesting definition is ‘A supply chain is a series of customer and supplier relationships that form an interwoven set of binding links in a seamless and integrated fashion delivering a high-level of customer satisfaction (Watts *et al.* 1999)’. A business need is multifaceted, where the complex interactions of many participants in different organisational groupings all have an impact on the eventual outcome.

Among numerous definitions put forward by authors from different perspectives, a definition by Marbert and Venkataraman (Marbert and Venkataraman 1998) aptly fits the apparel export manufacturing supply chain. It says 'Supply chain is the network of facilities and activities that performs the functions of product development, procurement of materials from vendors, the movement of material between facilities, manufacturing of products, distribution of finished goods to end consumers, and after market support for containment'. Whether supply chain is defined as a process/activities (Marbert and Venkataraman 1998) or a relationship (Watts *et al.* 1999), there are three aspects to every supply chain; first, upstream – those activities linking organisations to their suppliers; second internal - or primary activities of the organisation; third downstream – those activities link organisations to their customers (Nick 2001). Also, 'supply chain' is often correctly referred as 'supply network', because it describes more accurately the nature of supply relationship, which is non- linear flows, network like systems and a web of suppliers and customers (Jayaraman 1999, Rice and Hoppe 2001a, Christopher 2006a). A recent definition of 'supply network' says 'A network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users (Aitken 1998 cited in Christopher 2006a)'. Strangely, 'chain' signifies 'linear' and 'network' implies 'non-linear' flows, thus projecting an antithetic meaning; the phrase 'supply chain network' is also used in numerous documents (McCormack *et al.* 2002, Gattorna *et al.* 2003). However all three terminologies convey the same meaning in the overall context and in this document 'supply chain' will be used as a word.

The coordination of a supply chain from an overall system perspective with each of the tactical activities of distribution flows viewed within a broader strategic context is more accurately called a Supply Chain Orientation and actual control of this orientation across various companies in the supply chain is more appropriately called Supply Chain Management (SCM) (Council of Logistics management 2001). According to Roger Blackwell, a business professor at Ohio State University, Supply Chain Management is all about having the right product in the right place, at the right price, at the right time, and in the right condition (Stein and Sweat 1998). Mentzer *et al.* (2001) proposed a definition of supply chain management that is broad, not confined to any specific discipline and adequately reflecting the breadth of issues that are usually covered under this term:

"Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer et al. 2001).

SCM concepts are broadly classified into two groups: the 'soft' people-focussed constructs that deal with social relationships; and the 'hard' system-dominated constructs that deal with technological and infrastructural issues (Croom 2001; Power *et al.* 2001). The chain or network of activities adds value to the product as it flows downstream and thus the term Value Chain Management was coined. Value Chain Management is the process of maximising the flow of products, services and information from raw materials to the final point of consumption through a value-added chain of suppliers to meet or exceed the customer's expectations (Logility 2000).

SCM literature appears to be concentrated in a handful of industry sectors; namely consumer goods retailing, computer assembling and automobile manufacturing (Burgess *et al.* 2006). Conceptual representations of SCM have a large bearing on the nature of the definition and explain the expectations that organisations have of SCM. Confirming the inconsistency among researchers Burgess (Burgess *et al.* 2006) reported that a majority (57 percent) of the literature available framed SCM as some kind of process, about a quarter (24 percent) viewed SCM as a system, a smaller proportion (9 percent) saw SCM as a simple activity and the rest saw it as 'other' category. A process means where SCM was a chain of related activities; a system means where SCM was a series of related processes, loosely connected collection of concepts, networks and frameworks; an activity means where SCM was described as an individual function in a process; and 'other' category explained SCM as a deeper level of analysis that dealt with sociological, psychological and philosophical concepts. However closer analysis revealed that almost all literature discussed concepts concerning 'the flow of goods and information across organisations'

(Burgess *et al.* 2006), which reinstated the importance of goods and information flow in supply chain.

Literature supported the view that the integration of key business processes within and across companies that add value for customers and other stakeholders could be called SCM (Cooper *et al.* 1997; Bechtel and Jayaram 1997). Operations management literature also identified processes linked to SCM such as logistics, New Product Development (NPD), customisation and distribution of goods, including the balancing of demand needs and capacity requirements in the transformation of raw materials into final products delivered to customers (Lee 1993). Within the logistics discipline, Cooper and Ellram (1990) defined SCM as an 'integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user'. Both Harland (1996) and Christopher (1998) reached another conclusion; instead of managing flows, SCM was seen as the management of a network. Harland (1996) defined SCM as 'the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers'. Rather than looking at SCM as the management of a vertical pipeline of inter-linked firms, Harland (1996) considered SCM as management of a complex network of organisations involved in exchange processes. Some scholars (e.g. Christopher 1998; Heikkilä, 2002) also suggested that 'supply chain management' should really be termed 'demand chain management' to reflect the fact that the chain is driven by the marketplace to satisfy the needs of the end-users. Although different researchers talked about several distinct yet interrelated flows in a supply chain like ownership flow, payment flows (Paik *et al.* 2007), financial flow and physical flow (Bussler and Haller 2005), human flow and cash flow (Nguyen *et al.* 2007), the two important flows that drives the supply chain from the point of view of this research are material flow and information flow (section 1.1).

2.1.1 Information Flow in Supply Chain

Information is a key ingredient in making good supply chain decisions in all three levels of decision making, i.e. strategic, planning and operations and each of the supply chain drivers, i.e. inventory, transportation and facilities. Macbeth and Fergusson (1994) classified the range of information flows into four major categories, technical, involvement, business and people. The Technical category covered detailed specifications of what was to be supplied in accurate media, while the involvement dimension accounted for measurement and feedback processes on performance and degree of involvement in the other party's decision-making processes. Business communication covered aspects of relevance to the other party (in future) but was not immediately key to current activity; the people aspects recognised the need to signal personnel structures and role changes. As explained in Chapter One, information flows both ways in a supply chain. While the market information flowed upstream from the marketplace, a second important flow of information, called fulfilment information (Popp *et al.* 2001), flowed downstream. Fulfilment information detailed the progress of suppliers in meeting orders. Logically, if the order information decoupling point was to be positioned as far upstream as possible, then the fulfilment information decoupling point needed to be positioned as far downstream as possible. In other words, undistorted information about fulfilment needed to be available in timely fashion throughout the supply chain (Popp *et al.* 2001). Mason-Jones and Towill (1999c) demonstrated through simulation that moving the information decoupling point as far upstream as possible, by ensuring access to undistorted market order information to all members of a supply chain, had beneficial consequences for the supply chains as a whole. However, they also went on to note that in many supply chains, only the player closest to the end customer had the luxury of knowing the true demand because the information decoupling point was traditionally at the marketplace or with the retailer. As a consequence of the traditional attitude that *information is power*, companies deliberately distorted order information to mask their intent not only to the competitors, but even to their suppliers (Pagh and Cooper 1998).

Information Distortion: The Bullwhip Effect

As a rule of thumb, based on a number of supply chain studies, the demand amplification experienced is about 2:1 across each business interface. Hence, in a typical traditional chain involving retailer - distributor - original equipment manufacturer (OEM) - sub-assembler - raw materials supplier, the latter could be bombarded with swings 16:1 bigger than the marketplace. In consultancy practice this highly undesirable phenomenon was frequently explained by reference to the 'Forrester flywheel effect' or 'bullwhip effect' in which every 'player' over-ordered against uncertainties in both the marketplace and the supply chain.

The term ‘bullwhip effect’ was first coined by the logistics executives of Procter and Gamble (Lee *et al.* 1997) when they experienced extensive demand amplifications for their diaper product ‘Pampers’. It is so-called because small order variability at the customer level amplifies the orders for upstream players. The first research to extensively study the amplification of demand information in a supply chain was reported by Forrester (Forrester 1961) while an empirical study of industrial dynamic control problems was done by Van Aken (Van Aken 1978 cited in Fransoo *et al.* 2000). While studying the causes of this demand amplification, Forrester identified two types of delay, namely the delay of transferring demand information and the delay of transferring physical products through the supply chain (lead time). While Sterman (1989) argued that the bullwhip effect was caused by irrational decision making of participants, Lee (1993) no longer blamed the irrational behaviour of decision makers for the bullwhip effect. Instead, they thought that the bullwhip effect was a consequence of rational behaviour given the supply chain structure and its related processes (Lee *et al.* 1997). Lee had discussed four possible causes of the bullwhip effect: demand forecast updating, order batching, price fluctuation, and rationing and shortage gaming. Demand forecast updates suggested that demand amplification occurred due to the safety stock and long lead time. As orders were forecast and transmitted along the supply chain, safety stocks were built up, and thus the bullwhip effect occurred. Towill and his co-authors studied the bullwhip effect by using a computer simulation model (Towill, 1991; Evans *et al.* 1993; Mason-Jones and Towill, 1999c; Towill and McCullen, 1999). As a benchmark, they used the Forrester's simulation model comprised of a retailer, a distributor, a factory warehouse and a factory. The results of their studies indicated that information and material delays might be major contributing factors to the bullwhip effect. When the authors eliminated the time delays in the model, the demand amplification was significantly reduced. This result led to the argument that both material and information delays could be possible causes of the bullwhip effect. Along with this, they argued that the removal of one or more intermediaries led to the significant reduction of the bullwhip effect. This argument was also reinforced by Ackere *et al.* (1993) and Hong-Minh *et al.* (2000). Although recent work (Disney and Towill, 2003a; Dejonckheere *et al.* 2003) showed that the bullwhip effect is not avoidable under order-up-to replenishment policy whatever forecasting method is used, articles of Disney and Towill (2003b, c) discussed the impact of vendor-managed inventory (VMI) system on the bullwhip effect. Their analysis showed that, by implementing the VMI supply chain, both rationing and order batching effect might be completely eliminated.

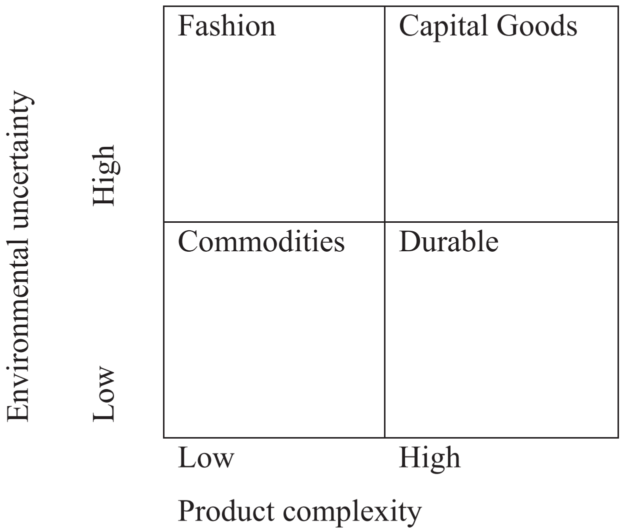
The shrinking profits for apparel manufacturers at the expense of retailers' stable margin over the last decade could be explained by this theory linked with the theory projected by Hayes and Wheelwright in 1984, who described how demand volatility damaged profit upstream. Paik (Paik *et al.* 2007), observed that when all nine possible causes of the bullwhip effect were present in the simulation models, the following six factors were statistically significant: demand forecast updating, order batching, material delays, information delays, purchasing delays and level of echelons. Among these six factors, demand forecast updating, level of echelons, and price variations were the three most significant.

2.1.2 Material Flow in a Supply Chain

Material flow downstream in the supply chain ultimately reached the customer; however, material types were very important. There are several way material types are classified; fashion, commodities, durable and capital goods (Westbrook and New 2004) or fashion, seasonal re-order product, and the perpetually replenished item (Abernathy *et al.* 1999a). The role of product uniqueness (the fashion content of the merchandise) had several critical implications on three parameters; the extent of information and knowledge sharing, cost transparency and sharing of resources between actors within the chain (Fisher 1997).

The nature of the material flow, and the complexity relating to it depended on the existing type of supplier-customer interface. The different types of interfaces are single sourcing, preferred supplier agreements, tiered supplier interfaces, outsourcing sub-assemblies and contracting out services (Westbrook and New 2004).

Figure 2.1 Product Type



Source: Puttick 1994 cited in Westbrook and New 2004

These sourcing policies worked to reduce the overall complexity of the system either through simplification or by paying a premium to some external party for managing the unwanted uncertainty.

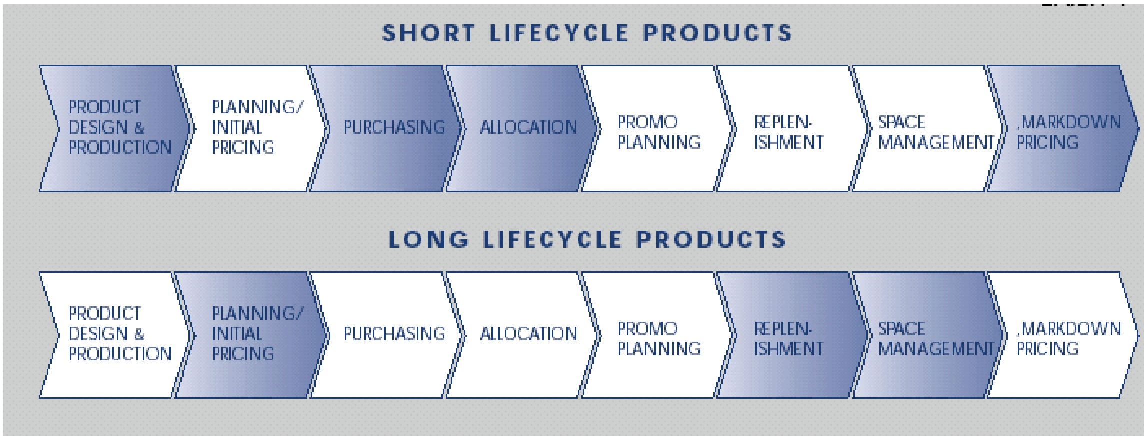
Different types of merchandise required different supply chain approaches. Merchandise could be classified into three categories (Oxborrow 2000, Abernathy *et al.* 1999c). The 'fashion item' was one which the customer was unlikely to find in his next visit. Second was the 'seasonal re-order product', in which the consumer would be able to come back and buy more, and the third category was the 'perpetually replenished item', which one would expect to always find on the shelf. The fashion triangle (Abernathy *et al.* 1999c) showed how the basic item constituted the base of the triangle with higher share and fashion item constituting the tip of the triangle. Figure 2.2 also shows how the demand uncertainty at SKU level increases with increasing fashion content. With each type of merchandise one needed to continuously review the order frequency, forecasting approach, material purchase and stock holding, finished goods stock levels, batch/lot size, lead times, etc. to see where improvements could be made. For any reduction in lead times to be effective, one needed to make staged commitments and share the risk, starting with capacity and raw materials.

Figure 2.2 The Fashion Triangle

Source: (Abernathy *et al.* 1999c)

Short lifecycle products and long lifecycle products have different priorities or pain points (Karabas and Granovsky 2003) in managing a supply chain. According to Karabas and Granovsky (2003), retailers selling short lifecycle products like fashion and seasonal should concentrate on areas like assortment, allocation, promotion planning and markdown management, whereas retailers selling long life cycle products, e.g. commodity clothing, classic styles should focus on replenishment, initial pricing, promotional planning and store space management.

Figure 2.3 Short Lifecycle Product and Long Lifecycle Products



Source: Karabas and Granovsky 2003

Traditionally, commodity products really driven by brand/value, like underwear, socks, T-shirts, jeans, etc. used to be dominated by the large corporations, who operate super-efficient supply chains, whereas the smaller companies dealt with fashion-oriented merchandise, where perhaps super-efficient supply chains and cost weren't the driving reasons for being in business (Bobbin 2000). However, in the recent past, Zara proved the concept wrong. Zara is a $ 1.6 billion turnover fashion retailer with 500 stores across 58 countries, but manages very efficient and flexible supply chain through own production units in Spain, and manages 20-30 days design to sales cycle time (Watson 2002).

2.1.3 Fashion / Clothing Market Demands

The interdependent relationship of merchandise type and market demand was, essentially, the business driver of cost and time. From the moment when decisions were made about sourcing and procurement of material through the manufacturing to the final distribution and after-market support, logistics lead time management (Christopher 2006a) gained utmost importance. Originating from the manufacturer, there were three channels of distribution of goods to the customer (end user); first through distributor/wholesaler and retailer, second only through the retailer and third, direct to customer (Gattorna 1998b). Various formats of these three distribution channels are listed in table 2.1.

Table 2.1 Merchandise Distribution Channels

Type	Formats
Manufacturer > Distributor/Wholesaler > Retailer > Customer	Buying consortium, One step distribution, Two step distribution
Manufacturer > Retailer > Customer	Mass merchants, clubs, convenience stores, chains, corner stones, speciality retailers
Manufacturer > Customer	Mail order, Internet/web, phone orders, TV shopping channel, direct marketing

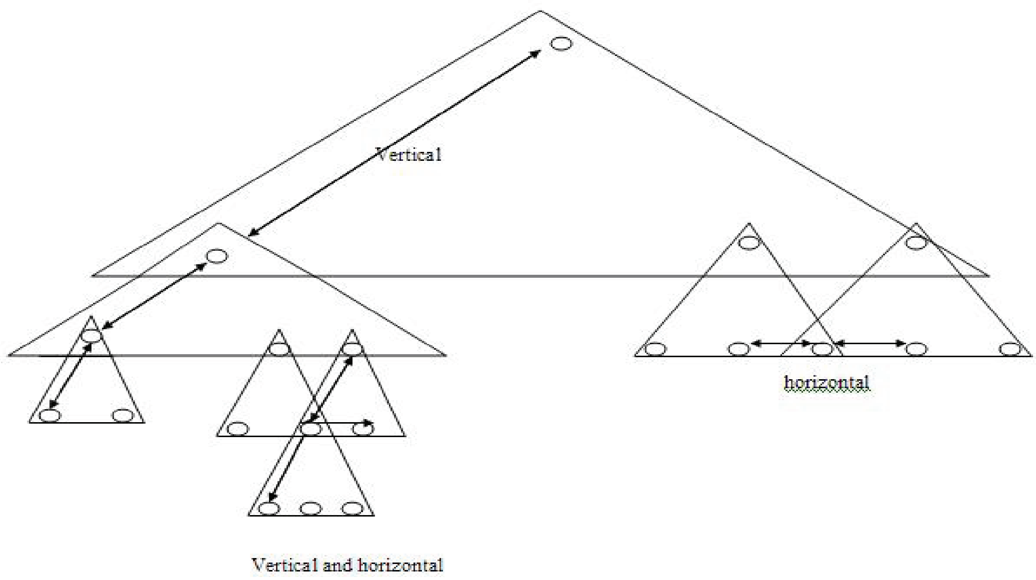
A retailer able to provide a range of shopping experiences through a variety of channels was poised to grab a larger share of the customer's wallet than a single-channel retailer. (Lewis *et al.* 2001). In an effort to maximise returns, everyone was trying to break stereotyped patterns. Abernathy (Abernathy *et al.* 1999d) identified two trends that created problems for the traditional retail model; firstly, product proliferation and secondly, dramatic expansion of total retail space, which revealed the costs inherent in the traditional retail model.

Three types of costs were found to be high in the traditional retail distribution model; forced markdown to clear out unsold goods, lost sales from stock outs, and the costs associated with holding inventory. Lean retailing concept holds a promise for the future as it minimises or replaces inventory with information (Abernathy *et al.* 1999a) as a competitive strategy and relies on a smaller number of suppliers.

2.2 Supply Chain Structure and Trading Partners

Different trading partners in the supply chain, their types, roles and responsibilities, relationship between them (conceptual structure) and flows (physical structure) determined the efficiency of the supply chain. A generic model of supply chain described by Likert (Figure 2.4) showed an integrating structure which had 'linking people' assisting the free flow of information both vertically and horizontally within the organisational system (Likert 1997 cited in Massey 2000).

Figure 2.4 Generic Model of Supply Chain



Source: Likert 1997

The classification of SCM could be from a conceptual angle (Gereffi 1999), (Burgess *et al.* 2006, Fisher 1997, Yeung *et al.* 2007) or a structural angle (Rice and Hoppe 2001c, Hines 1994); the conceptual classification dealt with the constructs and structural classification dealt with the linkage of different echelons in the network.

2.2.1 Conceptual Classification

A Supply chain can be classified either based on relationship (Yeung *et al.* 2007, Burgess *et al.* 2006), product type (Fisher 1997), or market drive (Gereffi 1999 cited in Tyler *et al.* 2006). According to Yeung, the relationship between an organisation, its supplier and its customer could be divided into three categories. Monopolistic was where a single company owned nearly the entire market for a given type of product or service; in an oligarchy, a few or a small exclusive group of companies ruled the market, and a free market was open to all for free competition. Apparel manufacturers, who trust only a few buyers closely and deal with limited retailers, but source raw material from many suppliers depending on variety required, are classified by Yeung as oligarchy-loose-oligarchy-close (OLOC). Large manufacturers with strong product specialisation, like lingerie manufacturers, who generally trust a few large raw material suppliers closely but have no implicit connection with any particular customer and can therefore supply to any customer are classified as the oligarchy-close-oligarchy-loose (OCOL). Due to retailer domination in the apparel industry, the OLOC type would be more common amongst apparel manufacturers.

Burgess's (Burgess *et al.* 2006) classification talks about a set of seven constructs: leadership, intra- and inter-organisational relationships, logistics, process improvement orientation, information system, and business results and outcomes. 'Leadership' captured the strategic nature of SCM and the need for the senior management team to be proactively involved; 'intra- and inter-organisational relationships' focussed on the nature and type of social and economic associations between stakeholders both within and between organisations; 'logistics' described the issues associated with movement of materials within and between entities in a supply chain; 'process improvement orientation' facilitated interactions within and between organisations, with a view to continually improving them; 'information system' covered aspects of communication both within and between organisations and 'business results and outcomes' captured performance related outcomes that accrued to organisations from adopting strong SCM orientation.

Product based classification talks about innovative products (e.g. *fashion merchandise*) and functional products (*perpetually replenished merchandise*). While a supply chain for fashion product needed speed and flexibility, or agility, as their primary concern, chains for functional products had to be lean and cost efficient, since volatility of specification and demand was low.

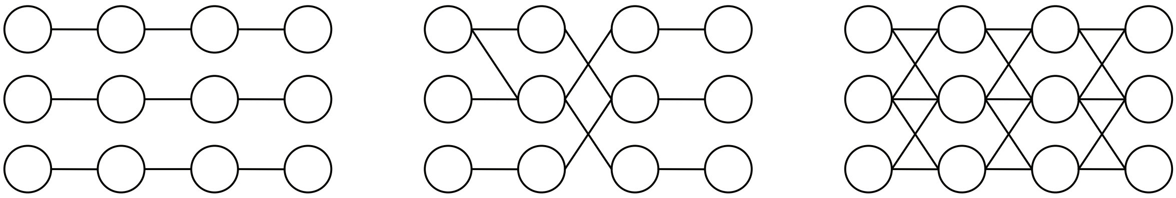
Gereffi's market drive theory talks about whether the chain is upstream controlled (producer driven) or downstream controlled (buyer driven). During the 1960s, textile supply chains were producer driven; large fibre producers (Du Pont, Courtaulds, etc.) indirectly used to influence market directions (Rigby and Bryne 2000). However during the '80s and '90s, significant power shifted from manufacturers to retailers because of consumer patronage (Drucker 1992). Clothing, shoes, office supplies, toys, etc. were classified as buyer driven, whereas automobiles, aircraft, computers, heavy machinery, etc.

were producer driven. Gereffi (1999 cited in Tyler *et al.* 2006) noted that profits in buyer-driven chains are derived not from scale, volume and technological advances as in producer-driven chains, but from unique combinations of high-value research, design, sales, marketing and financial services that allow the retailers, branded marketers and branded manufacturers to act as strategic brokers in linking overseas factories with evolving product niches in the main consumer markets. In the apparel supply chain, the relationship-based classification really did not apply as, unlike automobile and aircraft manufacturing, the apparel industry sold to a free market. In the case of Indian manufacturers, the supply was buying-house driven and because India's strength lay in valued added fashion merchandise (Koshy 1995, Chandra 2005), the supply chain needed to support quicker lead times. To a certain extent, the Indian supply chain was flexible (Jana 2000) due to concentration of small and medium entrepreneurs and use of outsourced capacity in production.

2.2.2. Structural Classification

Under structural classification, the supply chain is classified based on flow pattern and presence of echelons in the supply chain. There are tier systems (Hines 1994), network systems (Rice and Hoppe 2001c), and systems based on the virtual shape of the network (Macbeth and Fergusson 1994). The Japanese automotive network works with a tiered system, where the assembler is the customer for the first tier supplier (and would normally be concerned with only the first tier); the first tier supplier is the customer for the second tier supplier and would control them and so on. A network's main components of actors, resources and activities are linked and form a 'dependency' on each other, the ultimate goal being to deliver effective product or service. This seamless link is either described as 'network sourcing' (Hines 1994) or 'partnership sourcing' (Macbeth and Fergusson 94). Shapes of networks vary based on product type, flow of goods and information, etc. A completely disconnected network is vertically integrated; partially overlapped and completely overlapped are horizontally spread and generally fits apparel. However Zara is a good exception as it has a completely disconnected network.

Figure 2.5 Classification of Supply chain

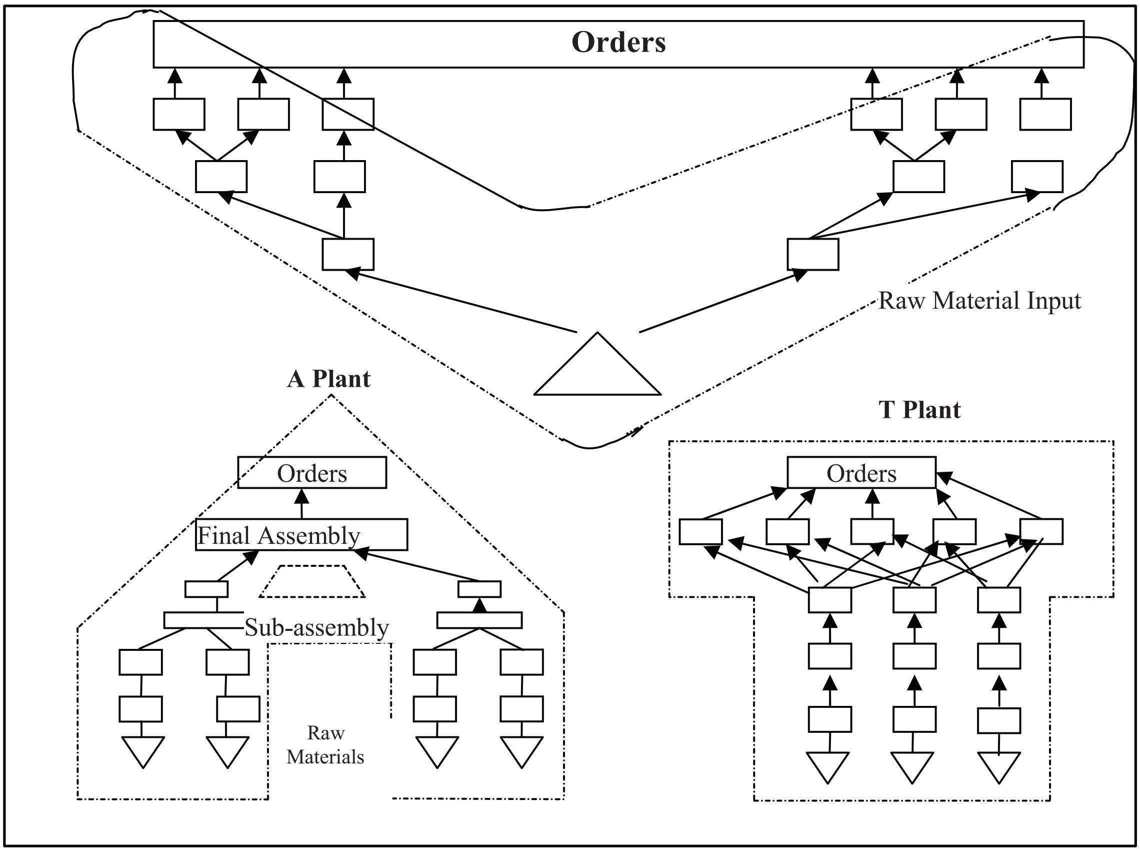


Completely Disconnected Networks	Partially Overlapping Network	Completely Overlapping Network
Highly vertically integrated manufacturers-retailers such as Zara in fashion apparel.	Limited vs. branded apparel products from Levi's sold through retailers.	Private label apparel retailers that source from contract or FOB manufacturers in Southeast Asia.

Source; Rice and Hoppe 2001c

Macbeth and Fergusson classified supply chain based on the virtual shape of the network (Macbeth and Fergusson 1994). The four classifications are I-V-A-T, where the letters suggests the virtual pattern of inter-organisational material flow. The 'I' shape is the unidirectional vertical enterprise. A 'V' shaped network starts with limited raw material at the input stage and a wide variety of finished products with product variety determined early in the transformation process. Examples are textile fibre, metal fabrication, etc. An 'A' shaped network has numerous raw materials at the input stage with limited variety of finished products, e.g. aerospace and food retail. A 'T' shape tries to keep a simple flow path until the latest possible moment before suddenly branching out into a wide variety of finished products, e.g. in electronics and home appliances. The 'T' shaped network is favourable from the supply chain management point of view, since the decision on the final product specification is delayed till the end, thereby supporting fast response to varying demand of customers (Macbeth and Fergusson 1994). However due to multi-sourcing practice when the apparel and textile supply chain is compared with automobile supply chain, both can look alike, as 'A' shaped, due to similarity with the tier manufacturing concept.

Figure 2.6 V-A-T Supply Chain



Source: Macbeth, D.K. and Ferguson, N. 1994, pp 65

Even single-sourcing offers great benefit in quality consistency (Macbeth and Fergusson 1994). However, the final retailer may have to deal with multi-sourcing if various products are not available from one vendor. Multi-sourcing is also inherently more expensive in administration costs than single-sourcing (Macbeth and Fergusson 1994). Sharing of information without any diminution across a wide area of activity does not prevent one continuing to use it, but sharing information between two competing entities can be problematic (Macbeth and Fergusson 1994).

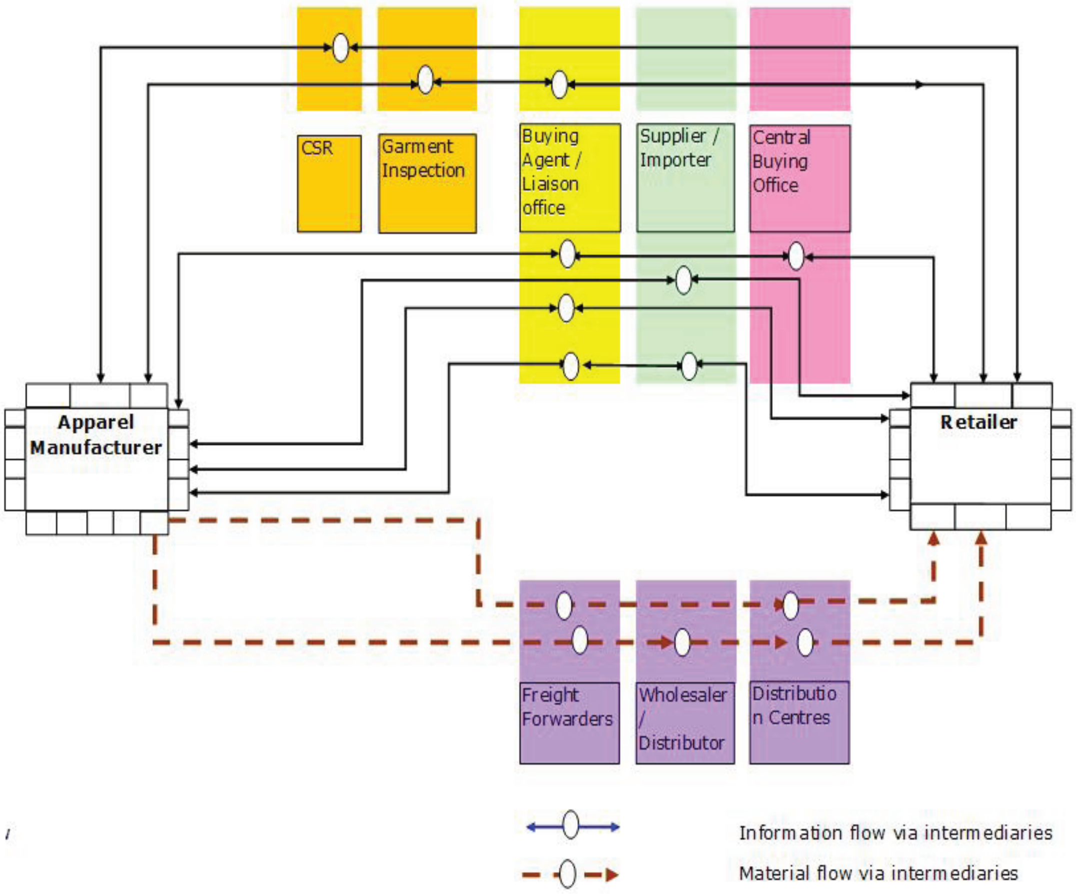
2.2.3 Supply Chain Structure for Apparel Manufacturing

The generic apparel and textile supply chain (Figure 1.1 in section 1.1) depicts a structure of intra-company organisational units and extra-company agents and dealers, wholesale and retail, through which a commodity, product or service is marketed. Specific apparel and textile supply chain (Figure 1.2 in section 1.2) structure can be viewed as systems of relationships between trading partners that are engaged in fibre, yarn, fabric and apparel manufacturing with wholesale-retail services supported by nominal trading partners like trim suppliers, testing houses, freight forwarders, etc. to deliver the merchandise to the ultimate consumer. As the scope of the research is mainly contract apparel manufacturing, the supply chain structure between three trading partners, namely fabric manufacturing, apparel manufacturing and retail are studied in depth.

Figure 2.18 shows the supply chain typical for contract apparel manufacturing. There are two sections; while the upper section show the flow of information, the lower section shows the flow of goods. In the information flow channel, there are three nominal trading partners; buying agent/liaison office, supplier/importer and central buying office. In the material flow channel again there are three nominal trading partners; freight forwarders, wholesalers/distributors and retailer's Distribution Channel (DC). In the information channel, there are three other nominal trading partners, who are third party (independent body) inspection or quality / compliance enforcement agencies. While explaining the role of testing houses in the apparel supply chain Popp (Popp *et al.* 2001) commented… "The testing house, whilst valuing and protecting its independence and loyal to a culture of scientific objectivity, occupies an ambiguous position in many clothing supply chains; it can be a locus for the generation and transmission of data of considerable value and a site for mediation of a conflict between quality control as a science and quality control as a business function".

The different ways a contract manufacturing supply chain works (retailer can source merchandise from manufacturer) depends on three factors: retail DC, product types, sourcing types and 'non-cost' factors (Walwyn 2002), like political situation, language/cultural barriers, raw material supply, etc.

Figure 2.7 Contract Manufacturing Supply Chain



While Koshy tried to classify the supply chain based on product and market, here an effort has been made to first generalise the different trading partners and then their respective positions in the supply chain. Different combinations of the supply chain work by triggering different trading partners on or off. In Figure 2.7, there are four different options of information flow between retailer and manufacturer involving one or two nominal trading partners in between; similarly, there are two options of material flow channel when goods are shipped. So there are eight (four multiplied by two) different procurement channel options. Similarly there are options of inspection and compliance too. For example, one retailer may procure via retailer-central buying office-liaison office-manufacturer route (for example, Gap Inc. for India), while the second retailer procures through the retailer-liaison office-manufacturer route (for example, H&M for India).

From the country perspective, it is important to note that while an importer or central buying office is located in the same country as the retailer, the liaison office/buying agent is located in the manufacturer's country. Similarly, in a material flow channel, freight forwarders are located in the manufacturer's country and wholesaler and DCs are located in the retailer's country.

Information flow in the supply chain shows garment and raw material inspections were routed through the buying agent and/or liaison offices, but the compliance function may totally bypass the in-between nominal trading partners and establish direct communication with the manufacturer. Every manufacturer/retailer must identify the key players (the nominal trading partners) in terms of demonstrated skills, developed tools and depth and breadth of relationship with the next trading partner in the chain. Once roles and investments are determined, the supply chain can maximise economic value for the each market segment. (Gattorna 1998c).

2.2.4 Nominal Trading Partners and Intermediaries in Supply Chain

Intermediates or intermediaries or agents can be defined as firms whose principal role is to handle information flows rather than material flows. Although Van Hoek (Van Hoek 1998) suggested that supply chain management address interfaces at the functional, geographical and organisational level, the crucial issues of interface and intermediaries are subjected to general neglect in supply chain literature. Intermediaries are specialist carriers of information costs. They improve communication between buyers and sellers by acting as a hub. Intermediaries are able to economise on information costs because specialisation allows them to reap economies of scale, scope and learning. Using information, they are able to integrate markets over space and time, adding value by improving co-ordination. The ability of intermediaries to economise on information costs is a two-stage process. First, through specialisation, learning and cross subsidisation, their costs of collecting and analysing information may be reduced. These can be particularly important where distance and culture impose a barrier to communication. Second, by collating and synthesising collected information, they can improve the quality and reduce the quantity of information (thus reducing the number of points of contact). Migration of manufacturing enterprises from developed countries (place of consumption) to newly industrialised economies has increased the scope of the role played by intermediaries in the global supply chain. Casson states, “Market making intermediation is one of the most important sources of added value in the entire economy” (Casson 1997a).

In this context, merchant apparel exporters (Raman 1995), specially in NCR in India cannot be termed as intermediaries; instead, they can be compared with the *impannatore* of Italy (Casson 1997b), where entrepreneurial merchants co-coordinate the dispersed subcontracting network by importing necessary raw materials for the manufacturers (subcontractors) and finally exporting the finished goods. Conversely, intermediations are also a potential barrier to greater transparency in the supply chain and might be seen frequently as a non-value added activity.

The evidence of intermediaries in the textile and clothing industry exists way back in nineteenth century; the cotton industry of Lancashire, England was dependent on a dense web of merchants and brokers for its pre-eminence in the world market (Popp 2000). Casson identified five main tasks undertaken by market making intermediaries, namely search, specification, negotiation, completion and enforcement (Casson 1997b). While the search function included identifying additional capacity, better price and new products for a buyer, it also gathered market intelligence regarding expansion and collaboration sales trends for the manufacturer. Specification included comprehension and interpretation of data and messages to overcome language and cultural barriers. In a partnership environment, completion encompassed helping buyer and supplier achieving milestones and even financial help like opening Letters of Credit (LC) on behalf of a buyer. Large intermediaries also offered value added services like multi-country costing to enable a buyer to decide where to source. The function of intermediaries varied from ‘dictator’ to ‘handholding’ approach depending on the scenario, with the primary objective of getting the work done.

With fewer companies remaining vertically integrated, sourcing became an important function and some companies outsourced their interactions with the supplier network. Outsourcing suggested benefits such as elimination of holding cost, lower ordering cost, no inventory management, better service level by vendors (Lawrence *et al.* 1999) for selective commodity products (Tedesco 2000). Tedesco explained that it was unlikely to bring any benefit for custom products due to cost reduction tending to be superficial as intermediaries passed on the same as their fee for service and made it difficult to believe customer service could be better through a intermediary (Tedesco 2000). From the above analysis, it was clear that intermediaries added value as specialised knowledge and information providers to achieve economies of scale or scope in the business. Wherever they acted merely as middlemen, they only added cost with no countervailing value-addition, leading inexorably to their demise (Bhat 2002, Gupta 2004).

Whether any intermediary added value or cost to the supply chain was decided by many factors. For example, an importer who procured in bulk from an overseas manufacturer and stocked close to a retailer bore forecasting risk. For fashion garments an importer could add value (as that merchandise could be procured by a retailer in zero lead time) and for basic garments it could add cost (as that merchandise could be procured by a retailer with a longer lead time). Again, for small retailers the same importer could add value (as a retailer may not afford direct procurement due to small scale of operation) but to a large retailer, it was only addition of cost (as the large retailer could procure directly). It was also observed that all nominal trading partners might not perform all five tasks, for example fibre and cloth merchants had no role in enforcement but testing laboratory had an important role in enforcement. Casson classified the role of intermediaries under five different task heads: search, specification, negotiation, completion and enforcement (Casson 1997b) for possible value addition and/ or cost addition in the whole supply chain.

Intermediation could reduce communication cost but increase distortion in communication. It could add to the cost of collecting information but improve the quality (thus value) of information. Intermediaries aided in completion of tasks, but behaved as overheads in transactions. While an intermediary could add value, the question remains: was it value for money? Scale of operations and market awareness was inversely proportional to requirements of intermediaries. Intermediaries held more information than required by trading partners, thus becoming the common person for more than one trading partner in the supply chain, thus providing ‘value for money’ by balancing capacity of tasks. For example, an intermediary, with knowledge of the Indian market, was acting as a trading partner of a retailer from the EU sourcing ladies wear from India. Gradually that intermediary would have gained additional knowledge about Indian manufacturers making other products (say, kids' wear) depending on exposure. Thus the intermediary would gradually hold more and more kids' wear knowledge (which was not required by his trading partner). Then he could become a trading partner of another retailer looking for sourcing kids' wear from an Indian manufacturer.

Buying houses, liaison offices/importers played a very controversial yet important role in the procurement channel. Their role as intermediaries evolved over the years. The role of intermediaries in the Indian scenario was summed up as:

"30 years ago...the buying office function was primarily one of 'order follow up i.e. completion; quality check, i.e. enforcement. Factory and vendor evaluation, i.e. search and negotiation was slowly added and the search was widened to include product availabilities. Presently the criteria of a good versus an average buying office/agent are where product development design is also offered. Buying Offices are marketing offices of their locations and this is true of whether you are a liaison office or an agent. In no way can we consider the office as a mere intermediary." *(Kapur 2003)*

Different intermediaries in the channels were not merely adding time. Their position in the channel was determined depending on how every intermediary added value to the total chain. If any player did not add value, he simply ceased to exist (Bhatt 2001).

It may be noted that all the above parameters influenced the product development processes in a synchronised manner, depending on different procurement channels. For example Wal-Mart could procure merchandise for its private label Faded Glory through its own liaison office in different countries or an importer based in the U.S.

2.2.5 Vertical Integration to Partnership Model

2.2.5.1 Vertical Integration

Historically, companies 'managed' linked supply chain operations by ownership, i.e. vertical integration (Bain 1968, Bucklin 1966, Clark 1961 and Harrigan 1983). For example, car maker Henry Ford had a sheep farm that grew wool for car seat-covers, General Motors made car paint, newspaper magnates owned forests and paper mills (Thackray 1986), Courtaulds had fibre manufacturing to retail functions in the U.K. (Knox and Newton 1998). A major motivation for companies to vertically integrate was the desire to control critical activities in the chain of supply (Kumpe and Bolwijn 1988). Additionally, vertical integration offered complementary benefits of matching assets in the chain (Doz 1988, Mowery 1988 and Teece 1986). Vertically integrated networks were basically 'product oriented' networks. In the recent past, however, there has been a decline in vertical integration as a means of managing the apparel supply chain. Rigby & Bryne (Rigby and Bryne 2000) cited continuously increasing product variety as the main reason. The supply chain was increasingly being used as an alternative form of market organisation earlier known as vertical integration (Ellram 1991). Porter (Porter 1988) and Thackray (1986) identified systematic vertical disintegration in manufacturing industries including automotive, machine tools, consumer appliances, etc. Interestingly, Zara of Spain is a rare example of vertically integrated apparel operations owning retail, logistics, and fabric cutting and dyeing to product design operations (Christopher 1998, Rice and Hoppe 2001b).

Some of the other recent examples towards vertical integration are 'textile city' in Mexico (Middlebrook and Zepeda 2003), Xiqiao Light Textile City in China (Li and Fung 2006) and Brandix Apparel City in India (Just-Style 2007). While it was denim concentration in Mexico, the Chinese city had a comprehensive production chain from product R&D, material production, weaving, dyeing & finishing, fashion design to sale and export of finished apparel. The Brandix group produces exclusive casual trousers, inner and active wear, textiles, knitted fabrics, sewing and embroidery thread, accessories and hangers and also offers wet processing and finishing as well as fabric printing. There are several advantages and disadvantages of vertical integration; while there is better control, faster communication and lower cost, it also leads to limiting competition, less flexibility and higher risk, etc. The advantages and disadvantages are listed in the table 2.2

Table 2.2 Advantages and Disadvantages of Vertical Integration

Advantages	Disadvantages
Control More difficult for non-integrated firms to enter business Weakens non-integrated competitors Reduces uncertainty in costs, quality and quantity of supply Convergent expectations Reduces probability of externalities, like	**Diseconomies** Balancing scale of economies Volume requirements vary by process Firm has insufficient volume to achieve scale Inability of management to control large organisations effectively Increased inefficiency Large size of firm

dependence on monopoly suppliers and protects proprietary/competitive knowledge Ease of conflict resolution; easier to enforce/monitor internal compliance	All communication costs borne internally Reduced probability of opportunism
Cost Economics of scale through avoidance of intermediaries in procurement, sales promotion and distribution Process integration by technical or physical integration and improved asset utilisation	**Risk** Asset concentration Exit barriers Perpetuate obsolete processes Exaggerate synergies
Communication Improved co-ordination of processes and greater goal congruence	**Limiting competition** Inability of market integration to replicate market incentives Less awareness of market issues

Source: Adopted from Ellram L, 1990

2.2.5.2 Partnership

The rigidity of vertically integrated organisations due to non-economies of scale, asset concentration and inflexibility to change encouraged business enterprises to look for an alternative ‘process oriented’, consumer-focussed approach to cater to variability in product. During the ‘70s, business enterprises started concentrating on those activities which centred on their core competencies (Prahlad and Hamel 1990), and outsourced the rest from other members in the supply chain, thus improving cost, quality, service and lead times and also providing opportunities for small and large suppliers to fill the product gaps so created. Lamming (Lamming 1993) and others called this supply chain model the ‘partnership’ model. Partnership was seen as an alternative form of relationship to the extremes of markets and hierarchies, and which, in some circumstances would be a more effective way of doing business’ (Boddy *et al.* 1998). In the automotive industry this led to structuring of supply chains in tiers, the first tier acting as a systems integrator buying from the second and sometimes the third tier supplier. The basis of supplier selection changed from primarily price-based to collaborative/ technology/ core competency-based. The concept of tier manufacturing is not very common in apparel and textiles, though in NCR India, the second tier converters e.g. sewing contractors, embroidery contractors, wet processing contractors, mentioned as *apparel contractors* by Raman (1995) often fitted in the chain, providing flexibility to large manufacturers. In apparel and textile supply chains, retailers partnered with the manufacturer and manufacturers partnered with trims and accessories suppliers.

The essence of partnership is trust, which played a significant role in collaboration. Marks and Spencer's erstwhile partnership with UK manufacturers speaks about the unmatchable trust and loyalty achieved in those years (up to late 20th century).

"When the going was good, the M & S suppliers reaped the benefit and acquired for themselves Rolls Royce cars, trophy wives and villas in Spain. When the going got tough they were expected to cut their margins and 'make a contribution'. …….M & S would often invest millions of pound in a supplier's factory or technology simply on the basis of a conversation or handshake". (Bevan 2007)

In the apparel industry, another form of partnership existed, through accreditation (also known as 'approved' or 'nominated'). Fabric suppliers, accessories suppliers, fabricators (sewing contractors) and even apparel manufacturers entered the supply chain often through accreditation by a buyer. The Lycra Assured program was a new, close partnership between DuPont and leading fabric mills. The concept would progressively broaden to include yarn suppliers and garment makers and the buyers would also be able to connect with approved suppliers of quality yarns and fabrics via a sophisticated global database (Just-Style 2000).

Partnership as a strategic option could be exercised in different forms like acquisition, merger, Joint Venture (JV), etc. When exercised either within same tiers or between different tiers, partnership could result in numerous benefits as listed in table 2.3

Table: 2.3 Partnership as a Strategic Option: Joint Ventures and Alliances

	Develop new product markets	Share upstream risks	Developmental costs sharing	Leapfrog product technology	Increase capacity utilization	Exploit economies of	Fill product line gaps	Penetrate new markets
Acquisition				Y	Y	Y	Y	Y
Merger			Y	Y	Y	Y	Y	
Core Business JV			Y	Y	Y	Y	Y	Y
Sales JV				Y	Y		Y	Y

Production JV				Y	Y	Y		Y
Development JV			Y		Y		Y	Y
Product Swap			Y	Y		Y	Y	
Production License	Y		Y	Y	Y	Y		
Technology Alliance	Y	Y						
Development License	Y	Y	Y					

Source: Technology Strategies, MCB, July/August 1993

The meaning of partnership was best summarised by Carlisle and Parker who talked about a few important parameters; trust, willingness to become vulnerable, sensitivity to each other's need, and high level of clear and candid communication (John Carlisle and Bob Parker cited in Macbeth and Fergusson 1994). Three key factors redefined the way in which the industry thought about relationships between trading partners. Hines (2004b) combined six broad types of relationship into three categories: adversarial, partnership and integrated. Adversarial maintained arms length where emphasis was on price. Partnership could be co-operative, co-ordinated or collaborative in nature, based on relationship. Integration could be joint venture or vertically integrated where emphasis lay on sharing risk and rewards, owned and controlled by a single organisation.

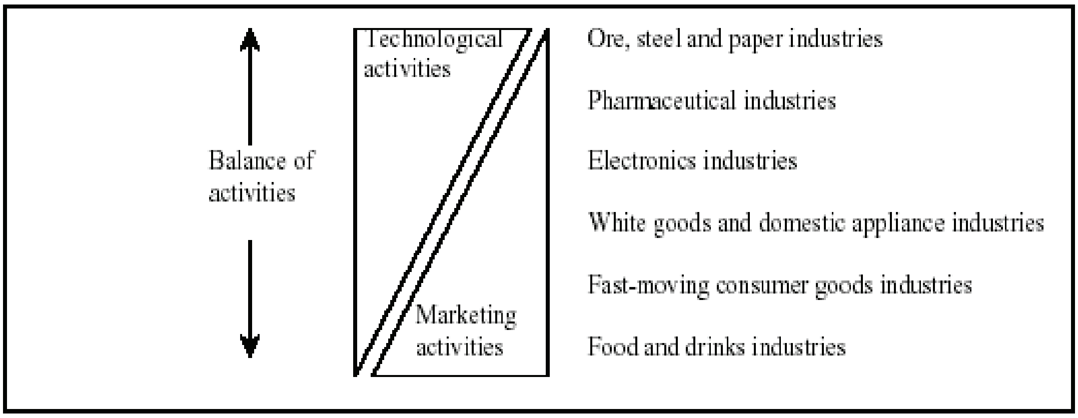
Large assemblers in case of automobile industry and high street retailers in the case of the apparel industry assumed leadership and integrated the supply chain (Stevens 1989) to some kind of virtual corporations (Johansson *et al.* 1993). By handling core supply chain functions themselves, some large apparel manufacturers were still able to respond quickly. Companies like the Esquel group, with 47000 employees from China, became one-stop sources for big apparel brands like Nike; these were part of an integrated supply chain (Ayers 2006). On the other hand there are asset-light companies, with little or no fixed overhead cost that recommend reliance on big trading partners, large retailers who naturally assumed leadership position in apparel supply chain (Jurgen *et al.* 2000).

2.3 Product Development in Supply Chain

In Lee's definition of SCM (1993), product development or new product development were important activities in any supply chain. Womack and Jones defined product development as the set of all specific actions to bring a specific product or service (or increasingly, a combination of the two) through the three critical management tasks; problem solving, information management and physical transformation (Womack and Jones 1996). The importance of product development as a potential area of improvement in the supply chain arose from two reasons; first, the requirement of the omnipresent retailer's thirst (Jones 2006b) and second, the obvious step after lowering of component costs and per unit manufacturing costs, the easily identifiable and achievable savings (Pearson and Knudsen 2003). The terms product development (PD) and new product development (NPD) are found to be used interchangeably conveying the same meaning (Lim *et al.* 2006). A generic NPD process can be analysed in three steps: planning, design, and production. In the automotive industry, the planning phase is often referred to as the functional specification phase, whereas the design and production steps are often referred to as the detailed engineering phase (Clark and Fujimoto, 1991; Lamming, 1993; Womack *et al.* 1990).

Two parallel processes involved in the NPD are idea generation, product design, and detail engineering on the one hand, with simultaneous market research and marketing analysis. The balance of technological and marketing activities in NPD across industries is explained by Trot (1998). In fast moving consumer goods and in apparel, marketing activities increased, whereas, with steel or papers, technological activities increased.

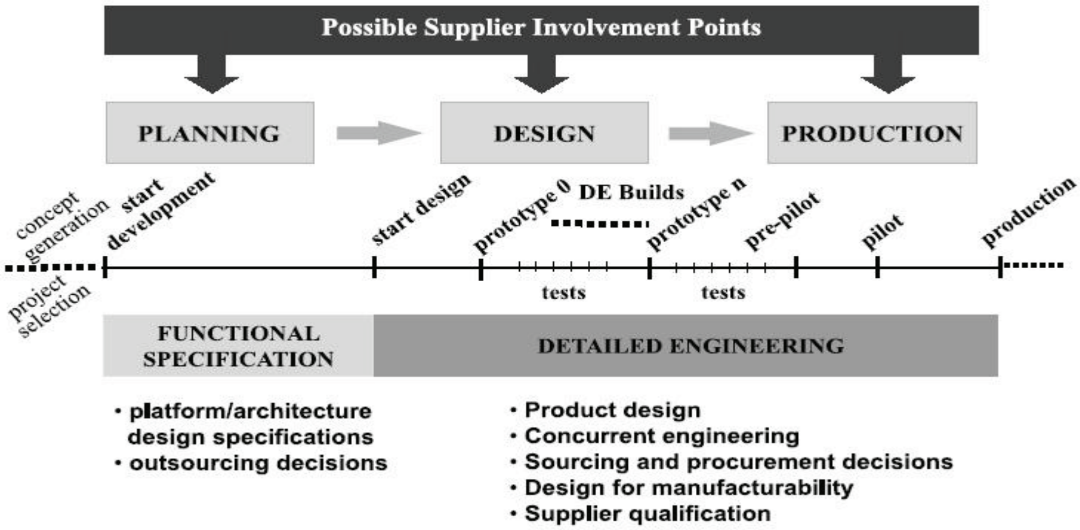
Figure 2.8 Balancing of Product Development Activities



Source: Adapted from Trot 1998

To increase efficiency of PD, different researchers studied different routes, like concurrent method of development (Nobeoka 1998 cited in Massey 2000), collaborative route (Justwin 2002) and supplier involved. Supplier involvement in the PD process could help reduce its cycle time (Karlsson *et al.* 1998) as well as its cost (Droge *et al.* 1996; Jacobs and Herbig, 1998). The degree of supplier involvement in NPD depended on the complexity of the technology outsourced, which would determine the degree of interdependence shared between the manufacturer and the supplier, as shown in Figure 2.9.

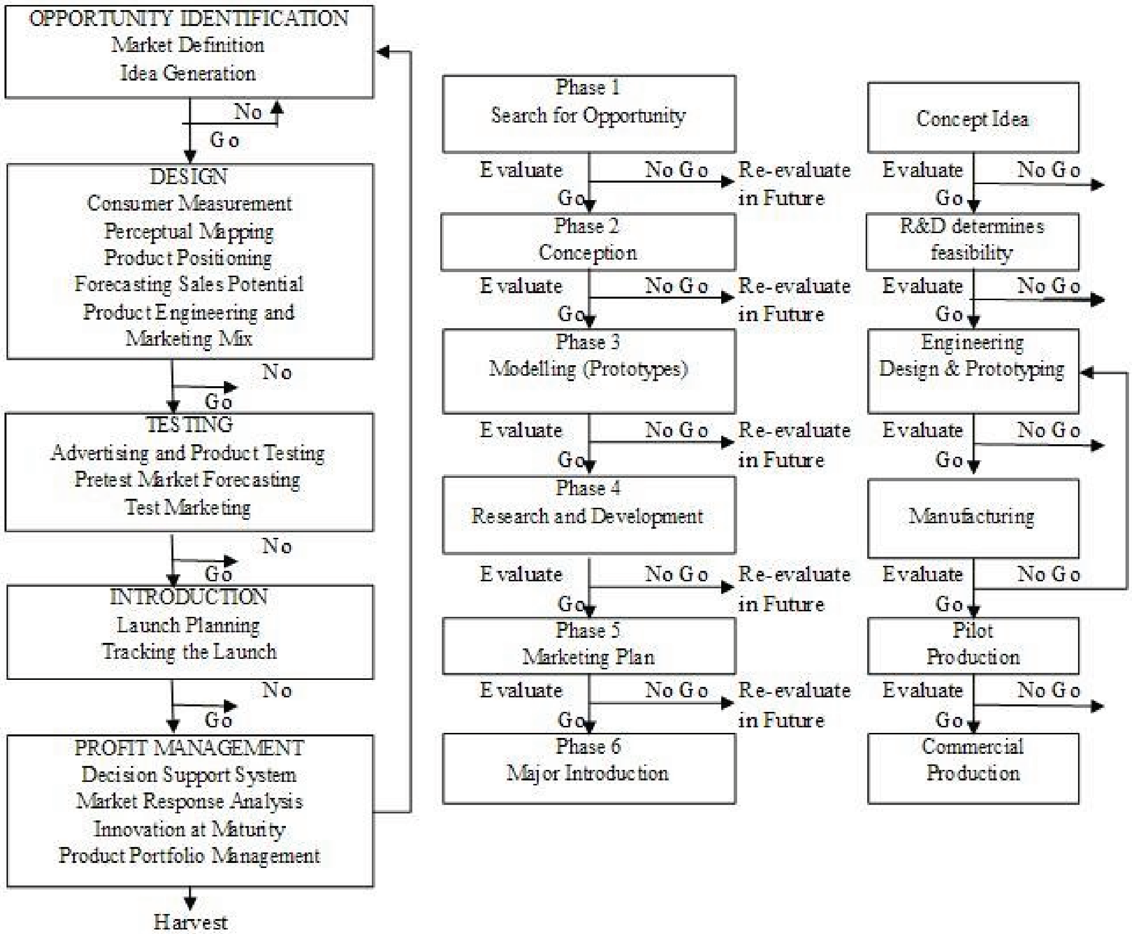
Figure 2.9 Supplier Involvement in Product Development



Source: Mikkola and Larsen 2006

The aim of any new PD is to reduce cost and time over-runs, limiting iterations, limiting redundant (non-value added) activities, and maximise conversion (to production). Different models are recommended by different researchers, Urban and Hauser, (1980), Gruenwald (1992) and Himmelfarb (1992) provided examples of sequential models of the NPD process, Cooper and Kleinschmidt (1986) fine tuned sequential model with 10 to 13 activities in an ordered list. Rochford and Rudelius (1992) obtained similar results using a 12 activity model.

Figure 2.10 Sequential Models of the New Product Development Process



Source: Urban and Hauser, (1980), Gruenwald (1992) and Himmelfarb (1992)

The sheer importance of PD in a supply chain could be summarised as:

"With changing business environments supply chain design as opposed to supply chain co-ordination will become core competitive advantage, resulting partnership between equals, collaborative planning and collaborative product design"

- Anderson and Lee 2000

2.3.1 Product Development in the Apparel Supply Chain

Product development in the apparel industry is still retailer driven and executed in developed countries closer to consumption (Li 2007). Earlier, apparel product development was seasonal, ranging from two seasons to six seasons (AAMA 1995). However, with fast fashion, products were developed virtually continuously around the year (Mintel 2007). Examples of simple, generic models of the PD process used in the apparel industry can be found in the academic literature (Gaskill, 1992; Regan *et al.* 1998), trade literature (Fashion Apparel Manufacturing, 1982; Garfield, 1985; Marketing Committee, 1989; Sadd, 1996) and reference books (Burns and Bryant, 1997). Tyler (2008b) mentioned a five-stage manufacturing cycle starting with product concept and culminating with bulk production. Out of these five, the first four stages i.e. product concept, design sample, customer approved sample and bulk trial can be termed as pre-production processes in a contract manufacturing perspective.

The most comprehensive description of apparel product development process was found in Plumlee's six stage no-interval coherently phased product development (NICPPD) model (Plumlee and Little 1998).

Phase one is line planning and research. The research and parameter establishment guides the development process. Marketing, merchandising and design all contribute to this research phase. The information gathered in Phase 1 formulates the creative direction of the line.

Phase two is design/concept development phase. In this phase, the general line concept identified by the line plan is translated to specific colour stories and concepts for the multiple product groupings which will compose the line. Following the colour and concept meeting to review initial plans, some firms take their concept selections to the consumer for review. The mall intercept interview is a common strategy for conducting these concept tests. Approved concepts are then translated into design specifications and sketches.

Phase three translates the line from sketches and specifications to actual samples of the product line; material is evaluated and ordered to construct the prototype of each design to be included in the line. Patterns are developed and fit standards finalised. Constructed prototypes are evaluated for fit using a fit model and in some cases provided to a consumer panel for wear testing. The prototypes are then reviewed by merchandising, marketing and product development agents, culminating in final adoption of the line.

Phase four sees the line marketed to retail channels through markets and calls by sales representatives. This process requires duplicating the prototype garments to provide samples for the sales representatives and detailed costing to refine preliminary cost estimates. Based on the response of buyers and retail accounts, the line may be modified.

Phase five is the pre-production phase and involves translating the prototypes and first patterns in sample sizes into the complete size range (through grading) required for sale to the consumer. Additionally, quality, production and process standards must be finalised in preparation for manufacture. Sourcing and scheduling production according to sales forecasts generated by sales to retail is also completed.

Phase six is line optimisation. In this phase, improvements are made to the line as orders continue and sales forecasts are modified. Modifications may be made to the line to enhance sales or to balance a line which is having erratic sales. Phase 6 may be cycled through indefinitely as production continues, although the ideal is to have as little change as possible at that stage of development.

While the NICPPD model allowed the researcher to visualise the impact of changing business environment, processes, suppliers and customer requirements and identify opportunities and establish priorities for research, it allowed the practitioner to benchmark and modify apparel development processes, build the organisational structure required to effectively execute the apparel development process; develop effective strategies for the rapid product development required for line optimisation and market responsiveness and strategically plan organisational and procedural changes to facilitate apparel development.

Birnbaum (2003) suggested a 101-step manufacturing cycle, starting with Designer attends fabric show to Order ready for shipment, out of which the first 19 steps designed an in-house PD activity; then the factory collected information (receives tech-pack). PD and pre-production activity continued till the 86th step, where the order was ready to cut. A study by JBA (1998) among European and US organisations revealed that out of 167 days of average supply lead time, product development consumed 104 days leaving approximately 25 percent of the lead time for manufacturing.

Apparel products do not exist in isolation, but are usually part of a portfolio of products that, when manufactured, may share elements of the manufacturing process with other products (Krishnan and Ulrich, 2001). Studies (Redfern and Davey 2003) showed that it was possible for supply chain firms to improve success rate of a new PD through objective measurement of customer perception. Kano's model of customer perception measurement mapped customer satisfaction with three key product features: performance, described as expected features, delighter features and linear features.

2.3.2 Product Development Process in Contract Apparel Manufacturing

The apparel industry in India produces both small volume fashion (value added) garments and large batch, commodity garments. The most popular business model applied in the apparel industry is to keep design and colour selection at company headquarters or home country and to outsource labour intensive production offshore (Li 2007). Once the colour, silhouette and fabric selection process is completed at headquarters, the development/costing request comes to the apparel manufacturers in India. In the Indian export environment, the PD process is a tripartite activity involving buyer, manufacturer and supplier. Further, 'developing' often means 'sourcing'. There is a great deal of difference in terms of expertise required for 'development' and 'sourcing'. The main developments done are developing fabrics (texture, design & colour), developing the pattern (silhouette), developing and/or sourcing accessories, developing the wash effect if required and developing embroidery / value addition / hand work.

While PD and product sourcing are both followed in the Indian garment industry, people tended to follow two different models of operations. Manufacturers involved in PD either sourced/developed from/with numerous raw material/accessories vendors or only one consolidator, who in turn are/were networked with numerous vendors to source (or develop) and offer the total package to the manufacturer. For sourcing imported trims, working with an accessory consolidator was a common practice.

PD processes followed by different sourcing companies for different procurement channels were basically the same, as logically there would be design inspiration, development of ranges, sampling, and approval of sample in every channel (Li & Fung 2009, Triburg 2009, CMT Sourcing 2009). Merchandise brands that laid more emphasis on silhouette/cut and worked around basic colour palette might settle for alternate fabric sample during fit approval (as fit is more important than look) while those merchandise brands that laid emphasis on yarn dyed, prints and colours would ask for fit approval in the actual fabric only. Catalogue buyers generally worked around colours and such visual effects in the garments that could be communicated through catalogues (William E Connors & Associates 2009). They generally avoided texture details and special feel effects (wash effects) as customers would not be able to feel it during actual buying. Catalogue buyers would ask for a photo shoot sample which should be correct in all respects. As what was depicted in the catalogue was to be supplied to the customer, photo sample visual accuracy was very important (Li & Fung 2009, CMT Sourcing 2009). Once a photograph was inserted into the catalogue, merchandise details were not changed. In case of catalogue buying, the logic was similar to 'stock to sell'. The initial buying quantity was low and repeat buying was common, to obviously minimise the risk factor.

Fabric development involves specific fibre composition, special yarn effect, special weaves or knit effect, special surface print, special wash effect or any other means. In the fabric development there is fabric construction as well as fabric colour approval (lab-dips, strike off, desk loom etc.). All approvals require the actual sample to be couriered, while comments (either approved or rejected) are often received by fax/e-mail. Electronic colour management was not used by any manufacturers or buyers. However it was noticed that colour approval process was gradually changing from subjective comments to objective evaluation by mentioning 'delta value' range for approval or rejection (ApparelOnline 2005).

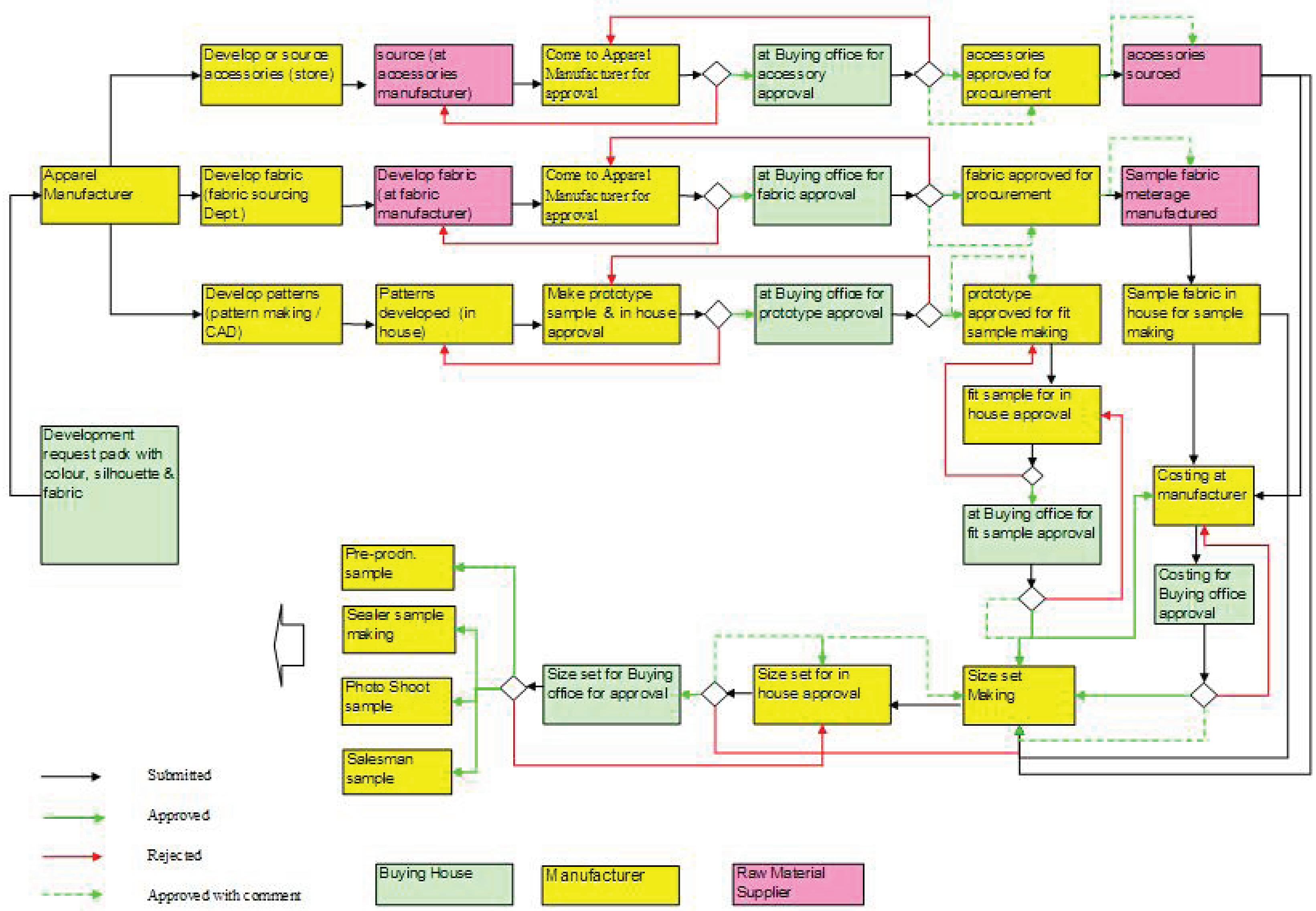
In silhouette development, there are generally three stages of sample approval; prototype, fit and finally size set. Developing the first pattern following a size chart and silhouette could be a problematic and/or slow process. It was observed (Sareen 2006) that many did not follow the concept of pattern development by altering the basic block but developed new patterns every time. However in recent years, use of CAD and transferring pattern files via e-mail has made the process comparatively faster. The prototype and fit sample development is the most arduous task and multiple iterations are common. The reasons for iterations are lack of market knowledge, faulty interpretation of instructions and lack of technical understanding of 'fitting session' at the buyer's end (Sareen 2006, Mac 2006). No electronic fitting (using fit simulation software) was found to be practised, thus inordinate delays in the sampling process was common (Sareen 2008). Electronic virtual fitting can reduce product development time to 10-15 days or by 50 percent (Sareen 2008).

Common accessories used are button, thread, zipper, etc. Developing new types of accessories are rare. In the majority of cases, sourcing the right type of accessories (at most dyed to match colour embossing, etc.) from a set of vendor bases was common practice. Sometimes the finished merchandise required value addition, achieved by special dry or wet processing techniques at the fabric or garment stage, or performing hand or machine embroidery and/or attaching embellishments at fabric/cut panel/finished garment stage. Labels and packaging materials were being either sourced from 'nominated' vendors, or sourced and then approved by the buyer.

Once pattern, sampling fabric and accessories were sourced, costing and size set were prepared simultaneously. After approval of size set and agreement on costing, a sealer sample (and any other buyer specific additional sampling request) was made and the manufacturer initiated necessary steps for bulk sourcing of approved raw materials.

Figure 2.11 shows a diagrammatic representation of a PD process for a typical Indian apparel manufacturer.

Figure 2.11 Product Development Process for a Typical Indian Apparel Manufacturer



It is interesting to see that buying office decisions are either 'approved' or 'rejected' or even 'approved with comments', which means subject to certain amendments. These are often used for saving precious time during development. However, these also lead to confusion due to differential interpretation of comments by manufacturers and buyers. Often, the buying office dominates proceedings and manufacturers are always at the receiving end as the end decision will decide confirmation of order.

Generally, the development pack, i.e. colour, silhouette and fabric (structure, texture etc.) is sent to different manufacturers (maybe in different countries) to get an idea of actual achievable parameters and achievable price of a style. Sometimes target price is also sent along to match. After prototype and fit approval, the manufacturer is selected based on quality, delivery capability and price quoted. Then a confirmed order is sent to the selected manufacturer with specifications and other details of the style. During this post-order merchandising stage, the manufacturer is expected to submit samples in actual production fabric and trims for 'seal sample' approval, which is referred to for all standards during production. Three production sample were generally sent by manufacturer which is sealed and one sent to warehouse, one kept at head office and one sent back to supplier (Hobbs 2002)

From Figure 2.11, the process flow is clear with dependency relationship. There are three clear parallel process flows; fabric development, accessories development and pattern development. All three process flow converges to one point at size set making, which requires all three inputs. The organisations in India can be classified into three categories (ApparelOnline 2007). There are large organisations, which cater to both basic merchandise and fashion-basic merchandise. Then there are medium sized that are either only fashion or only basic. Then there are small ones whose USP is fashion merchandise. Although product development processes remain more or less similar, it is the execution which changes. When compared with Plumlee's six stage product development process (section 2.3.1), for basic product, a manufacturer in India would probably get involved in only two steps, i.e. prototype and pre-production sample development (Naik 2000, Chawla 2000, Banerjee 2003). Other activities like line planning and research, concept development, marketing to retail channel and line optimisation are generally done by retail organisation/brands themselves. In case of fashion products, a small manufacturer will be involved in four stages except marketing to retail channel and line optimisation. In case of a medium sized company making fashion products, having offices and design studio abroad may involve all six stages.

According to Kurt Salmon Associates (KSA), a prominent global management consulting firm, almost 95 percent of product development cycle times is made up of non-value added processes and more than 70 percent of the activities that are non-value added can be eliminated (Parnell 1999). Also, 67% of companies polled by KSA (Parnell 1999) said that improvement of product development was their number one priority. In a recent analysis of pre-production delays of an Indian knitwear manufacturer exporter (Mahajan *et al.* 2003), it was found that on an average, 20 days are spent on developing lab dips for three shades, which is almost three to four times higher than originally planned. The two main reasons for delay are internal rejection followed by non-prioritised tasks. Other reasons for delay are frequent changes by the buyer, external and internal communication lapses. It is also noticed that sample making time reduces gradually along the downstream supply chain. While the proto sample approval on an average took 9.5 days, the preproduction sample approval took only 7 days. Mahajan (2003) also observed that main reasons for prototype sample delay was again misplaced priorities followed by machine availability; all these suggest absence of prioritising activity, leading to haphazard work and poor resource utilisation creating avoidable delays.

There appears to be huge scope of improvement in reducing the lead time during the product development and pre-production process. Collaborative product development, i.e. simultaneous development of raw material and accessories was practiced by some large buying organisations, but is not a regular practice among small and medium manufacturers. Manufacturing organisations migrated to new industrial economies primarily due to cheaper labour wages (Dickerson 1995, Jones 2006a), and not because of their product development skills (Jana 2003). Though CAD was used in pattern making, electronic fitting (e-fit simulator, Browzwear) was not common among small and medium manufacturers during the research tenure.

It was reiterated that getting fit sample approved right first time was not a positive strength of a contract manufacturer. Possibly a retailer can strategically outsource the product development function of a season to a specialist organisation, which involves complete pattern development, fit sample making and marker making. Once the order is placed with a manufacturer, he will have to buy the pattern-pack from the specialist organisation and start production (bulk cutting) straightway. This will drastically reduce the pre-production activity cycle for manufacturer. While both approaches use 'core competency' logic, the rear approach also uses 'scale' and 'scope' to optimise the cost.

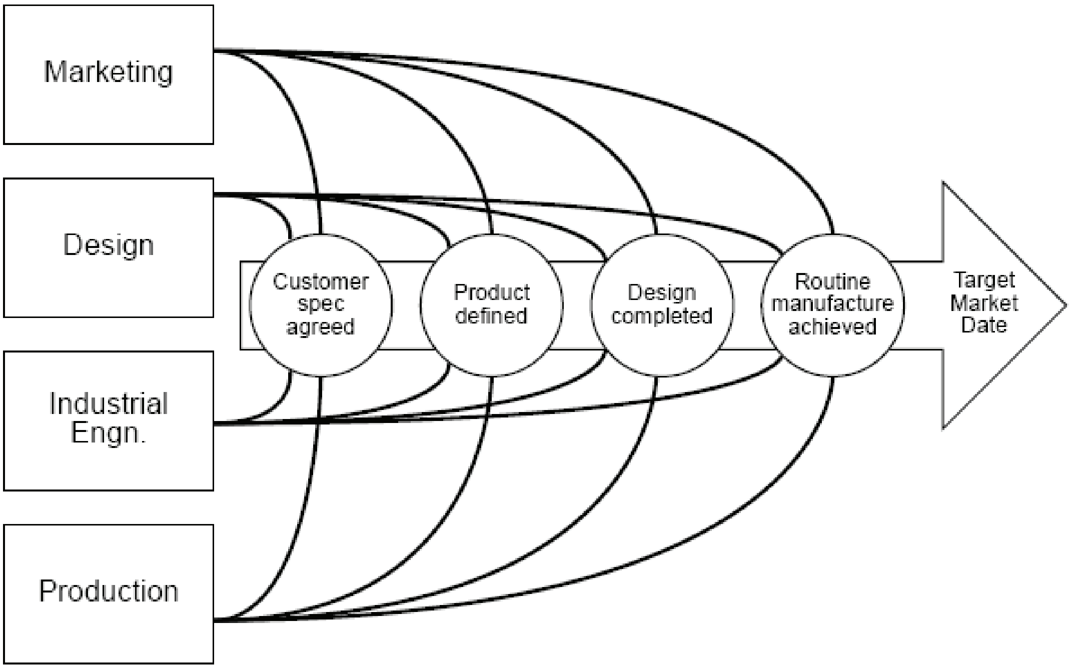
Product development from India has changed over time. Earlier, designers and buyers from developed countries used to come with specific requirements and Indian manufacturers only used to duplicate them; the order used to begin with fit sample. However, nowadays buyers are looking for the manufacturer's capability in terms of raw material options, style silhouette options, uniqueness and innovation (Malik 2009). Due to this, the merchandisers are now product-specific and not client or market-specific (Malik 2009). The Indian designer now travels to Europe, attends forecasts and is expected to develop his own collection fusion of Indian fabric and embellishment strength with European design sensibilities. Although Indian product development teams are strong in fabric development, sourcing, pricing, innovation and crisis management, they are very poor in colour matching, knowledge of fit and pattern details and correct interpretation of approval comments from the buyer resulting in inevitable iteration and stretched lead time (Malik 2009). With product development envisioned to be the real growth for the Indian apparel industry (ApparelOnline 2007a), the key issues for India as a supplier is immediate improvement in the areas of raw material and sample approvals. If Chinese USP is quality and volume, then India's strength is PD (Apparel Online 2007b).

2.3.3 Collaborative and Concurrent Product Development

Due to increased focus on NPD, the concept of concurrent engineering, simultaneous engineering and design for manufacturability became popular (Mcdermott and Handfield 2000) and were often used interchangeably. Collaborate means to work together, especially in a joint intellectual effort, while concurrent means operating or acting in parallel with another and meeting or tending to meet at the same point. Both are likely to apply with true partnership in new product development (Alistair 2009).

Many authors (Himmelfarb, 1992; Nijssen *et al.* 1995; Zahra and Ellor, 1993) view sequential processes as obsolete and see industrial product development shifting toward a parallel or concurrent product development process model. Erhorn and Stark (1994) and Barclay *et al.* (1995) emphasised and modelled an integrated approach, where product development occurs simultaneously in multiple departments and product improvements are accomplished without hindering the process.

Figure 2.12 Integrated Approach towards Product Development

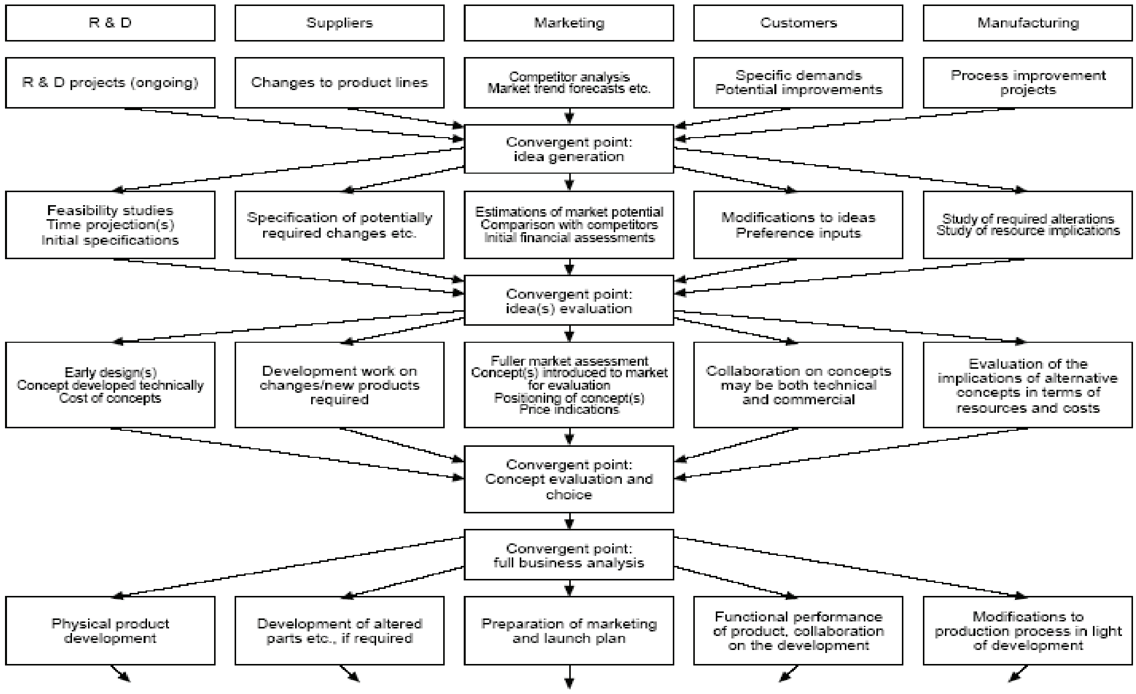


Source: Erhorn and Stark (1994)

Hart and Baker (1994) attempted to limit the functional divisions suggested by 'parallel' processes with a multiple convergent processing model. In their model, however, multiple convergences occur during the development phases that follow concept generation, development and screening, which is in contrast to Bruce and Biemans's (1995) multiple convergent model diagramming the early stages of development. The use of information technology and virtual prototyping on the World Wide Web can also improve the speed of decision-making and facilitate collaboration among customers, suppliers, and the firm's personnel (Giachetti 1999; Park and Baik 1999; Dahan and Srinivasan 2000). Pearson and

Knudsen (2003), (Gilmore and Pine (2000), Karlsson *et al.* (1998) all suggested involving the customer and supplier, thus leveraging their expertise and improving effectiveness.

Figure 2.13 Multiple Convergent Model of Product Development



Source: Bruce and Biemans (1995)

The style of 'over the wall' product development does not typically afford communication between functional areas, instead, it results in a process that is essentially sequential—with the product and information passing from one functional area to the next on its path to the customer (Cooper, 1990; Gerwin, 1993). There is little or no feedback or discussion between areas with respect to potential improvements in the product (e.g., a design improvement) or in the process (a change in material that might make the product easier or less expensive to produce). In this model, the manufacturer's role in the process of developing new products is often viewed as strategically neutral (Abernathy & Utterback, 1988), and the interaction between the design department and manufacturing in such environments could be defined at best as sequential, if not nonexistent. Similarly, purchasing managers often have little influence over the evaluation and selection of key input suppliers within this process. The only benefit of sequential approach, however, is the lack of ambiguity within functional tasks; when one functional area passes the project on, the receiving group can be relatively assured that the responsibilities and tasks of the previous (sequential) function are more or less complete.

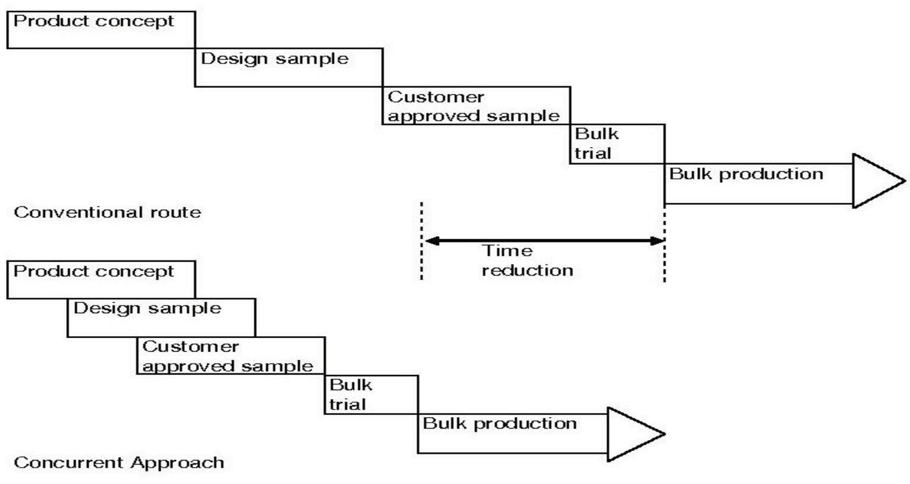
Collaborative Product Development (CPD) involves collaboratively developing, building and managing products throughout the entire lifecycle, no matter what tools are used, and no matter where they are located geographically or within the supply chain (Collaborative Product Commerce 1999). In the apparel manufacturing context, it is about sharing colour, texture (Kapur 2003), costing (Knox 2009) and other details while developing a range. During the product development process, the brand, retailer, apparel manufacturer, fabric manufacturer, accessories manufacturer, sewing thread (Coats 1999) and colour service providers, garment finishing chemical suppliers share information so that the necessary development can take place much before the order actually placed with apparel manufacturer.

For instance, Gap Inc. shares its seasonal forecast colours with Coats worldwide so that the correct embroidery thread can be developed. All Gap vendors are then directed to source their embroidery thread needs from local Coats suppliers (Coats 1999). Levi's shares its specifications with accessory manufacturer and supplier Universal Fasteners to develop zipper and rivets, stud buttons collaboratively (AAMA 1995). Freshtex, the speciality garment finisher shares forecasts and develops washes with leading jeans brands during the concept stage (Freshtex 2005). Liz Claiborne and M&S collaborate with fabric manufacturers to develop designs based on forecasts. New product development in apparel industry requires cross functional, intra departmental teams that communicate vertically and horizontally across the supply chain (Tyler 2008a)

The major benefits of CPD for apparel companies includes accelerating time-to-market, which provides improved customer satisfaction, greater profit potential, and gains in market share; improved management of frequent specification changes; yields higher quality products and reduces costly design flaws; automatic tracking and notification of key milestones and improved scheduling between multiple layers of suppliers; effective data sharing 'anytime, anyplace' keeps everyone on the same page, eliminating costly errors and delays.

Parallel approaches to NPD result in improvement in several performances like time to market (Cooper 1990), (Zirger and Hartley 1996), (Kumar and Midha 2001), (Valle and Va´zquez-Bustelo 2009), (Tyler 2008b) manufacturability (Venkatesan,1992; Whitney,1988), cost (Taguchi & Nonaka,1986), (Tyler 2008b) and product superiority in the case of incremental innovations and in terms of development (Valle and Va´zquez-Bustelo 2009). Closer relationship between buying and supplier in NPD taking advantage of market opportunity was documented (Merrills, 1989; Raia, 1991; Whitney,1988). Involvement of purchase and supplier early in the development process decreases time-to-market from concept to production (Clark,1989; Smith and Reinertsen,1991) and is smoother and less expensive (Gupta and Souder, 1998). There are two types of development; incremental and radical. Concurrent engineering practices are appropriate for incremental development using well defined technologies in meeting time to market, lesser cost and market penetration objectives. However a serial approach to product development is appropriate for NPD for developing radically different products using new unproven technologies (Mcdermott and Handfield 2000). A concurrent product development model suggested by Tyler (Figure 2.14) explains a five stage process where technologists have a vital role to play.

Figure 2.14 Conventional and Concurrent Approaches to Product Development



While in optimisation of manufacture and resource analysis technologists are supposed to interact with production people, in simplification and material optimisation they are supposed to interact with the design team. Tyler (2008a) expressed his concern over practicing a concurrent product development process in contract manufacturing scenario as people are not used to work in multidisciplinary teams, especially if they involve different companies (in different geographical locations) in the supply chain.

2.4 Optimisation Techniques

Supply Chain Optimisation, Supply chain integration (Shah 2009), supply chain restructuring (Shah 2009), network optimisation (Chopra and Meindl 2005b) are some of the interchangeably used techniques to ensure a balanced and improved supply chain performance. This includes optimal placement of inventory (Chopra and Meindl 2005b), minimising operating costs (including manufacturing costs, transportation costs, and distribution costs), delaying point of differentiation (Shah 2009, Chopra and Meindl 2005b), shifting the bulk of cost addition to as late as possible and improved customer service (Shah 2009). The technique often involves the application of analytical models, product redesign, process redesign, network design restructure and value offering to customer (Shah 2009). The optimisation result includes flexible, short-cycle schedules (quick response) supported with the minimum inventories (inventory management), just in time delivery, consolidated complex traffic routing without increased costs (Poirier and Reiter 1996). Optimisation also uses sophisticated information technology to operate in a concerted fashion on a comprehensive business strategy, rather than local optimisation at the expense of other members of the supply chain (Poirier and Reiter 1996).

2.4.1 Postponement

Postponement refers to a concept whereby activities in the supply chain are delayed until a demand is realised (Bucklin, 1965; Van Hoek, 2001). Van Hoek (2001) defines postponement as the delaying of supply chain activities until customer orders are received with the intention of customising products as opposed to performing these activities in anticipation of future orders. Researchers suggest that postponement has the potential to improve responsiveness while reducing inventory, transportation, storage, and obsolescence costs (Yang *et al.* 2004). Postponement has a long history of practical business application dating back to the 1920s (Council of Logistics Management 2001).

The concept of differentiation is important for the textile and apparel industry as it offers a variety of end products to customers. In case of garment manufacturing, the fabric dyeing and sewing represent two main points of differentiation. In dyeing, an irreversible change takes place about colour and in sewing, irreversible change takes place about style. In the apparel industry Benetton used postponement to improve its responsiveness to customer demands. By postponing the dyeing of its garments, Benetton[1] was better positioned to respond to demands for popular coloured clothing and reduce excess inventory of less-popular colours (Dapiran, 1992). Postponing the shipment of appliances to Sears[2] until a customer order is received allowed Whirlpool to realise a significant reduction in inventory and transportation costs (Waller *et al.* 2000). Hewlett Packard postponed final assembly of its DeskJet printers until the very late stages of the supply chain. This postponement of final assembly, combined with the shift of assembly locations closer to customers, resulted in a more cost-efficient production process while reducing transportation and logistics costs (Feitzinger and Lee, 1997). For example, many organisations are now utilising postponement principle to delay differentiation in the manufacturing process, hoping to reduce inventory obsolescence and other logistics costs (Rabinovich and Evers, 2003). Waller *et al.* (2000) expanded the concept of postponement to include upstream postponement, production postponement and downstream postponement. Brown *et al.* (2000) describes product postponement in which some of the functionalities of products are specified in the field, even after delivery to the customer.

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[1] *Established in 1965, the Benetton Group is present in 120 countries worldwide. Its core business is fashion apparel: a group with a strong Italian character whose style, quality and passion are clearly seen in its brands, the casual* United Colors of Benetton*, the glamour oriented* Sisley*, the leisurewear brand* Playlife*. The Group produces over 150 million garments every year. Its network of around 6,000 contemporary stores around the world, offers high quality customer services and generates a total turnover of over 2 billion euro. Benetton is now controlled by Edizione Srl (a holding company wholly owned by the Benetton Family) with a 67% stake. It listed on the stock exchange in Milan in 1986. (http://www.benetton.com)*

[2] ***Sears Holdings Corporation,*** *with approximately 3,900 full-line and specialty retail stores in the United States and Canada, is USA's largest provider of home services and leading home appliance retailer as well as a leader in tools, lawn and garden, home electronics and automotive repair and maintenance. It also has a broad apparel offering, including such well-known labels as Lands' End, Jaclyn Smith and Joe Boxer, as well as the Apostrophe and Covington brands. Sears Holdings Corporation operates through its subsidiaries, including Sears, Roebuck and Co. and Kmart Corporation. (http://www.searsholdings.com/)*

Aviv and Federgruen (2001) expand the concept of design for postponement where products and processes are designed/redesigned to facilitate postponement. Yang *et al.* (2004) further extended and refined the concept of postponement to include product development postponement, purchasing postponement, production postponement, and logistics postponement. Production postponement and logistics postponement are similar to previously discussed concepts of postponement. Purchasing postponement relates to Bucklin's (1965) concept of shifting risk by delaying the purchase of raw materials up to the point of production. Using cases involving four different companies, Van Hoek *et al.* (1999) found that both strategic and operating characteristics influence the feasibility of postponement in restructuring European supply chains. Growth in postponement is partially reflective of the increased demand for customised products. In order to enhance product offerings, many organisations are altering their supply chains to accommodate mass customisation processes (Su *et al.* 2005). The newly created supply chain structures often involve time postponement or delaying product differentiation points until customer orders have actually been received. As mentioned above, postponement often results from organisations adopting a mass customisation strategy in order to enhance their ability to meet customer demands. However, postponement and mass customisation are distinctly different and the terms should not be used interchangeably. Some researchers believe that postponement is mainly a pragmatic means to move towards mass customisation (Feitzinger and Lee, 1997; Kotha, 1995; Lampel and Mintzberg, 1996). Digital supply chain offers numerous opportunity of postponement in apparel product development. Electronic fit simulators where virtual models are used to test fit samples actually postpone physical pattern cutting and sample making (Fralix 2003), digital colour approvals through colour management systems (eWarna's Online Colour eXchange basis of Leveraging Colour Management within PLM 2006) are a postponement of colouring of material. Yeung (Yeung Y, *et al.* 2007) concluded that when a supply chain has a balanced structure, it should use speculation or production postponement. When the supply chain has an unbalanced structure, it should use purchasing postponement or product development postponement.

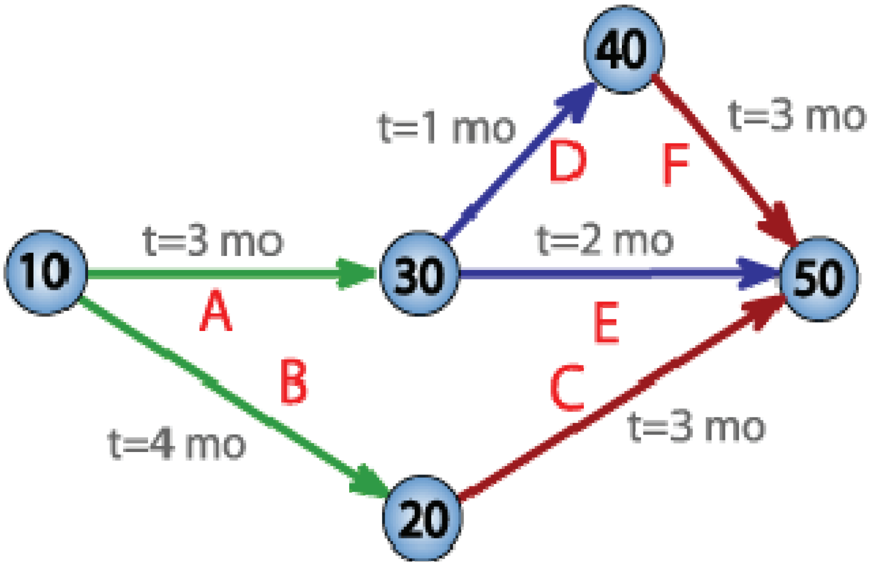
2.4.2 Critical Path Method

"The complexity of supply network increases due to interdependency….thus becomes impossible to simultaneously take account of all these interactions either manually or using simple analytical tools like spreadsheets…..in such cases sophisticated network modelling tools like linear and mixed integer programming are required for optimising the supply chain." (Gattorna 2008d).

Research in operations deals with linear programming, transportation and scheduling problems, network analysis, etc. which are very close to operation philosophies of supply chain. Even then role of operational research in the supply chain is found to be limited. Supply chain scheduling plays an important role in supply chains (Little *et al.* 1995); in his paper Nurmilaakso (2004) addressed distributed simulation and presented a conceptual model to formalise a mathematical model of supply chain scheduling that is based on a resource-constrained project scheduling problem (RCPSP). Alvarez-Valdes and Tamrit (1989) have reviewed and listed four kinds of priority rules applied to RCPSP. They have found that the Minimum Slack (MINSLK) rule, which is based on CPM, is the most efficient rule considering due dates. An activity consists of activity periods, which have unit duration. Its lower time bound, i.e. the earliest scheduled period in or after which the activity should be started, and its upper time bound, i.e. due date is the latest scheduled period in or before which the activity should be finished. These time bounds can be deduced by applying the critical path method (CPM) (Nurmilaakso 2004).

The **Program** (or **Project**) **Evaluation and Review Technique**, commonly abbreviated as **PERT**, is a model for project management designed to analyze and represent the tasks involved in completing a given project, especially the time needed to complete each task, and identifying the minimum time needed to complete the total project. This model was invented by Booz Allen Hamilton, Inc. under contract to the United States Department of Defense's US Navy Special Projects Office in 1958 as part of the Polaris mobile submarine-launched ballistic missile project. Figure 2.15 shows a simple PERT network with 6 activities; A, B, ..to F.

Figure 2.15 PERT/CPM Network



Source: www.wikipedia.org

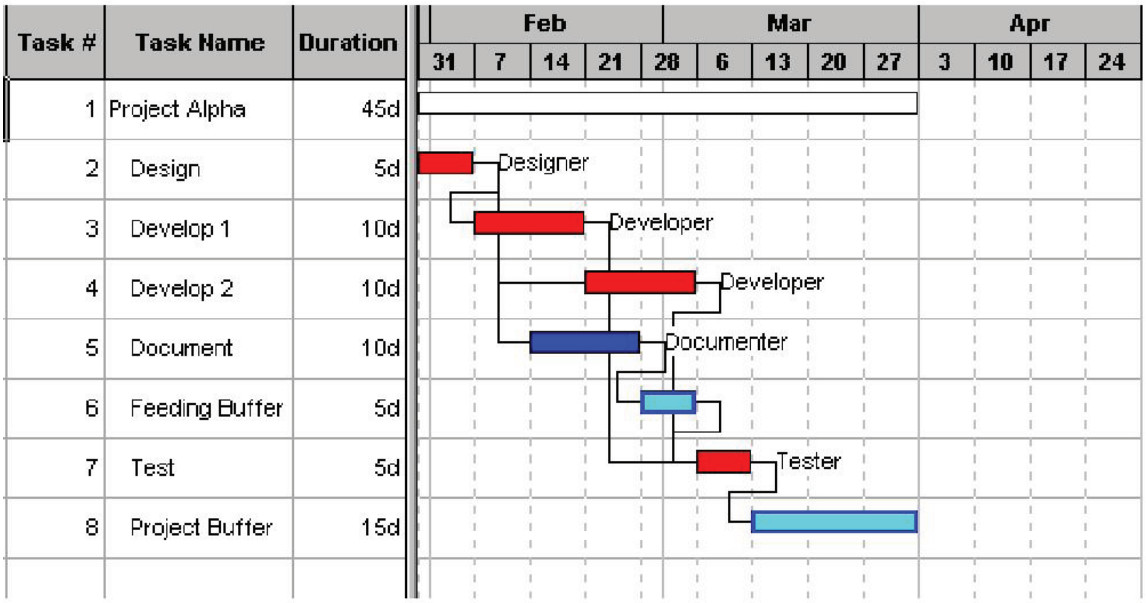
Activity duration for A and B are 3 and 4 months respectively. C is successor activity to B, similarly A is predecessor to both D and E. The critical path is B-C or A-D-F , where both path takes longest time of 7 months.

Proven operation research tools like PERT and CPM were used for scheduling merchandising and production activities and lead-time measurement in the traditional supply chain, popularly known as Time N Action calendar in the apparel industry (Jana 2003). It was found that apparel associates use a 'time-and-action' calendar, also called a work flow, to organise everyone involved to establish and adhere to deadlines (Regan 2007). Many apparel managers use project management tools, such as Gantt Chart, to monitor time and manage employees who work on PD and production (Regan 2007). In a contract manufacturing scenario, work was tracked through the order fulfilment process (OFP) by monitoring specific order points decided by the critical path reporting agreement (Rollins *et al.*2003). Critical path was reportedly used for conformance to pre-production milestones by U.K. and U.S. buyers on manufacturers in Hong Kong (Bruce and Daly 2006, Popp 2000), Turkey (Popp 2000). The technique is also referred to as merchandising 'calendar time scale' (Pan and Holland 2006), or time and action (TNA) calendar in India (Dutta 2004).

Not surprisingly, many software solutions catering to apparel pre-production planning were also found using the critical path management logic. Task-tracking system (Critical Path Management) in Momentis (Momentis 2008), allows companies to define key tasks, task dependencies and milestones related to the pre-production and development of finished goods. Customer specific critical path formats in Fast React Systems (Fast React 2007) allows follow up on the events and monitoring of garment cutting activities (Styleman 2008). Purchase orders are mapped to assigned dates and critical path (Cantel 2008) to track and activate alarms. Although the word 'critical path' was found commonplace in organisations, it was rarely used from the viewpoint of operation research logic. The critical path was interpreted by practitioners from apparel industry from its literary viewpoint rather from operation research viewpoint. The criticality/importance of the path (or process) was judged either based on quality vulnerability or cost vulnerability or error prone, etc.

Goldratt in his book "Critical Chain" (Goldratt 1997) exemplified and summarised human nature of working in a project environment (Refer Appendix I). While the critical path method was found to be more appropriate for machine driven activities (Goldratt 1997), the critical chain was found appropriate for people oriented functions by incorporating both the human side and algorithmic methodology side in a unified principle (Goldratt 1997). Garment pre-production (also known as merchandising) activities are characterised by mainly people oriented functions, where interdependent activities are synchronised between succeeding and preceding activities to make the process network. Furthermore, some of the critical chain characteristics have commonalties with garment pre-production activities like backward scheduling, multitasking and resource dependencies. Thus critical chain methodology was found to hold promising application in rationalising apparel manufacturing cycle time.

Figure 2.16 Critical Chain Gantt Chart



Source: *Sciforma* Corporation (www.**sciforma**.com)

Figure 2.16 shows Gantt chart using critical chain principle. The critical path for the example is design--develop1—develop2—test and critical path duration is 30 days. Document is parallel activity with duration of 10 days. The figure shows feeding buffer of 5 days and project buffer of 15 days are inserted in the project.

2.4.3 Lean Manufacturing

Lean Manufacturing is a systematic approach to identifying and eliminating waste or non-value added activities in a process through continuous improvement with the goal of creating maximum value. It is a manufacturing strategy trying to maintain minimum inventory. Lean manufacturing strives to reduce waste in human effort, inventory and time to market (Seth and Gupta, 2005). The first approach of Lean is to assist in the identification and steady elimination of waste (*muda*). As waste is eliminated, quality improves while production time and cost are reduced. Modular systems require a managed flow of materials that resembles just-in-time (JIT) systems, reduces inventory (Bonacich *et al.* 1994) and increases flexibility (Katla *et al.* 1998). Examples of other lean 'tools' are Value Stream Mapping, 5S, Kanban, and poka-yoke (error-proofing). Kanban means 'visual signal' in Japanese, control of inventory by means of kanban reverses the material flow from ‘push’ to pull system, thus enabling maintainenance of minimum possible inventory. In Toyota approach to lean manufacturing, the focus is upon improving the ‘flow’ or smoothness of work (thereby steadily eliminating *mura*; ‘unevenness’) through the system and not upon 'waste reduction' per se. Since lean thinking analyses business processes systematically by identifying and removing wastes, it helps also to distinguish between value added and non-value added processes (Harrison and van Hoek, 2005).

2.4.4 Inventory Management

‘Inventory is like a security blanket,’ according to Joan S. Adams, MD and CEO of Pierian Consulting, New York. Companies build up inventories because they don’t know about future needs and do not want to lose an order for lack of items. Inventory control also depends on make-to-stock versus make-to-order control. In a make-to-stock system, every stage ‘blindly’ produces inventory up to a certain target level ahead of time, i.e. before any demands have arrived at the system, so that when a demand arrives, there is a good chance that it may be pulled from inventory. In a make-to-order system, no inventory is produced ahead of time. Instead, production is initiated whenever an order arrives at the system.
Mentzer (2001) suggested four major approaches to inventory management; economic order quantity (EOQ), material requirement planning (MRP), distribution requirement planning (DRP) and just-in-time (JIT). The right approach will depend on nature of demand (dependent or independent), type of system (push or pull) and level of solution (single facility or system wide). For a single facility solution in a pull system while EOQ is an appropriate approach involving independent demand items, JIT is most applicable for dependent demand. Therefore, while JIT would be suitable controlling inventory in apparel manufacturing, EOQ would fit for retail inventory management. Other requirements for practicing JIT in manufacturing environment are scale of operation (Millstein 1999) and geographical proximity (Sharma and Jana 2005). For a system wide solution in a push environment while MRP is best applied involving dependent demand items, DRP is a preferred approach for independent demand. According to G. Liberopoulos and Y. Dallery (G. Liberopoulos and Y. Dallery 2003), material resource planning (MRP) is a deterministic make-to-order system that copes with uncertainty, usually by initiating lead times than by introducing an inventory target level in the form of safety stock. Managing Inventory in the textile and clothing supply chain requires managing inventories at an

aggregate level and there are different types of inventory to be maintained for different reasons. For example, a cycle stock inventory may be required for economies of scale while anticipation inventory may be required to deal with seasonality in demand. An inventory classification for the apparel industry is listed in the following table (table 2.4).

Table 2.4 Classification of Inventory in the Textile and Apparel Supply-chain

Type of Inventory	**Explanation**	**Example**
Cycle Stock Inventory	Due to batches of production, created on account of: 1. economies of scale 2. manufacturing process requirements , and 3. process flow management	Fibre production is a continuous manufacturing process where batches are introduced in order to achieve economies of scale and/or production efficiencies.
Work-in-process Inventory	Due to an assembly line or multi-level (echelon) distribution system	Assembly of cut components in sewing of apparels
Decoupling Stock Inventory	To snap continuity in the process and to achieve production economies	Stock of grey fabric for dyeing process
Safety Stock Inventory	To extend customer service based on consumers' demand pattern and product characteristics (to avoid stock outs)	Stocking of SKU's in retail store
Anticipation inventory	Due to seasonality of demand or supply	Stocking of basic merchandise (winter cardigans) in retail store

Source: Adapted from Chandra Charu and Kumar Sameer 2001

The apparel industry is mostly a made to order scenario, based on forecasting retail sales and consequent consolidated orders placed with manufacturers (maybe in a different country). But there is an uncertainty (lack of or no information) at the retailers end about selling patterns, which is why inventory is maintained at retail level. At the manufacturer's end, often raw material is stocked in anticipation (lack of correct information) of buyer's order, these are anticipation inventory.

Inventory management issues also relate to local-information versus global-information control and centralised versus decentralised control (Chandra Charu and Kumar Sameer

2001, Chenet al. 2000 and Simchi-Levi *et al.* 2000). Local information implies that each stage sees demand only in the form of orders that arrive from the stages it directly supplies and has visibility of only its own inventory status, costs, and so on. Global information implies that each stage has visibility of the demand and inventory status of all the downstream stages in the system (Silveret al. 1998). One of the major advantages of global information over local information is that using global information can help significantly reduce the so-called 'bullwhip effect' (Lee *et al.* 1997 and Chenet al. 2000), which can result in important inventory cost savings.

Management of inventories at various textile sectors is proposed as part of an overall production planning and control (PPC) philosophy which integrates inventory policies with appropriate procurement policies and scheduling heuristics (Chandra, 1996a; Lee and Billington, 1993). Due to very high material and labour content of activities at the apparel maker, a materials requirement planning (MRP) model is more appropriate for production planning. This model uses a bill of material for the product, its forecast and/or actual requirements, inventory on-hand, and inventory on-order as inputs and generates orders for the planning horizon.

Zara, for example, does not order as much in advance of season as conventional retailer (six months pre-season stock is 15-25% against industry average of 45-60%). It operates more flexibly with high proportion of in-season adjustment (40-50% in season stock against industry average of 0-20%), very close to make to order model of inventory (Hines and Bruce 2007).

The other two forms of inventory control are consignment and vendor managed inventory (VMI). The APICS Dictionary (Williams 1999) defines consignment as "The process of a supplier placing goods at a customer location without receiving payment until after the goods are used or sold". VMI goes one step further; under VMI, instead of the customer monitoring its sales and inventory for the purpose of triggering replenishment orders, the supplier assumes responsibility for these activities (Fox 1996). Vendor Managed Inventory (VMI) is defined as a mean of optimising Supply Chain performance in which the manufacturer is responsible for maintaining the supplier's inventory levels. The manufacturer has access to the supplier's inventory data and is responsible for generating purchase orders (Taras 2001). VMI is a streamlined approach to inventory and order-fulfilment. With it, the supplier, not the retailer, is responsible for managing and replenishing inventory. An integral part of VMI is EDI, electronic transfer of data over a network (Emigh 1999). In a Vendor Managed Inventory (VMI) model, the manufacturer receives electronic data (usually EDI or via the internet) that tells him the distributor's/retailer's sales and stock levels. The manufacturer can view every item that the distributor carries as well as true point of sale data. The manufacturer is responsible for creating and maintaining the inventory plan. Under VMI, the manufacturer generates the order, not the distributor. Altering inventory management technique to postponement and VMI enabled, inventory went down from 12 weeks to two weeks between IBM and its distributors and eliminated a lot of errors, redundancies, and duplications (Latamore 1999). This was an example of postponement and vendor managed inventory in supply chain. While Zara uses geographically close inventory systems to rapidly transfer sales knowledge to production facilities, JC Penney uses knowledge sharing vendor managed inventory (VMI) system with geographically distant apparel manufacturer, TAL apparel in Taiwan (Rothberg and Erickson 2004).

VMI concept is similar to the concept of 'purchasing postponement' (Aviv and Federgruen 2001, and Bucklin's 1965), where risk is minimised by delaying the purchase of raw materials up to the point of production. VMI does not change the 'ownership' of inventory. It remains status quo. Payment is not made until the item is actually sold. Success in inventory management is measured in improved service levels and in 'turns', the number of times that the entire inventory is replenished annually. The higher the number of turns, the less the time stock gathers dust.

The effect of type of merchandise on VMI is also important. While commodity products hold better yield, fashion products are expected not to gain much out of the initiative. The concern is clear from the following statement from the exclusive manufacturer of Ralph Lauren and LittleMe children's wear (Frastaci 2001).

"We don't do any vendor managed inventory. All retailers that we deal with are major department stores and specialty shops, dealing with a lot of fashion product that's not re-orderable, so its a one-shot deal."
- Doug Schwab, Vice President, Technology, S. Schwab Co.

2.4.5 Quick Response Manufacturing

Quick response is a concept that has become synonymous with the textile and apparel supply chain. Quick response was a concept first developed by KSA in the US, who in a 1986 study of the US apparel industry, found that on an average it took 66 weeks for an apparel product to get from manufacturing into store, despite a total production time of only 11 weeks. The major delay in the supply chain was due to inventory delays (Hines, 2004a), although fabric is also recognised as being a key factor in causing delays. A major strategy during the 1980s and 1990s (particularly in the US) has been to develop quick response (QR) programs to promote responsiveness by reducing lead times, cutting inventories and reducing risk. In 1994, according to Jones (1995), 60 percent of large US apparel and textile manufacturers had QR programmes with their retail customers, and in 1995 the figure had risen to 72 percent. This figure compares well with that found by Fiorito *et al.* (1995) who said that "73 percent of the responding retailers claimed to be implementing some phase of QR".

The most significant difference between quick response and more traditional apparel supply chains is the move towards collaboration and vertical integration in order to improve efficiency in the supply chain. Quick response supply chains are considered to be information driven (Hines, 2004a), but rely on a measure of trust in sharing information. Response within a quick response supply chain is based on the sharing of information i.e. it is demand driven based on sales information, rather that being forecast driven (Birtwistle *et al.* 2003, quoted in Barnes et al, 2006). Within the fashion industry, quick response is centred around the notion of minimal pre-season ordering, taking advantage of improved speed and flexibility in the supply chain by placing more frequent, in-season, small orders (Bruce *et al.* 2004). Production may be pre-booked, but final product specification is not confirmed until nearer delivery time (Birtwistle *et al.* 2003). This has also meant that the proportion of "open-to-buy" budget has increased significantly, all of which leaves a measure of the 'unknown' in the equation.

A number of researchers have addressed the notion of 'agile supply chains' (Bruce *et al.* 2004), which like quick response, describe shorter, more flexible, demand driven supply chains. Quick Response also means "having the talent to reduce lead times and having a flexible workforce" (Jones 2003). Though used interchangeably, both being information driven (Hines, 2004a), responsive and agile supply chains often differ in characteristics. Responsive supply chains are characterised by high demand and low-supply uncertainty. Agile supply chains are high on both supply and demand uncertainty (Lee, 2002). A variety of technologies and management practices related with QR has been identified from industry sources (Coopers and Lybrands Technologies 1991; Ernst and Whinney 1988; Hunter 1990; KSA 1992). QR technology includes automated sewing operations, bar coding, CAD, point of sale (POS) data, short cycle sewing and unit production system (UPS), among others. QR management practices calls for electronic reorder, sharing product info with trading partners, product planning with customer short cycle cut planning, reduced inventory size, small lot orders, scanning fabric rolls, computerized inventory system and shade sorting.

The fast fashion business model is based on either vertical integration (like Zara), or on a shift from Far Eastern suppliers to those closer to the domestic market (like New Look) in order to take advantage of quick response times. However, there are also other perspectives of fast fashion such as Guercini's (2001) 'quick fashion', whereby retailers integrate with suppliers to develop a range renewal service that is not associated with the traditional advanced seasonal plans.

2.5 Value Added Analysis in Supply Chain

A supply chain can also be regarded as an 'added value' chain. "Operating processes that transform some amount and mix of input resources, add appropriate value and deliver the output result to the customer in apparel supply chain are physical transformation to a physical tangible product (cutting/sewing, etc.), desired relocation of goods, services and/or customers through transportation (fabric supply from fabric manufacturer to garment manufacturer), distribution (re-sizing, re-packaging and even collecting disparate items together into a coherent list), and information provision (organises and delivers data in a easy to read report suitable for use by customers) (Macbeth and Fergusson 1994)".

There may also be activities which add no value, e.g. goods in storage, but which may exist for traditional reasons. In summary, there are three types of activities; first, category value-added; second, category necessary but non-value added and third, category non-value added activities (Monden 1993 cited in Hines and Rich 1997). Classification by Womack and Jones (1996) renamed the second and third category as Type One muda and Type Two muda respectively. “Muda” is the Japanese word for “waste”.

Value added activities involve the conversion or processing of raw materials or semi-finished products through the use of manual labour. Examples include activities such as sub-assembly of parts, forging raw materials, and painting bodywork (Monden, 1993 cited in Hines and Rich 1997). Thus, value added activities are the machinery working times required to produce a product. Necessary but non-value added activities (NNVA) may be wasteful but are necessary under the current operating procedures. Examples include walking long distances to pick up parts, unpacking deliveries, and transferring a tool from one hand to another. In order to eliminate these types of operations, it would be necessary to make major changes to the operating system such as creating a new layout or arranging for suppliers to deliver unpacked goods. Such changes may not be possible immediately (Monden, 1993 cited in Hines and Rich 1997) and often not possible to eliminate completely. Non-value added activities or Type two *muda* stands for sheer waste and involves unnecessary actions, which can be eliminated completely. Examples include waiting time, stacking intermediate products, double handling, etc. (Monden, 1993 cited in Hines and Rich 1997).

Value stream analysis of the apparel industry is not new. An example of process mapping exercises in textile and apparel supply chain in US was conducted by KSA during 1986. For a ladies night suit it was observed that total 66 weeks were required from fibre stage to consumer. However out of the 66 weeks only 11 weeks were spent on actual production i.e. spinning-weaving-wet processing-cutting-sewing-packaging-distribution; the rest of the time was inventory delay (Bruce et al. 2004).

Table 2.5 Clothing Pipeline Inventories and Works in Progress

		Inventory	WIP (in weeks)
Fibre	Raw material	1.6	
	WIP		0.9
	Finished fibre @ fibre	4.6	
	Fibre @ textile	1.0	
	Total	**7.2**	0.9
Fabric	WIP – greige		3.9
	Greige goods @ greige	1.2	
	Greige goods@ finish	1.4	
	Finishing		1.2
	Finished fabric @ textile	7.4	
	Fabric @ apparel	6.8	
	Total	16.8	5.1
Apparel	WIP		5.0
	Finished apparel @ apparel	12.0	
	Ship to retail	2.7	
	Apparel @ retail Distribution centre	6.3	
	Apparel @ store	10.0	
	Total	31.0	5.0
	TOTAL	**55.0**	**11.0**

Source: Lawson, King and Hunter, 1999

The break up of working time (termed WIP in table 2.5) and inventory time is shown in table 2.5. Apparently, the analysis combines the necessary non-value added activities with the 'value added' category, thus the value added component comes out to be 17% approximately.

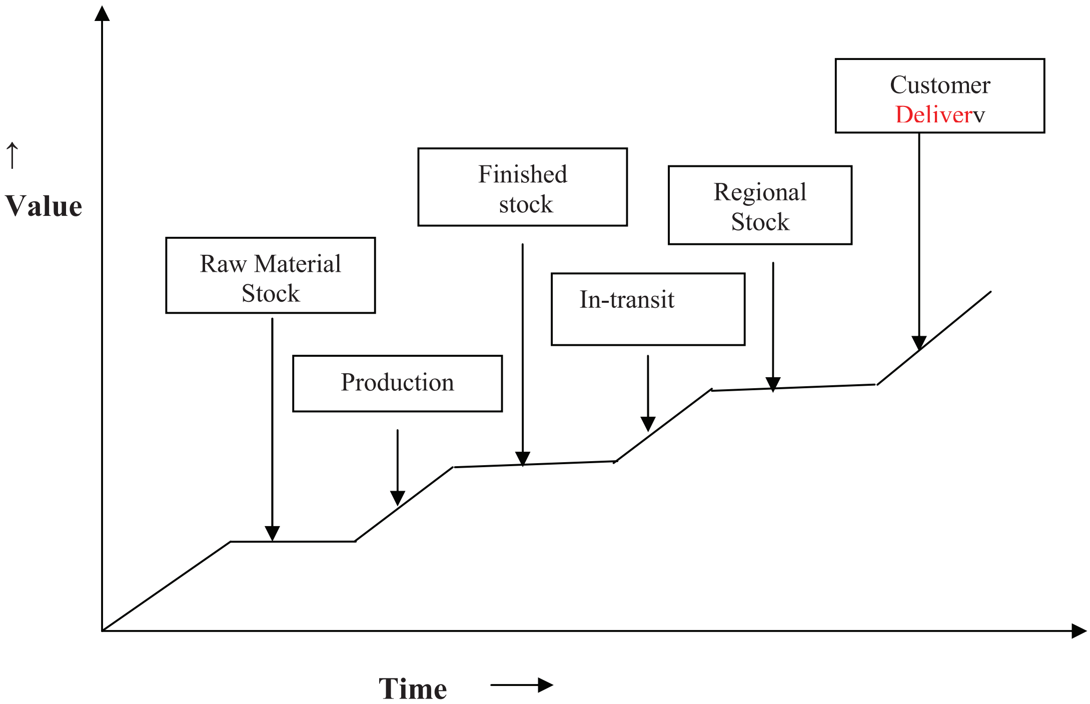
Since inventory was identified as the prime reason behind an excessively long supply chain, efforts were made to develop manufacturing systems with less inventory as a buffer. With simultaneous market change from mass market to individualistic (Piore and Sabel, 1984), the quick response concept came into being; modular/team work and Toyota Sewing System were introduced. In traditional progressive bundle unit system inventory (work in process) was being maintained between every sewing operation in first in first out (FIFO) logic. Throughput time for assembling a garment used to be calculated as process time plus waiting time in between operations. The multiple days of inventory in factory sewing floors is reduced to zero in the Toyota Sewing System (TSS), resulting in the components being moved between operations in a hands-off approach, leading to a quicker throughput time for sewing. Modular manufacturing surely increased value addition percentage in sewing but pre-production and product development activities still consumes a major chunk of non value added time and will be studied later in this research.

2.5.1 Representation of Value Added and Non-value Activities

One approach to diagrammatically represent value addition in a supply chain is given by Christopher (Christopher 2007a) in Figure 2.17. Activities where value is added over a period of time are represented by diagonal lines, for example production, in-transit, etc. Where inventory between activities and the waiting time is a cost adding time, it is represented by a horizontal line.

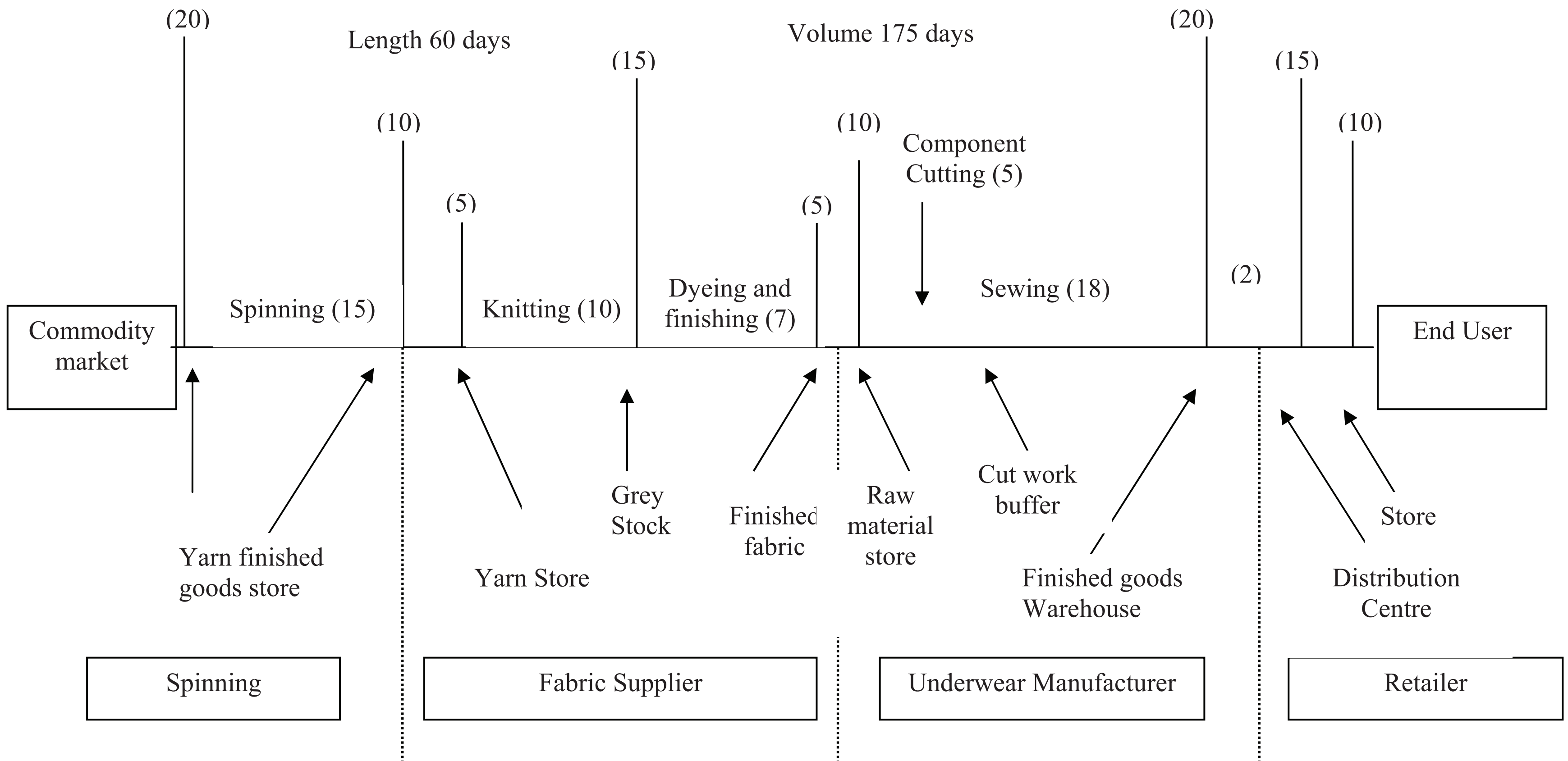
A different representation of value added and non-value added activities was advocated by Scott and Westbrook (Scott and Westbrook 1991 cited by Christopher 2007b), as seen in Figure 2.18. In this diagram, horizontal lines represent the average process time while vertical lines (drawn to the same scale) represent the waiting time in the queues for each process. The representation shows two useful measures: the sum of the horizontal lines is the process lead time and indicates responsiveness to a demand increase within same stock constraints. Pipeline volume is determined by adding vertical and horizontal lines together and indicates the time taken to respond to decreases in demand, given the same rate of manufacturing throughput.

Figure 2.17 Value and Cost Addition



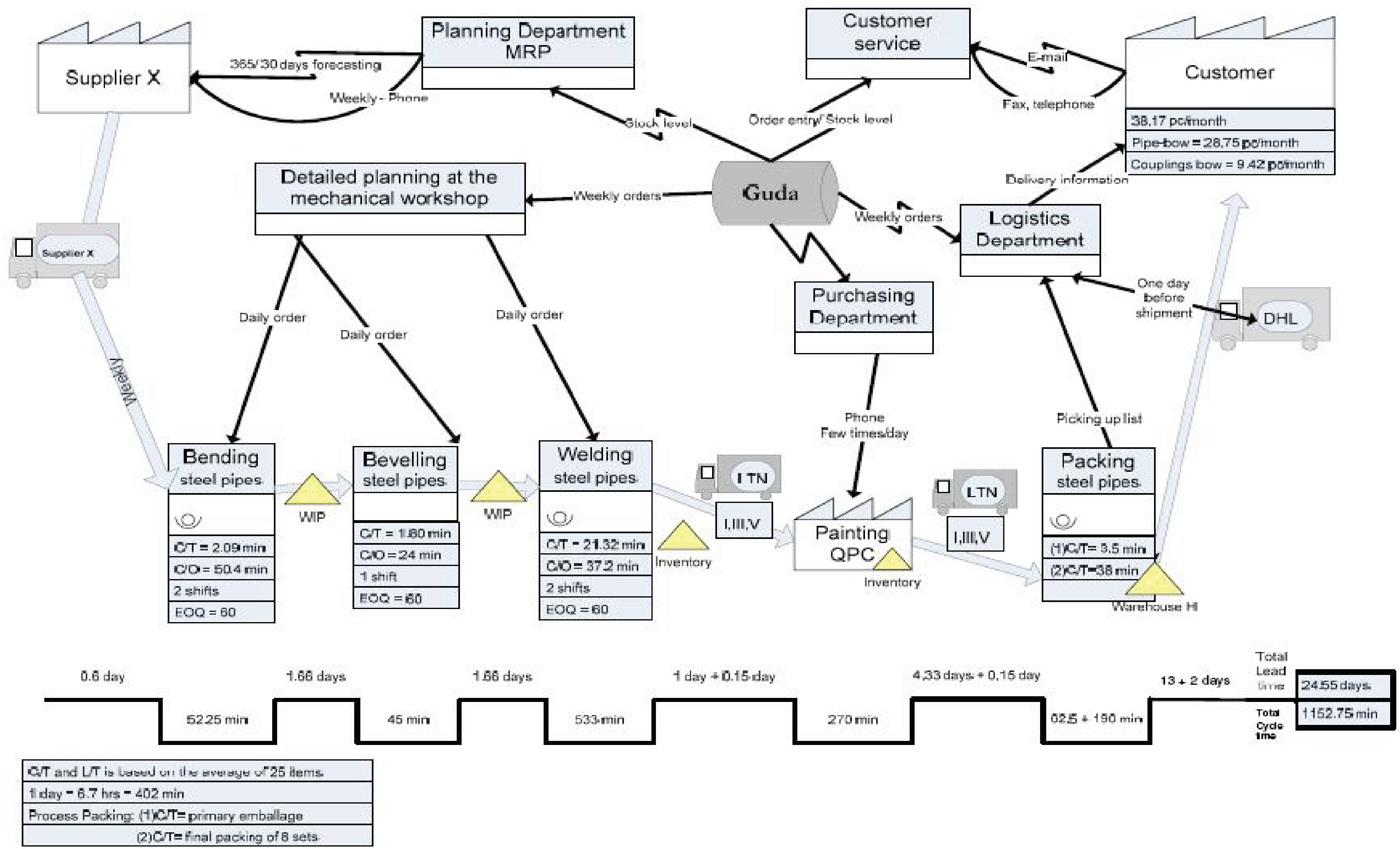
Source: Christopher 2006

Figure 2.18 Value Added and Non-value Added Activities



Source: Scott and Westbrook 1991 cited by Christopher 2006

Figure 2.19 VSM: Value Added and Non-value Added Activity Representation



Value stream mapping is another tool gaining tremendous popularity for measuring and expressing value added and non-value added activities in a supply chain. Value Stream Mapping (VSM) is a Lean technique used to analyse the flow of materials and information currently required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as 'Material and Information Flow Mapping' (Rother and Shook 1998). Hines and Rich (1997) defined seven Value Stream Mapping tools: Process Activity Mapping, Supply Chain Responsiveness Matrix, Product Variety Funnel, Quality Filter Mapping, Forrester Effect Mapping, Decision Point Analysis and Overall Structure Maps. It is the process activity mapping that records the value added and non-value added activities in a supply chain.

Value stream mapping of manufacturing enterprises in developing countries are just catching up as an important benchmarking tool for supply chain efficiency. Literature available on value stream mapping for several non-apparel and apparel organisations reveals that value added activity ranges from a mere 1 percent to 11 percent. Value stream mapping of a modular rubber screen panel manufacturing organisation (Carr 2005) reveals only 6 percent activities are value added and 94 percent activities are non-value added. In another first tier, an automobile steel component supplier (Tylor and Brunt 2001) shows the value added proportion of time to manufacture one sub frame was 4922 seconds and the time spent by steel in the plant i.e. from entry as steel to departure as a finished component is 13.07 days. This means value was being added for only 1.38 percent of the time that the steel was on site. Value added time for a knitwear manufacturer in Bangalore, India being measured for activities from bulk fabric arrival to shipment are a little above 4 percent (Agarwal and Sahani 2007). Value added activities of a steel pipe manufacturer is found to be 11 percent and non-value added activities 89 percent (Belova, Inesa Martinkute and Zhu, Yansong 2008). In an equalizer beam manufacturing process in India, the value added time was found to be roughly 3.5 percent (Grewal and Singh 2006).

However, there are several cases where commercial literature classifies all activities into just two categories: value added and non-value added, wherein necessary non-value added activities were clubbed with the value added category. This explains how 33 percent of the resources allocated to supply chain processes were identified as non-value adding (GEAC 1998). On a similar note, a case study on Indian apparel manufacturer (Singh and Arora 1998) reveals that the percentage of non-value added time is inordinately high in every department, with fabric manufacturing accounting for 89 percent, cutting 65 percent, sewing 82 percent and finishing 76 percent. Fabric manufacturing takes nearly 80 percent of the total non-value added time in the supply chain.

2.6. Information Technology in Supply Chain Management

"With information technology, the value of inventory is quickly being replaced by the value of information,"

- Kevin Rollins, former President and CEO, Dell Computers

The role of information technology (IT) in managing supply chain is unpredictably straightforward (Stein *et al.* 1998). At almost every step, technology had simplified repetitive tasks and provided greater capacity to gather and analyse critical information (Gattorna 1998e). Information Technology also serves as the eyes and ears (and sometimes a portion of the brain) of management in a supply chain, capturing and analysing the information necessary (Chopra and Meindl 2005c). The effect of IT adoption in a supply chain may be classified into three areas; operational, strategic and financial. Among the operational benefits relevant for the research were better efficiency and pre-emptive capability (Sethi and King, 1994), faster delivery period (Hwang and Weil 1998) and evidence of enhanced communication capabilities (Andersen and Segars 2001).

Application of IT in Apparel Manufacturing Process (StitchWorld 2006) listed suggested use of IT solutions in design and forecasting, raw material development, colour management and pattern making for efficiency, accuracy and speed in product development.

Use of web based forecasting services, illustration and storyboard software enables a designer to create and share a collection digitally, faster than in the manual mode. The design team can use fabric simulation software enable to create print/weave/knit fabric digitally, make digital pattern using CAD, try numerous fabric rendering options digitally, try the fit of the garment on digital dress forms, and numerous ‘what-if’ options thereby saving precious time and money in the PD cycle (Sareen 2006). Lately videoconferencing is also used by companies to showcase new product collection to buying and design team in UK backed up by actual fabric swatch couriered earlier (Whitehead 2001).

Pattern making and marker making service is available in cloud-based computing mode (Assyst 2008, Stitchworld 2005, Lectra 2008) to enable small organisations to apply the IT advantage without huge capital investment. Tukaweb offered pattern making, grading, marker making and even fit sample make services to North American and European retailers through its business process outsourcing (BPO) model (Tukaweb 2002). Any design house in developed economies wanting to outsource its product development activities can upload the style specification to the Tukaweb site. The specification is downloaded at a BPO centre in India, China or Vietnam; a pattern is made, virtually fit tested in 3D model, altered and uploaded back to the web. Apart from taking advantage of cheap labour wages in new industrialised economies, this model also uses the geographical time difference to its advantage. For example a measurement specification submitted at end of the day by a design office at New York can be ready next morning.

Digitally printing fabric directly from a computer is said to have reduced the sample making time in actual fabric from 14 days to 4 hours (Gerber 2003). 3D motion simulator for fit development and fit verification, with colour tension mapping, X-Ray vision and many other features accurately simulate real fit sessions, with results that are identical to actual fit sessions – but without physical samples. Many retailers have eliminated physical samples while approving digital samples to save time (Sareen 2008). Now, even the sample fit can be checked on an i-phone and fit comments sent while travelling. Live video streaming and innovative still photography application over the net (www.shapelyshadow.com) enables a manufacturer-buyer discussion to sort out sample fitting remotely. These IT applications enabled PD activity to be more efficient, accurate, first time right, cheaper, with crucial time saving being the prime achievement.

Colour approval requires a physical swatch to travel back and forth between buyer and manufacturer across continents, wasting valuable time. A computerised colour management system can use a calibrated monitor to approve colour digitally without a physical sample being couriered. Marks and Spencer reported that a computerised colour management system enabled them and their suppliers to communicate colour codes back and forth, reducing physical swatches by 20-25% (DNR 2000).

In pre-production, IT solutions are available for cut planning, labour costing, thread costing, product data management and critical path management (Application of IT in Apparel Manufacturing Process 2006). Cut planning software replaces the existing method by a rational/scientific method using an optimal combination of marker and layer (Jana 1999). Labour costing software enables planning of sewing time (and calculating labour cost) scientifically, using pre-determined motion time systems. Product data management and critical path management applications aim to organise the interdependent maze of pre-production and production activities for every style/order by maintaining a digital style file, automatic reminders, alerts and a to-do list. However these IT solutions for pre-production activities are not commonly used by small and medium organisations (Bheda & Shanbhag 2000). Although use of critical path approach was reported in numerous publications (section 2.4.2), use of software in critical path implementation was not found in the literature. At Oxford Industries, the cost of labour for each garment was lowered by $0.15−$0.20 apiece after implementation of demand planning and production planning solutions from Manugistics (Hirschkind 2001). Liz Link, Liz Claiborne's custom developed order-tracking system, tied the systems together via client-server technology, linking factories, freight consolidators and customers.

In organisation level applications, Enterprise Resource Planning (ERP) and SCM software give control over operations, can communicate with all partners in the supply chain on time, and, most importantly, can analyse organisational data to help in the decision making process. Using XML (an infinitely extensible mark-up language), one can operate within one's own systems and use a common mark-up language to share information with their partners (White 2000). The use of software-based solutions for supply chain performance improvement was reported by several users like L.L. Bean and Healthtex. L.L. Bean implemented DAMA-developed software, called TEXNET, designed to enable the secure exchange of information over the Internet. It facilitated reduction of stockouts and markdowns for the retailer and reduction of wasted inventories and reduced lead time (from 70 - 98 days to 28-35 days) for the garment manufacturer and the textile mill (Vosti and Wimple 1997). Healthtex improved their on-time shipping to a consistent 85 to 90 percent and reduced raw materials, work-in-process inventory and finished goods inventories up to 10 percent after RHYTHM (www.i2.com) was implemented (Hardin 1999).

Previous studies regarding performance effect of IT have frequently provided inconsistent results. While some studies reported positive IT-performance relationship (Byrd and Davidson, 2003), others provide mixed evidence (Weill, 1992; Yosri, 1992; Hitt and Brynjolfsson, 1996). In a 1997 KPMG survey of companies with the experience of introducing new MIS systems, it was found that while companies were happily installing systems, they were not realising any benefits from them (GEAC 1999).

2.7 Global Apparel and Textile Supply Chain

The global fashion and apparel industry is highly segmented; each segment presents different challenges and requires a unique supply chain solution (Rushton and Walker 2007). At the lower end, retailers like Wal-Mart, Tesco and Carrefour buy huge quantities of garments and sell predominantly own brands at low prices. The mid- range features quality brands and retailers like Levi Strauss, Gap and Marks & Spencer. Hugo Boss, Ralph Lauren, and Burberry come in the premium range. Retailers have become increasingly powerful in recent years with Wal-Mart (US), Carrefour (France), Ahold (Netherlands), Tesco (UK), Metro (Germany), Kroger (US) leading the way. The combined turnover (including grocery) of these six retailers was US$ 600 billion (Forbes 2006, quoted in Mintel 2007), more than the global apparel and textile trade. Globally there is a continual trend to polarise between premium and value retailers (Mintel 2008). Post 2005, quota free environment had created a level playing field in global sourcing. However, the growing instances of free trade agreements started influencing the global apparel supply chain as it favoured business between some countries while acting as a non-tariff barrier for others.

While the industry is globalised and migratory in nature, it has a curious penchant for simultaneous consolidation and vertical integration. While product differentiation is the key, standardised work procedure is the constant drive. As the industry boasts of responsiveness as a key descriptor of success, it wants to be simultaneously lean. The apparel and textile industry can be best described as under:

*"More choice in existing product range, more choice through new products, more customisation, faster satisfaction of need, freedom to change late in the order cycle, increasing level of customer service (*Macbeth and Fergusson *1994)".*

Global trade in textile and apparel in year 2006 was US$ 530 billion, out of which clothing was US$ 311 billion (WTO 2007). Global apparel exports are largely dominated by developing countries from Asia (52.3 percent), Europe (34.4 percent) and North America (4.2 percent). China leads the country-wise exports at US$ 95.3 billion followed by the EU at $ 83.4 billion. The EU leads imports at $ 141.2 billion followed by the U.S. at $ 83 billion and Japan at $ 23.9 billion.

Some of the specific characteristics of the apparel supply chain are:

- The apparel and textile industry is migratory in nature. While the design and concept development takes place in a developed country, i.e. near the point of consumption, the sourcing and manufacturing facility has continued to migrate to developing countries in search of cheap labour (Gereffi, 1999, 2001; Dicken, 1998). This multi-country operation required efficient movement of goods and information. Efficiency of a supply chain will depend on how much time it is required to design, manufacture and supply the goods to store and at what cost.
- The industry has vested interest in planned obsolescence which necessitates frequent product development (Jones 2006a). The majority of European, North American and Japanese retailers manufacture a significant percentage of clothing offshore. Most still launch four to six collections per year (Rushton and Walker 2007). However, new product introduction of 12 times a year or more is becoming a common phenomenon for fast fashion retailers (Mintel 2007). Another important characteristic of the industry is product variety, fashion content and seasonality. As material flows downstream from fibre to retail, the fashion content in the product increases, thus SKU diversity also increases phenomenally (Massey 2000). A typical fashion retailer may have 10,000 SKU at any given point of time. This adds complexity to operational parameters, specially in adopting any legacy MRP or ERP system implementation leading to non-standard product development, sourcing and manufacturing practices across the industry.
- The retailer and manufacturer generally belong to different countries. Both are generally exposed to different cultural, socio-political and often technological scenarios. On the one hand, there are large financially powerful retailers (of $100 million or more average turnover) and on the other, there are small fragmented manufacturers (of $10 million or less turnover); this results in an adversarial relationship between manufacturers and retailers, which inhibits best

practices and transparency, resulting in the generation of supply chain inefficiencies. (EMAP 1998/99. p 154 cited in Jones 2006).

- The apparel supply chain is driven globally by large self-centric retailers, whose sourcing criteria differ from company to company. Different buyers seek different products, have different clients, different approaches to business, different core competencies and different levels of willingness to give up control and allowing manufacturers to take responsibility of more functions in the value chain (Lezama *et al.* 2005). There is very little sharing of knowledge across organisations. Every organisation feels proud to be different from others.

Large self-centric retailers want to be uniquely different from each other in sourcing criteria, but high SKU and frequent new product introduction pose operational complexities. Thus one of the greatest challenges faced by the industry is how to achieve excellence in product development.

The textile and apparel value chain is organised around five main parts: raw material supply (including natural and synthetic fibres); textile manufacturing; production networks made up of garment factories (including their domestic and overseas subcontractors); export channels established by trade intermediaries; and marketing networks at the retail level (Gereffi and Memedovic 2003). As explained in rationale (chapter 1.6), the production networks will be investigated, thus emphasised in this research.

2.7.1 Recent Researches in Apparel and Textile Supply Chain

The word 'recent' in supply chain research is difficult to define due to the pace at which research is taking place and theories are re-written. Different research initiatives in the U.S. during the 1990s culminated in development of several standards like VICS (Voluntary Inter-industry Commerce Standards) and metrics, which are repeatable and lead companies to measurable benefits. One such tool developed by the DAMA (Demand Activated Manufacturing Architecture) project is the Supply Chain Simulation for mid- and high-level planners (Lovejoy and Curran 1999). Supply Chain Simulation is a computer-based tool for supply and demand analysis that uses supply chain information exchanged among strategic business partners in a customer-supplier relationship. Traditional Industry Supply-Chain Simulation (TISS) and Collaborative

Industry Supply Chain Simulation (CISS) models were developed. These models include additional logic to model both lead-time and inventory cost. The CISS and TISS models are used to demonstrate the broader impact of building a supply chain based on DAMA Architecture (Lovejoy and Curran 1999). Research in Europe focussed on structural changes and technology intervention for lead-time compression in fabric supply (Forza and Vinelli 2000), the role of intermediaries (Popp 2000) and different sourcing methods.

Different types of products require different sourcing approaches, though their percentages vary in different countries, but a common trend noticeable across the U.S. (Abernathy *et al.* 1999a) and Europe (Oxborrow 2000) is that *fashion-basic product* percentage is reducing at the expense of both ***Fashion*** and ***basic products***. An Eurovet study (Walwyn 2002) mentioned four different methods of sourcing for Europe while Oxborrow classified the same into eight (Oxborrow 2000).

Reversing the trends to outsourcing and offshore sourcing has become significant to the survival of companies in developing economies from this sector. Design-led supply chain risk management (McLaren et al. 2002) thus presents a case for recognising design as more than a creative function but as a platform to manage risk in supply chains.

Since the Harvard Centre for Textile and Apparel Research (HCTAR) study on lean retailing (Abernathy et al. 1999a), the debate over lean and agile continues. Contemporary researchers maintain that a commodity product supply chain should be lean while fashion product supply chain can be agile (Fisher 1997, Abernathy et al. 1999a). A review of supply chain practices in the last two decades (Lam and Postle 2006) reiterated that companies used responsive supply chain strategy for innovative products and efficiency supply chain strategy for functional products. These two supply chain strategies are focused on the downstream supply chain aiming at shortening the time to research the market and also to reduce stock levels in the retailing industry. However, recent researches suggest both are not mutually exclusive; instead, the best of both should be extracted through the leagile concept (Towill and Christopher 2007). Leagile is where upstream supply is relatively stable but downstream demand conditions are variable, e.g. in fashion clothing.

Lean logistics techniques such as cross docking (synchronisation of delivery from supplier and picking for store delivery to avoid warehouse storage) has been assisted by technology as well. Manufacturers ship merchandise to DC in pre-packs required by each store. The floor-ready merchandise is assorted by laser guided conveyor belts that read the UPC labels. The re-assorted goods are loaded into trucks at the other end of DC to the store (Pradhan 2007). The recent concept of fourth party logistics service provider (Christopher 2006d) enabled by RFID technology will add efficiency and may set new benchmarks in the logistics service.

Since the ZARA phenomenon hit the fashion industry, researchers are trying to explore the 'fast fashion' or 'high clock speed' industry. Exploratory research with four Dutch multinational firms operating in industries with different 'clockspeeds' revealed that, with increasing clockspeed, the use of inventory as a means of providing slack against uncertainty decreases, whereas the use of lateral relations increases. Remarkably, the role of outsourcing is substantial in both low- and high-clockspeed settings, but limited in the intermediate group. Opposed to this, the role of vertical information systems is limited in low- and high-clockspeed industries, but substantial in medium clockspeed firms (Meijboom et al. 2007). Hines and Bruce (2007) summarise the fast fashion business model in comparison to traditional sourcing.

Table 2.6 Difference between Traditional and Fast Fashion Business Model

Characteristics	**Traditional apparel retailing business model**	**Fast fashion retailing business model**
Supply strategy	Efficiency – driven large volumes planned at lowest total cost.	Responsive to customer demand. Small-and medium sized volumes in response to customer identified by store data
Manufacturing operations	Outsourced to a number of different supplying contractors based on best prices (often globally). Do not own their supply chain but need to try and control it through standardised systems, policies and procedures. Larger organisations are bound to exert pressure.	Backward vertical integration enables organisations like Zara to manage closely the different supply chain operations from design to store. Own much of their supply chain. What they do not own is closely controlled and relatively local in Spain, Portugal and Morocco with short lead times.
Lead Times	Long lead times: 12-16 weeks fabric, 6-10 weeks apparel production, 2-3 weeks	Short lead times: 8-10 days on some lines, most within 15 days including store shipment.

	shipping times	
Demand based on	Forecast well in advance of the selling season.	Forecast much closer to season and heavily influenced by real time demand data transmitted from stores.
Replenishment	Inventory levels trigger automatic replenishment orders from suppliers at pre-agreed contract prices	No replenishment – when it's gone it's gone; move onto the next hot fashion.
Fabrics (textile chain)	Various fabrics produced to specification by Textile Mills, 12-16 weeks lead times, production has to be booked well in advance.	Mainly standard 'greige' fabrics, piece-dyed to seasonal colours in demand.

Source: (Hines and Bruce 2007)

Turning away from operational systems, a research interestingly reveals that for fashion supply chain organisation and management between the U.K. and China, attention should be focussed on improvement of three common aspects that could inhibit performance: deficiencies in design specification, language barriers, and cultural/human barriers (Chen et al. 2007). Retailers ignoring ethical issues risk a backlash against the true cost of clothing. Value-oriented companies do not want to make an issue of this, but ethical issues are an important point of difference for which people are prepared to pay a premium (Mintel 2008). Continuing the trend among manufacturing companies to reduce supplier base (Macbeth and Fergusson 1994), retailers are reducing supply base as it is easier to develop trust/relationship on a long term basis for investment in systems and technologies to improve overall efficiency.

This is a clear departure from the previous understanding of SCM and its associated theories (agile supply chains, JIT, QR etc) which have been largely supply driven concepts. Although some may argue that QR is a market driven concept, the key difference in fast fashion is that it is a concept derived as a direct consequence of changing expectations and demand from consumers, compared with QR which was developed as a result of supply needs in the face of low-cost competition. Fast fashion is so much in demand that retailers are doing every bit to keep ahead of competition. To compete in fast fashion, the Limited cut the length of supply chain by dropping the distribution network and developed a relationship with Li & Fung, a 'supplier conglomerate' from HK (Li 2007) to adopt a build-to-order and replenish-to-sale business model. Fast fashion actually is placing pressure on supply chains to increase the number of suppliers (rather than rationalising the number of suppliers) used by retailers. Consumer demand is for a larger variety of styles that are changing more frequently (Barnes and Greenwood 2006).

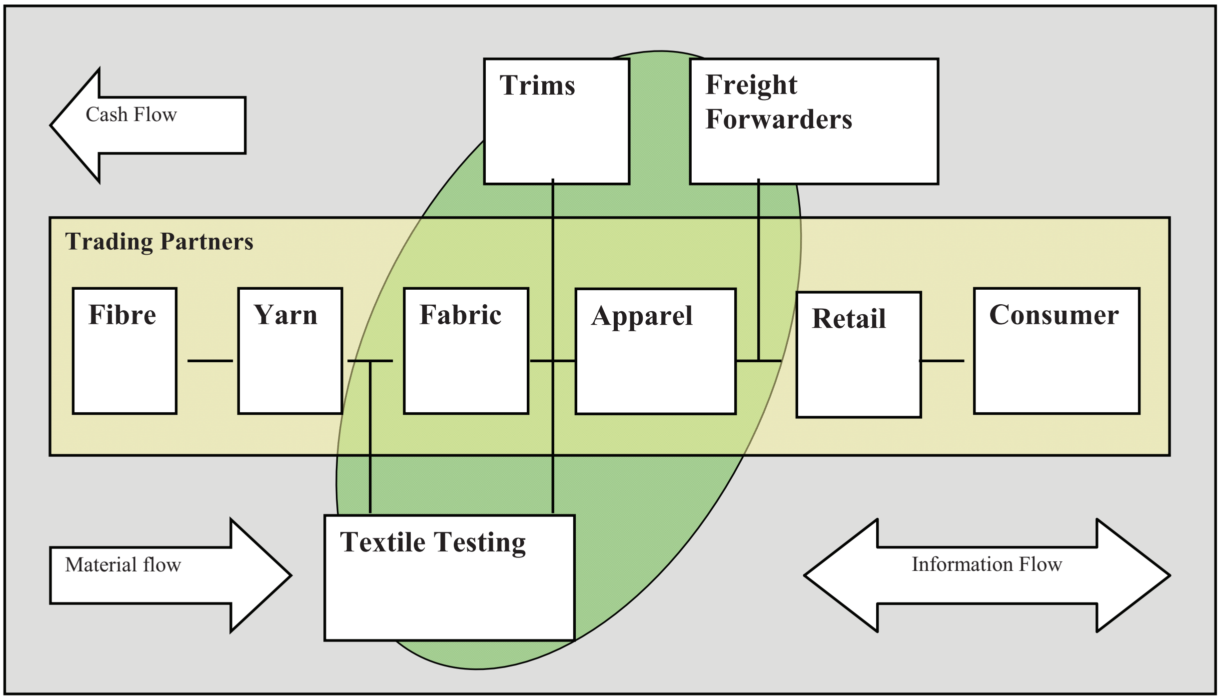
Product development and quality control are being eliminated from the supply chain process in an effort to be more responsive to consumer demand. ". . . there isn't time for product development in a six week cycle, or whatever it is for fast fashion. . . The retailers and manufacturers both have to say this is fast fashion, what do we have to compromise on or sacrifice to get the right product but get it to store fast?" "We sometimes have huge quality issues with garments that have maybe skipped a test or fit session to get into the shops quicker as the lead times we have been given are very tight".
(Barnes and Greenwood 2006)

It could be concluded that consumer demand is such that they are willing to sacrifice some elements of quality and design content and corporate social responsibility issues (when factories are running late to deliver fast fashion on time) in favour of having a particular style or look faster to consumer. (Barnes and Greenwood 2006).

2.7.2 Indian Apparel and Textile Supply Chain

Raman (1995) documented the supply chain for woven fabric apparel in India, which shows how the different players from cotton firms to shipping agencies are linked in the apparel supply chain. A basic apparel and textile supply chain structure for India by Chandra (2006) from fibre to retail distribution channel given in Appendix III will explain how the textile and apparel are interlinked. However, the structure lacks depth in apparel and downstream portion. As the scope of the research is contract manufacturing supply chain in India, primary focus will be on the apparel manufacturer and its supplier and customer network. The scope of research is marked by the shaded areas in the following figure. (Figure 2.20).

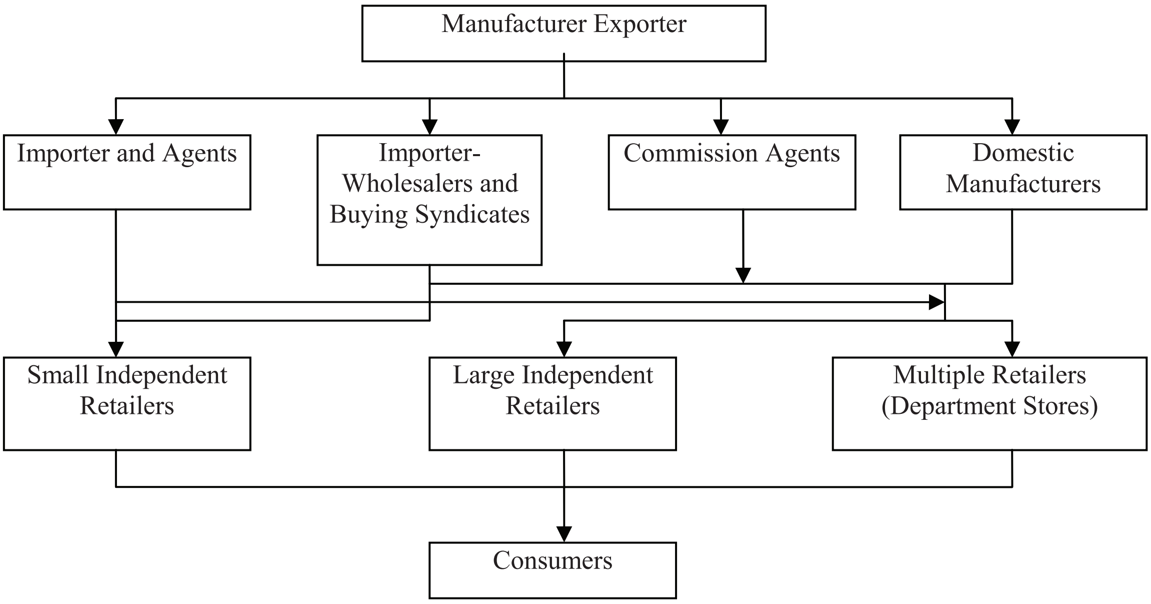
Figure 2.20 Sourcing and Manufacturing in Supply Chain



From the above figure it is clear that fibre and yarn in the upstream section and retail and consumer in the downstream section are out of the scope of this research. Primarily, there are apparel manufacturer, fabric supplier/manufacturer, trim supplier/ manufacturer, which are called echelons in the supply chain.

The term 'distribution channel' is commonly used to indicate how the merchandise is distributed to the end consumer by a retailer (chapter 2.1.3) after procurement from a manufacturer. The channel through which merchandise is procured by a retailer from a manufacturer can be called 'procurement channel'. Figure 2.21 shows an example of multiple procurement and distribution channels for exporting men's shirt for a Western European buyer.

Figure 2.21 Procurement and Distribution Channel for Men's Shirts for West European Buyer

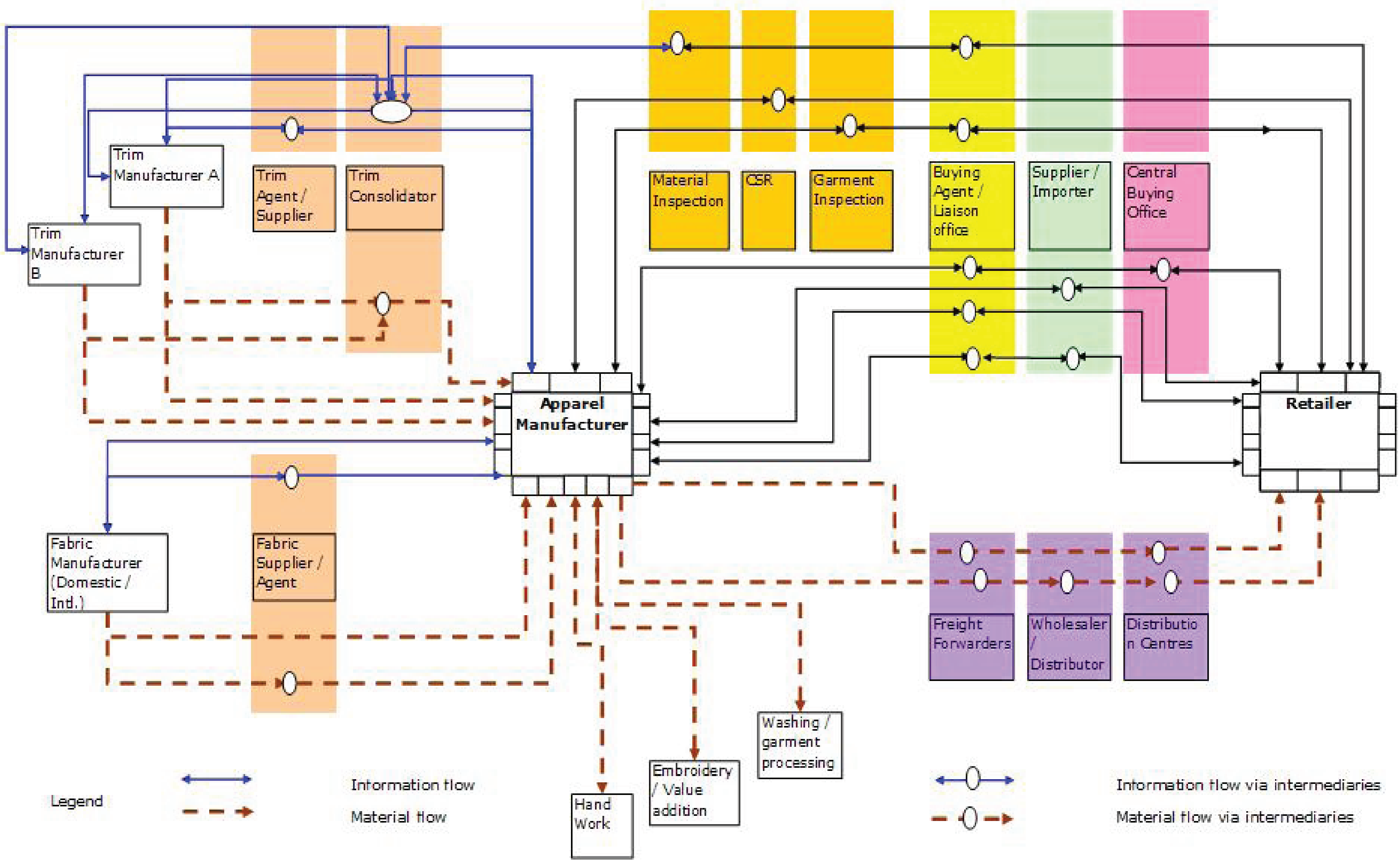


Source: Effective marketing to UK, US and Japan; Dr. D.O. Koshy

Figure 2.21 shows only multiple options of sourcing and distribution. However, if the link is expanded further and micro-details looked at, then there are intermediaries like agents/distributor/wholesaler and secondary players like testing services and subcontractors, who play an important role in the flow of information and material. A comprehensive picture of contract apparel manufacturing supply chain with information and material flow is given in figure 2.22.

Figure 2.22 shows that between an apparel manufacturer and retailer, there are intermediaries for procurement of buying agencies, liaison office, importer, central buying office, etc. Information flows between apparel manufacturer and retailer via these intermediaries. The material flow takes place through either a wholesaler/distributor or directly through the retailer’s distribution centres (DC). If the information or material flow passes through an intermediary, where the intermediary has a role to play, it is shown with an oval in the flow path. The figure shows multiple options of information and material flow between any two echelons.

Figure 2.22 Indian Apparel Manufacturing



For procurement of fabric, there are intermediaries between the apparel manufacturer and also the fabric manufacturer; however, there are cases where an apparel manufacturer directly procures fabric from the manufacturer. Trims and accessories are either procured directly, or through agents or trim consolidator in case of imported items. The information often flows via fabric suppliers/agents; however, the material was delivered (material flow) directly from the fabric manufacturer to the apparel manufacturer. Similarly, information flows through a buying agent or central buying office, but shipment flows directly to retailer's warehouse.

Large manufacturers may have in-house embroidery and or garment processing units, but in the case of small and medium exporters, these activities are often outsourced. The unique strength of Indian merchandise is value addition through hand work, which is again outsourced. There are third party service providers like freight forwarders, material and garment quality inspection agencies and compliance agencies.

While strength of Indian manufacturers is product development (2.3.2) it was seen that pre-production activities are delayed beyond schedule, thus putting pressure on cut-sew-finish activities (Angrish 2002, Bhat 2001). Even in case of delivery date extension (increased lead time) the actual production time (cut-sew-finish activities) generally remains unchanged (Angrish 2002, Naik 2000). While delivery date extension is not possible the actual production time (cut-sew-finish activities) is often reduced to accommodate stretched pre-production time resulting compromised process and product quality (Naik 2000, Banerjee 2000, Hinduja 2003, Bhat 2001).

2.8 Summary

Section 2.1 discusses how information and material flow influences supply chain collaboration. Mason-Jones and Towill (1999c) concluded that moving the information decoupling point as far upstream as possible, by ensuring access to undistorted market order information to all members of a supply chain, has beneficial consequences for supply chains as a whole.

Section 2.2 discusses the evolution from vertical integration to partnership, their comparative advantages and disadvantages in the context of supply chain collaboration among trading partners and lead time compression. Advantages of better control and faster communication from vertical integration can be explored for vertically integrated organisations, whereas literature does not report any tangible link towards lead time compression. Literature reports a rising trend of geographically dispersed vertically integrated operations that tend to benefit from global core competencies while simultaneously enjoying the benefit of vertical integration.

Section 2.3 discusses product development in global and Indian apparel industry context. PD in apparel means more of more of market research and marketing analysis and less of idea generation, product design, and detail engineering (Trot 1998). The Indian industry requires improving its product development efficiency, especially the pre-production approval processes, literature on concurrence and/or collaboration has established its proven record to improve product development efficiency through reduced cost and faster time to market, among various other benefits. This paved the way for exploring collaborative and/or concurrent product development in the Indian apparel manufacturing scenario.

In the retail industry, postponement of product development process offers the possibility of customers to collaborate in the product development process. However, as the scope of this research is focussed towards garment manufacturers, the postponement strategy in product development could not be explored.

Section 2.4 discusses several supply chain optimisations techniques and analyses the possibility of exploring them as a time compression tool. Postponement strategy was found to be useful for shifting the point of differentiation as late as possible and thus altering the value addition curve in such a way that the bulk of the cost is added as late as possible. Although postponement of the PD process can lead to a mass customization scenario, where customers are collaboratively developing the product, there is no scope for lead time reduction.

The critical path method was reportedly used for conformance to pre-production milestones by U.K. and U.S. buyers on manufacturers in Hong Kong, Turkey and India. While critical path was a commonly used application it was rarely used from the standpoint of operation research logic. It is probable that oversimplification of the critical path method by using start-lag time and pushing all activities into the critical path has taken scientific logic away from it. Even though the critical chain was found to be more aligned towards application in human controlled projects, (like garment manufacturing supply chain), and effectively used for time compression in project management, no literary reference was found about its application in garment industry. This makes a strong case for exploring critical path and critical chain in apparel manufacturing.

Lean philosophy focusses on waste minimisation and is centered around creating *more value with less work. While it's value stream mapping tool may be a useful technique to* identify and measure value added and non-value added activities in the manufacturing cycle, other techniques like Five S, Kanban (pull systems), and poka-yoke (error-proofing) do not offer substantial scope in lead time reduction of the manufacturing supply chain.

Several inventory management techniques in the apparel industry were discussed. Vendor managed inventory and consignment was a common practice between retailer and manufacturer, While both JIT and consignment try to minimise inventory level, in the former approach both possession and ownership of physical inventory remains with the supplier (and delivered to manufacturer just when needed), whereas in the latter approach, possession of physical inventory is with the manufacturer but ownership remains with the supplier (and billed just when consumed). To practice JIT, manufacturer's scale of operation was important to leverage relations with the supplier and geographical proximity was found important, whereas for consignment, it is of less significance. While JIT is more accepted practice in manufacturing environment, literature on consignment between the apparel manufacturer and their suppliers is rare. Although inventory management techniques are found to be effective in making the supply chain lean, they have no role in lead time compression.

Within the fashion industry, quick response is centered around the notion of minimal pre-season ordering, taking advantage of improved speed and flexibility in the supply chain by placing more frequent, in-season, small orders. While QR was primarily initiated to supply small volume, high fashion orders with minimum inventory, this was also an effort to retain the manufacturing industry in developed countries. Unlike many neighboring countries, the Indian apparel manufacturing industry offers higher PD potential (ApparelOnline 2007a) and is increasingly asked for by customers for responsive and smaller batch production (ApparelOnline 2007b, Jones 1999). Indian manufacturers require to develop quick PD capability, achieve higher sample conversion rate, reduce iteration in approval and produce with lower throughput time. While the make through system of production in NCR (Bheda & Shanbhag 2000) can make the garment in least throughput time, PD and pre-production activities are slow and require reduction of lead time. Thus identification of delay-contributing activities in manufacturing cycle, measuring durations of those activities, locating reasons behind delay and suggesting means of reducing it justifies the third objective (section 1.5).

The lead time reduction technique discussed can be further classified into four different categories based on the engineering procedure being adopted: elimination, compression, integration and concurrence (Towill 1996). The elimination, integration and concurrence technique often requires agreement from other supply chain echelons to implement. As the scope of the research (section 1.5) was to develop a generic solution which can be applied across industry, it was decided to choose the compression technique for longitudinal research. Critical path and critical chain were also found to be a compression technique to lead time reduction (Towill 1996), thereby making it an ideal option to choose for longitudinal study.

Section 2.5 discusses different value analysis techniques and appropriateness of using the same for measuring value added and non value added tasks in manufacturing cycle. Value stream mapping was selected for longitudinal study.

Section 2.6 discusses the role of information technology in collaborative product development and in supply chain optimisation. It was discussed how web based marker making applications and CAD process outsourcing are helping organisations across the globe to collaborate in the PD process. It was also discussed how CAD process outsourcing in different geographic time zones can reduce cycle time. It was shown how quicker and more accurate data capture and electronic data interchange (Towill 1996) help supply chain optimisation by time compression through re-engineering interfaces between successive processes or through removing time within a process.

Section 2.7 discusses the challenges of Indian supply chain in the background of global parameters. On the one hand, large self-centric dominant retailers (assumed leadership position) wanted to be uniquely different from each other in sourcing criteria, while on the other, increasing SKU and frequent new product introduction pose operational complexity. Indian small and medium companies with decentralised manufacturing set up and traditionally weak in sample development faces the greatest challenges is achieving excellence in product development and order execution.

Chapter Three

3.0 Research Design and Scope

In this chapter, various research methods have been presented to demonstrate skills in selecting appropriate methodologies to achieve the outcomes stipulated in the objectives. Discussion on each objective (section 1.5) is taken up individually and structured in three steps**:**

- Information required to achieve the objectives.
- Sources extant for collecting that information.
- Review of investigative tools and techniques required to select the right options for acquiring information from those sources.

The research tools and techniques are critically evaluated in terms of philosophy, approaches, strategies, time horizons and data collection methods (Saunders *et al.* 2007a) and the rationale for selection decisions is given separately for each objective. Selection of sample population and investigative tolls is discussed commonly for all objectives.

Research design depends on the topic and scope of the research, the population and the researcher himself (Saunders *et al.* 2007a). The broader topic in this case is the apparel manufacturing supply chain, the scope is the production lead time for contract apparel manufacturing supply chain, the population comprises apparel manufacturing organisations in NCR, India and the researcher himself is an academic scholar operating in this environment.

3.1

To achieve the first objective (*To develop a full understanding of the Indian apparel export manufacturing industry and its supply chain network*), it is necessary to collect information about perception/understanding of SCM among small and medium export manufacturing enterprises, their business infrastructure and the current manufacturing practices in terms of sourcing, product development, planning, and execution. The sources for this information are likely to be the senior operation/production manager, the merchandising manager, the purchase manager and the quality assurance manager. While some information has to be extracted from several documents of the organisation (the attributes), the rest are personal viewpoints and thus opinion-based.

Since the survey was neither to prove any scientific principles nor establish any theory with data, the inductive approach was thought most suitable as it would give an insight of the human aspects and also a closer understanding of the research context through collection of qualitative data. Even though a survey strategy is usually associated with a deductive approach (Saunders *et al.* 2007a), this survey was used to cover a reasonably large and representative section of the industry.

Investigative tools and techniques available to collect information are secondary data and observation, semi structured and in-depth interviews, or questionnaires. As the type of information to be collected tends toward characteristics of the organisation, processes and opinions of senior executives, it is unlikely to be available as a secondary data source. Since the objective was to unearth more organisational characteristics and executive opinions rather than the behaviour of the organisations or persons, the observation method of data collection, more appropriate for longitudinal surveys, was not selected. The choices left for data collection are either semi- structured and in-depth interviews or use of questionnaires.

From the literature survey, it was found that the sample population of SMEs are mostly in NCR (section 2.7), with a hierarchical organisation structure (section 2.7), and from the point of view of the research question, it was clear that the nature of research was descriptive. Semi-structured and in-depth interviews are more appropriate for explanatory and exploratory research respectively (Saunders *et al.* 2007b), therefore the questionnaire method was selected as most appropriate for the survey. As long questionnaires are best practised as structured interviews (Oppenheim 2000), it was planned to administer the questionnaire as a structured interview, where the questionnaire was carried by hand to the sample organisation by the research assistant and explained to the person concerned to ensure that the right person had responded. In most cases, the questionnaire was filled up in the presence of the interviewer; however, a few were allowed to be filled up by organisation in the absence of interviewer and sent back to him later. The structured interview, in its true sense, was not followed as it would have required personal visits by the researcher to all sample organisations. Multiple visits to single organisation were envisaged, as the sources information were multiple and it was unlikely that all persons would be ready with all information during a single visit. From the three types of data variables in any questionnaire, namely opinion, behaviour and attribute (Dillman 2000), the questionnaire was designed to collect mainly opinion and attribute-related information.

The sample population should be typical small and medium size companies, i.e., with turnovers between GBP one to ten million (section 2.7); having their own manufacturing facility as well as outsourced capacity (section 2.7); and carrying out business with both EU and US customers. The sample of representative companies was selected for data collation by purposive or judgmental sampling method. Having established that SMEs were mostly in the NCR (section 2.7), working with mainly European and US customers either directly, and/or through buying offices / importers (section 2.7), it was decided to conduct the survey on SMEs of the NCR.

3.2

To achieve the second objective (*To analyse the variability of processes within the network and develop best practice methods*), it was felt necessary to study all possible variations of the product development process that exist in the Indian contract manufacturing scenario (section 2.3.2). It was clear from the literature that the variability in PD processes in apparel manufacturing depended on the country being exported to (section 2.2.4), retail distribution channels (section 2.2.4), merchandise type (section 2.3.1) and raw material used (section 2.3.2). The information required is the step by step process flow diagram of product development that does not exists in any kind of written records, but as knowledge and experience with executives at manufacturing and buying organisations. The data can be collected through cross sectional survey of the executives or longitudinal observation. Since longitudinal observation would take much longer, the cross sectional survey was thought about.

As data collection would involve clarifying the how and why of the process, the interviewee should be an experienced senior level executive and the sample population should encompass all possible variables. A Focus group is a specific purpose group interview with a higher level of interviewer-led structure and intervention (Saunders *et al.*

2007c). The investigation in this case was about the product development process through interviewing a number of experts. The strategy to be adopted was survey, as the investigation in this case was about particular contemporary phenomena (the product development processes), to be investigated using multiple sources of evidence, i.e. the experts (Robson 2002a). In order to get representatives from different geographical locations and for a variety of merchandise, focus group discussions involving a cross section of experts were thought of.

The focus of data collection was to understand what was happening in each critical case so that logical generalisations were possible (Saunders *et al.* 2007f). This would fulfil all sampling requirements while keeping the sample size to the minimum. Since the select group has to be important to make a point (Saunders *et al.* 2007f), the critical case judgemental (purposive) sampling was chosen.

3.2.1

To rationalise the number of sample approvals, it was necessary to define the sample approval steps (what?), the need to identify different sample approval processes that currently takes place (how and when?) and the relevance/necessity of each process (why?). Such information would be available with industry executives with reasonable experience who worked with multiple-product type of organisations (preferably), dealt with customers from different geographical locations and different retail distribution channels. The sample population in this case comprised executives from various organisations fulfilling the criteria above. A Focus group discussion was thought to be most appropriate method; however, it was administered in a slightly improvised manner. Although the parameters of selection of the organisation remained more or less similar to the earlier objective, a few new samples (both organisation and executive) were selected for two purposes:

1. To get a non-biased, non-institutionalised outsider's point of view (not linked with the earlier objective of rationalising the PD process).
2. To extract opinions of executives who were more hands on to get an operational rather than strategic point of view.

It was then realised that it was not possible to organise a Focus group survey related to geographical locations of the samples selected. Moreover, the samples might have required consulting with other people in the organisation while finding an answer for the rationale behind the different sample approval processes. Accordingly, the Focus group survey was conducted among a cross section of industry through an open-ended questionnaire followed by a meeting tête-á-tête wherever possible, to understand the relevance of sample approvals in the PD process. Open-ended questions (Dillman 2000) allow respondents to give answers in their own way (Fink, 1995). Easterby-Smith *et al.* (2002) also pointed out that the use of open questions helped in avoiding bias. This mixed mode improvised research methodology was selected to realise the best possible outcome. Here data is first collected and a theory is developed as a result of data analysis and interpretation. The research philosophy used is Interpretive and approach followed Inductive.

3.3

To achieve the third objective (*To evaluate and measure delay-contributing activities in manufacturing cycles, analyse the reasons behind such delay and suggest means of reducing it*), information was required about each and every activity in the manufacturing cycle:

1. Clear identification was needed of pre-production and production activities in the manufacturing cycle.
2. The duration of each activity was to be measured.
3. Activities causing inordinate delay were to be identified.

The possible sources of information are departmental record books (issue and receipt), style registers, fax records, e-mail records, courier records, goods received notes in the warehouse as well as executives working in design, sampling, merchandising, purchase, planning, production and quality areas. As the researcher needed to observe, search records and collect information by asking executives questions, it was felt that a case study would be the most appropriate technique for data collection in the pilot stage. As data required here was neither an organisation's viewpoint nor documented as readily available information (fact sheet) in the factory, the data collection methodology assumed importance. It was decided to first carry out longitudinal pilot case studies with a few organisations to understand how best data could be collected, followed by a cross sectional survey through structured observation in a number of organisations.

Pilot case studies were conducted to define subject parameters (data to be collected), and process parameters (mode of data collection). As maximum activities are expected to be human-oriented tasks (rather than machine-oriented), analysing common human practices (during the pilot case study) and devising a simple easy-to-use data collection format (for the survey) are felt necessary.

Structured observation and interviews are conducted over a period of time to measure pre-production process time in a manufacturing cycle. After a pilot case study is over, the data collection format is finalised. The structured observation is quantitative, yields highly reliable results and can be delegated after suitable training (Saunders *et al.* 2007d). The task of data collection for a survey through structured observation was delegated to executives for outstation organisations. During the pilot study, data was collected by tracking how an order was being progressed from the date the order was placed till the shipment was trucked out of the factory.

During the pilot study, one order was selected from each organisation, PERT network (section 2.4.2) was prepared for each order, actual start and end date for every task was recorded to understand how PD, pre-production and production activities were executed in an organisation. One particular order is considered as one sample and variations in activity sequence and activity duration were due to merchandise type and/or retail distribution channel (section 2.3.2). It was decided to collect information from multiple orders from multiple factories to have representative data about the industry.

3.4

To achieve the fourth objective (*To identify and evaluate value-added and non-value-added activities in the manufacturing cycle*) information is required about each and every micro-activity of a manufacturing cycle. Firstly, there needs to be clear categorisation of activities into value-added (VA), non-value-added (NVA) and necessary non-value- added (NNVA) and secondly, the duration of each category is required to be measured accurately. The data required here is neither the organisation's viewpoint (which can be collected through a questionnaire survey or interview) nor documented in organisations as readily available information (fact sheets). Instead, only factual info is required. The study is about capturing the duration of in-house activity by continuous observation and time study. For out-of-workplace activity, duration is measured by tracking each and every conceivable completion of micro-activity and recording time taken against it. For example duration of 'pattern making' to be measured by actual physical presencet while the pattern is being made, observing the task and noting down the start and end time. Similarly for 'lab dip making' activity, the researcher has to note down the accurate date and time when information was conveyed to the dyer and when dyed swatches reach the manufacturer's office.

Maximum activities to be tracked are expected to be human-oriented tasks (rather than machine- oriented), either executed in-house or out-of-workplace, either skill-based or desk jobs. As the activities of multiple orders need continuous observation (for in-house activities) and tracking (for out-of-workplace activities), the most appropriate time horizon for the case study should be longitudinal and data collection method should be structured observation.

The sample organisation should have small to medium turnover, truly representing the typical Indian exporter (section 1.3) working with multiple procurement channels; small and medium buying office, importers abroad as well as direct export, working with a mix of out-of-workplace fabrication and in-house own manufacturing. As continuous observation would require willing and co-operative upper management, typical case purposive sampling was thought as most appropriate.

A simple easy-to-use data collection format was devised accordingly. The format with explanation to specific organisation executives will enable simultaneous data collection for multiple orders.

3.5

To achieve the fifth objective (*To evaluate the applicability of different optimisation techniques to reduce lead time in the manufacturing supply chain*), three optimisation techniques were studied, namely collaborative product development, critical path/critical chain application and avoiding intermittent work interruption. Three separate sub-objectives have been set for this objective.

3.5.1

To explore feasibility of lead time compression through collaborative and concurrent product development (CPD).

The aim of data collection was to understand what was happening in each case so that a logical generalisation could be made (Saunders *et al.* 2007f). To achieve the objective, information is required about whether multiple organisations carry out activities as a team where information is shared in such a manner that decision making is by consensus, involving all perspectives in parallel, right from the beginning of the product life-cycle. Information is likely to be available with executives of the apparel manufacturer, suppliers of accessories and fabrics, value-addition service providers and the buying office (and/or buying agents). The study is to explore co-operation and team values between the apparel manufacturer, supplier and customer. The information required is all that actually happens, the how and the why, and unlikely to be available in documented format or through a questionnaire survey. It could be obtained through a Focus group interview with selected experts. Wherever a Focus group was not possible due to non-availability of experts for joint discussion, expert knowledge elicitation was used by talking to experts on the subject separately.

Exploratory studies in a cross sectional time horizon are a valuable means of finding out what is happening, to seek new insights (Robson 2002b). Its great advantage is that it is flexible, allowing a researcher to change the direction of research as a result of new data (Saunders *et al.* 2007a). It was decided to follow up the Focus group interview with exploratory case studies using historical data in a cross sectional time horizon to study how and why actually collaborative and concurrent product development was practised, if at all, among specific organisations. The case study will help the researcher to decide the direction of research and whether to go for longitudinal study in the area or not.

3.5.2

To study the applicability of critical path and critical chain to reduce the manufacturing cycle time.

In the first stage of the study, information is required to be collected for a case (an order) about activity duration, successor and predecessor relationship during set up mode and actual completion date of each and every activity during the tracking mode. This information is likely to be available with sampling co-ordinators, merchandisers, pattern masters and other people in charge of pre-production activities in the organisation. The study would involve preparation of the PERT/CPM network by the researcher using the data collected during the set up mode, and briefing the executives involved in the order about the critical path and critical chain concepts and how to follow up in the tracking mode while the order is in progress. Data and time is to be recorded as and when activities are completed over a period of time, therefore the time horizon of the study is longitudinal and data collection method is structured observation. The research philosophy is positivism as the emphasis is on objective measurement (Saunders *et al.* 2007a) and the approach is deductive. Control was exercised through scientific principles like PERT and CPM.

The second stage of the study was to establish how multi-style critical chain helps bottleneck management of manpower resources. Information sources and data collection regarding activity duration, successor and predecessor relationship remains the same as earlier, however making of the Gantt chart was achieved using software. Different reports generated from the software about resource utilisation pattern were used as guidelines during the tracking mode. The software format (input screen) was used for structured observation and collection of data of multiple orders running at the same time in the organisation.

Both stages of the study were to provide an illustrative profile using a representative case.

3.5.3

To measure the potential of time saving for skill based activities by avoiding intermittent work interruption.

In this case, information is required to be collected for skill based activity/activities regarding start time, interruption time, if any, and end time. All information to be collected in real time about how the executive starts working on an activity and why he/she jumps to another activity leaving the earlier one unfinished, when he/she resumes the earlier activity and finishes it. All circumstantial evidence is also to be collected regarding such a practice. The possible sources of information are executives primarily engaged in skill−based activities. As such information is unlikely to be readily available in a documented format, it is to be collected in person as and when it occurs. The structured observation was found to be the most appropriate method of data collection. As the data to be collected from the same activity and/or executive over a period of time, a longitudinal study was found to be appropriate. This study is again to provide an illustrative profile using a representative case.

3.6 Selection of Population/Sample

Sample selection is primarily of two types: probability or representative sampling and non-probability sampling (Saunders *et al.* 2007e). In this research, no statistical inferences were planned from the sample so non-probability sampling was used. Non-probability sampling can be of different types; quota, purposive or judgemental, snowball, self-selection and convenience sampling method (Saunders *et al.* 2007f). The total number of large organisations in India is around 100 while that of small and medium organisations is around 2000 (ApparelOnline 2006). It was decided to conduct the survey in and around NCR due to maximum concentration of small and medium organisations (Bheda & Shanbhag 2000). Furthermore, organisations deal mainly with fashion merchandise (Trend Fusion 2005). To develop an understanding of the Indian apparel export manufacturing industry and its supply chain network, an SCM awareness survey was conducted with a focus to identify a useful rule of thumb and accordingly a set of 10-30 sample size was aimed for analysis (The Economist 1997).

The rest of the research can be categorised as exploratory case study. Focus group or longitudinal research and purposive or judgemental sampling technique was used as the objective was to select samples that best understood the requirement of this research, co-operated in the study and answered queries. Saunders *et al*. (2007f) suggest that purposive sampling may be used following the grounded theory approach. The grounded theory approach used in pre-production time analysis actually leads to heterogeneous purposive sampling for the selection of organisations for subsequent longitudinal study. For longitudinal studies, typical case purposive sampling is used to provide an illustrative profile using a representative case. For multi-project critical chain implementation and value-added and non-value-added time analysis, sample organisations were selected based on logical generalisation parameters (Patton 2002). For example, if something happens with the sample, it will happen with everyone; if the sample is facing a problem, then everyone will have problems and if a sample cannot understand a process, it is likely that no one will be able to understand the process.

3.7 Investigative Tools

Data collection and recording was planned using simple spreadsheet (MS-Excel). The qualitative data (opinion-based) data was simply grouped or averaged to arrive at a conclusion and quantitative data was analysed using statistical tools (MS-Excel) to establish a relationship. MS-Excel was also used for drawing single order PERT/CPM network using ‘autoshapes’ and ‘connectors’. A specialised project management software (extended trial version) was used for drawing multi-order critical path/critical chain network and generating different resource utilisation guidelines for managing resource bottlenecks during the longitudinal study.

3.8 Ethical Procedures

It was inevitable that much of the data collected would involve commercially confidential information from case study companies, or personal views of senior executives. In order to ensure open and honest disclosure, care has been taken to keep the people and organisations involved anonymous, where appropriate.

During the initial survey, the names of the five buying offices sampled to provide lists of their suppliers were kept anonymous, and only relevant characteristics such as sourcing country was revealed. This was required to establish the wider context of business for the supplier organization. The names of supplier organizations that responded to the final questionnaire were also coded at the request of respondents for reasons of anonymity.

However the financial and operational indicators of the companies were presented in a tabular form to help understand the organisations' characteristics.

To achieve the second objective of both understanding of product development processes and rationalising sample approval processes, focus group selection was based on their educational background, previous work experience, current job description, variety of retail distribution channels as well as the different geographical locations they represented. While the experts were not named, their organisation and designation were revealed to ensure that selection criteria were justified. The individual experts had taken necessary approvals from their organisations wherever required.

The third objective was to identify and measure durations of delay-contributing activities in the manufacturing cycle, and this study was conducted in two parts. First, a case study was done with three organisations, followed by the main survey of nine organisations. For each case study, the organisation's name was coded (with a fictitious name) at the request of respective organisation. During the survey, the sample data was actually orders (not the organisations), and order numbers were generally alpha-numeric coded. The organisations insisted that as long as the customer's name for those orders was not mentioned, the order code numbers did not require anonymity. Eight organisations out of nine who participated in the survey agreed to use their names; one organisation where data were collected by a research assistant, was code-named for anonymity.

The two company case studies to evaluate and measure value added and non-value added activities in the manufacturing cycle had no objection in allowing the use of their actual organisation names.

The focus group that discussed various optimisation techniques for reducing product development lead times consisted of experts from eight different organisations. The names of the experts were not used in any case. Four organisations were given fictitious names, while the others were happy to be named: Triburg Consultant, Coats India, Groz Beckert, and Tukatech.

The longitudinal studies conducted to evaluate the applicability of critical path and critical chain theory consisted of an anonymous pilot to Silvershine Apparels at their request, while the main study organisation name was retained as Kirat.

3.9 Summary

The overall research philosophy, to a large extent, was interpretive and approach inductive. Surveys were used as a strategy during the initial stage and case study in the later stages. The first stage of research was to develop an understanding of the Indian apparel supply chain through a survey, understanding of the product development process through a focus group discussion and 'expert knowledge elicitation' to rationalise the number of sample approvals. The second stage concentrated on cross sectional case study and survey to identify and measure durations of delay-contributing activities in the manufacturing cycle and value added and non-value added time in preproduction activities. Once the delay contributing activities were identified, the third and final stage of research dealt with different optimisation techniques to reduce lead time in the manufacturing supply chain. Longitudinal case studies were conducted; first on collaborative product development, followed by critical path and critical chain application and finally, to measure the potential of time saving for skill-based activities by avoiding intermittent work interruption.

Chapter Four:

4.0 Pilot Studies

This Chapter will cover the pilot studies done through the survey and case study with three objectives; first, to understand the characteristics of Indian apparel export manufacturing; second, the variability of processes within the supply network and identify delay-contributing activities in the manufacturing cycle and to measure the duration of those activities and third, to identify the reasons behind delays and suggest means to reduce them. Each research objective is presented with its methodology, data collection and analysis in respect of existing literature and contribution to knowledge.

4.1 Characteristics of Indian Apparel Export Manufacturing

There appears to be some confusion about what the supply chain across the industry is; whether it is a process, a system or an activity (section 2.1.1). However, the deliverables of Supply Chain Management unanimously talk about delivering the product at the 'right time' (section 2.1.1) and literature on apparel supply chain also dwells on 'product development' as an important component of supply chain management (section 2.7). As supply chain research is at a nascent stage in the Indian apparel industry (section 2.7), it was decided that the survey should collect information about perception/understanding of SCM among small and medium SMEs, their business infrastructure and the current manufacturing practices in terms of sourcing, product development, planning, and execution. As SCM bears a different meaning and interpretation to different people (New, 1997; Lummus *et al.* 2001; Mentzer *et al.* 2001; Kauffman, 2002, Kathawala and Abdou 2003), it was also decided to include a questionnaire on the opinion about SCM awareness in Indian industry.

4.1.1 Methodology

The methodology for data collection was survey through questionnaire (section 3.1), which involves questionnaire design and sample selection. Ten organisations were selected as the minimum (Fink 1995) opportunistically. A pilot questionnaire was done with a total of 39 questions to assess the design of the questionnaire. The pilot questionnaire was thus divided into four sections, organisation classification; information about the manufacturing unit; information about merchandise sourcing and information about organisational output. These four sections posed six, seven, twenty and six questions respectively. After the pilot data collected from ten sample companies was analysed, it was observed that separate sections on merchandise sourcing and organisational output were not required and hence both sections were combined into 'product development and pre-production planning'. Additional questions were included in all three sections to increase the total to 48 questions and finalised for the study (appendix IV-A). During the pilot testing, it was also observed that sometimes respondents scribbled illegibly, with the result that their selection of options was not clear, making data interpretation incomplete and analysis difficult. Therefore, a separate feedback form (appendix IV-B) was designed to enable clear and lucid data collection.

Out of the 48 questions in the final questionnaire, there were 15 questions on opinion, only three on behaviour and the remaining 30 questions were on attributes. The questions were divided into three sections: The first section of organisation classification contained nine questions; information about manufacturing unit another nine; and the last 30 on product development and pre-production planning. Different parameters in the area of product development, pre-production planning and manufacturing functions were recorded through mainly a close-ended type of options. The option types of questions were meant for senior operation executives to express organisational viewpoints, whereas the attribute type of questions required referring to some records.

The target was to get data from at least ten different SMEs. There are approximately 1200 small and medium garment manufacturing enterprises in the NCR (ApparelOnline 2006). Through personal contacts in buying offices (two European, two US and one Hong Kong-based) a list of SME's that fulfilled the above criteria was prepared. From a list of 117 SMEs, 30 companies were selected at random for the survey. This approximated 10 percent of the SMEs in the NCR (Subbu 2003). Out of the 30 companies selected and approached, 22 companies responded and 13 could be fully analysed. The rest were discarded due to incomplete information. Data was collected by sending the questionnaire either by person, by post, or by e-mail (only two cases). Companies were identified by codes to conceal their identity. All companies were from the NCR, with annual turnover ranging from GBP 0.4 to 8.67 million, working with 15 customers on the average and having a mean unit value realisation (UVR) of GBP 2.7.

4.1.2 Data Collection

Attribute-based data from all 13 fully analysed companies are presented in table 4.1 while opinion-based data is summarised in charts.

Table 4.1 Summary of Selected Company Profiles Being Surveyed

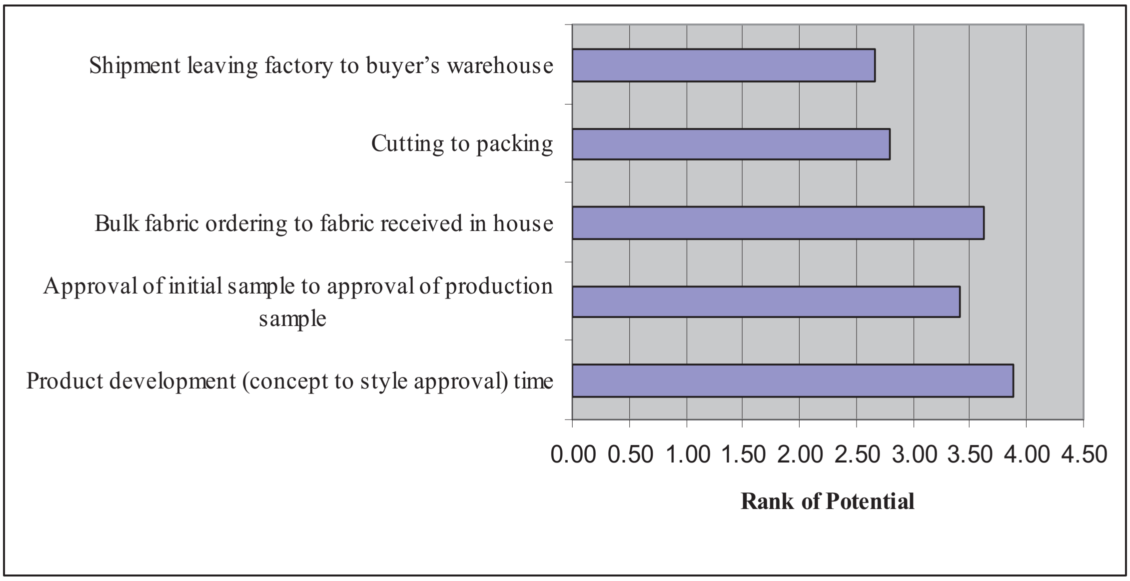
Company Code	Data for year	Turnover in millions of pounds	Turnover in millions of pieces	Average Unit Value Realisation	Total no. of accounts (customer)	Total no. of fabricators	Percentage of in—house production	Total no. of fabric vendors	Total no. of accessory vendors	Percentage value of sea shipment
B1	2001	0.4	0.17	2.42	9	50	80	10	N/A	75
B3	2001	2.67	1	2.67	17	20	75	20	25	50
B4	2001	2.13	1	2.13	6	5	90	5	10	95
B5	2000	1.6	1.72	0.93	15	20	80	12	20	100
B6	2001	8.67	3	2.89	18	15	80	10	10	90
B7	2001	3.33	1.5	2.22	20	15	82	17	22	60
B8	2000	8.67	2.6	3.33	20	N/A	100	20	15	85
B9	2001	0.53	0.18	2.96	5	40	60	8	30	75
B10	2001	0.53	0.18	2.96	5	40	60	8	30	75
B11	2001	4.4	0.85	5.18	33	35	60	20	46	70
B14	2001	2.48	1.06	2.34	26	8	N/A	8	2	N/A
B16	2001	2.63	0.87	3.03	19	N/A	100	10	16	100
B17	2001	3.29	1.58	2.08	4	10	100	N/A	N/A	N/A

Data regarding opinions of respondents was tabulated and summarised so that response to the questionnaire which essentially dwelt with the potential of improvement in the supply chain, importance of operational issues in planning, sample conversion rate, sample approval time, cost of product development, troublesome pre-production activities, and communication problems in sourcing accessories could be tabulated and opinions expressed in horizontal bar charts ranked as per importance and/or instances.

Potential of Improvement in a Supply Chain

The respondents were asked to rank potential of improvement of different activities in Product Development. The concept to style approval zone came out to be of prime importance in terms of possible usage of modern technology to reduce time. Bulk fabric procurement and approval of production sample were the next areas of concern. Shipment transit time, incidentally, was accorded last priority.

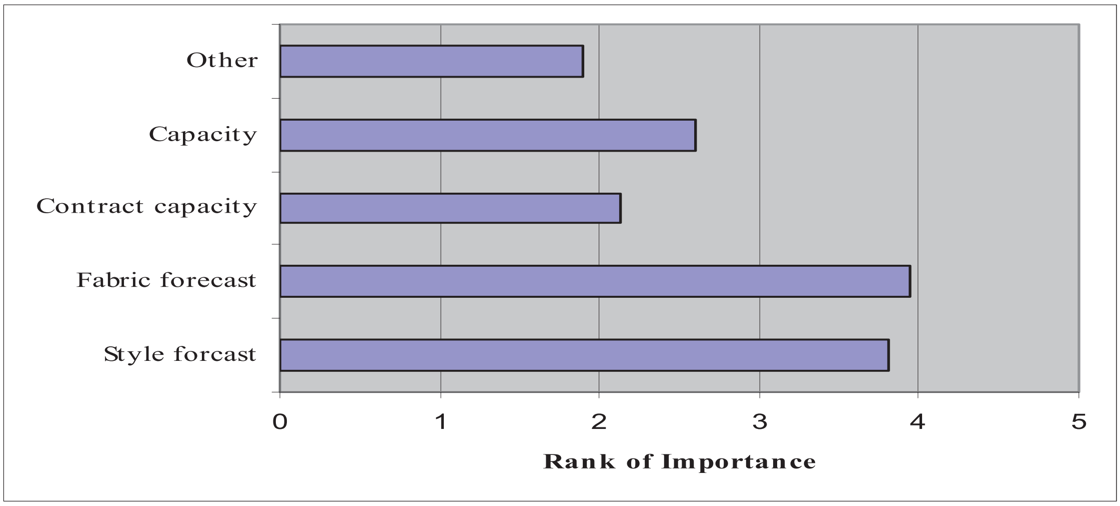
Figure 4.1 **Potential of Improvement in a Supply Chain**



Importance of Different Operational Issues in Planning

While investigating which issues affected planning most, it was revealed that respondents put style and fabric forecasts as the prime issues. In-house and contract capacity were found to be less important as the majority of the respondents used contract manufacturers which provided them flexible capacity.

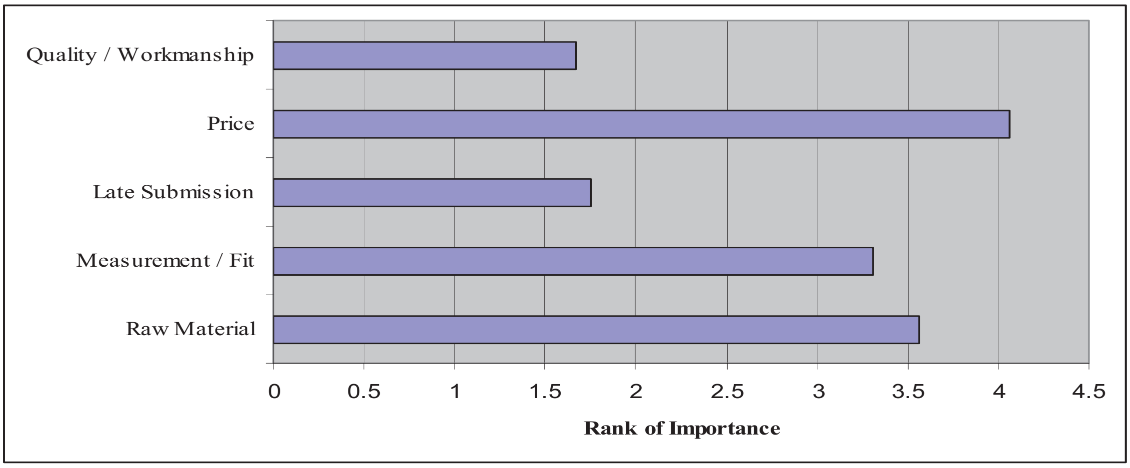
Figure 4.2 Importances of Different Operational Issues in Planning



Sample Conversion Rate

Average sample conversion rate of survey respondents was reported to be 56 percent. While enquiring about such a low rate of conversion, the majority of respondents rated 'price point not accepted' as the prime reason. Incidentally, 'late submission' was ranked as low as the 4^{th} important issue, behind incorrect raw material and measurement and/or fit problems.

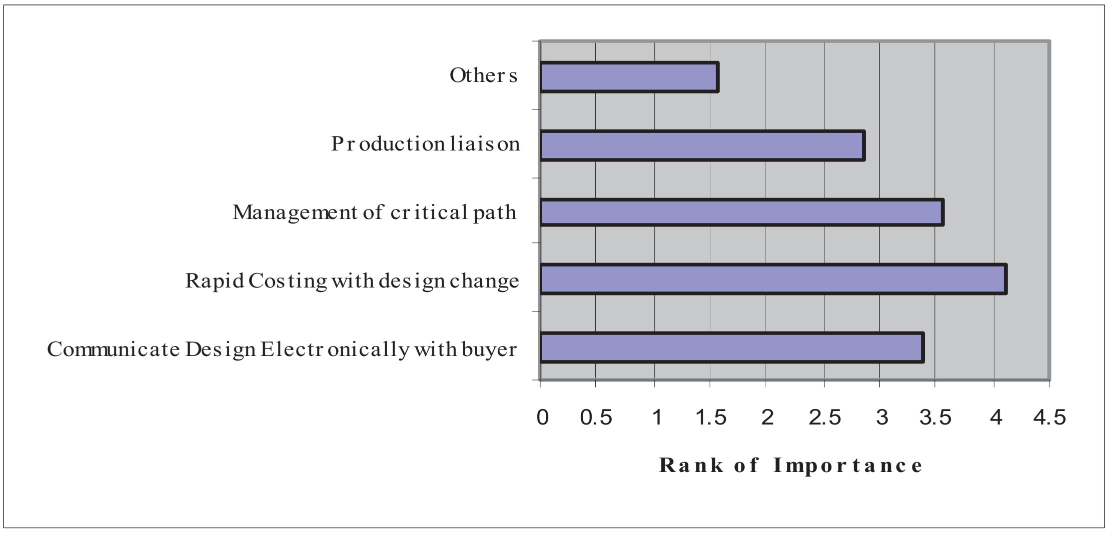
Figure 4.3 Sample Conversion Rate



Importance of Different Operational Issues in Product Development

When asked what the most important operational issues regarding product development process were, electronic communication with buyer and management of product development critical path were cited as strong issues. However provision of 'rapid costing with design changes' was rated as the most important parameter.

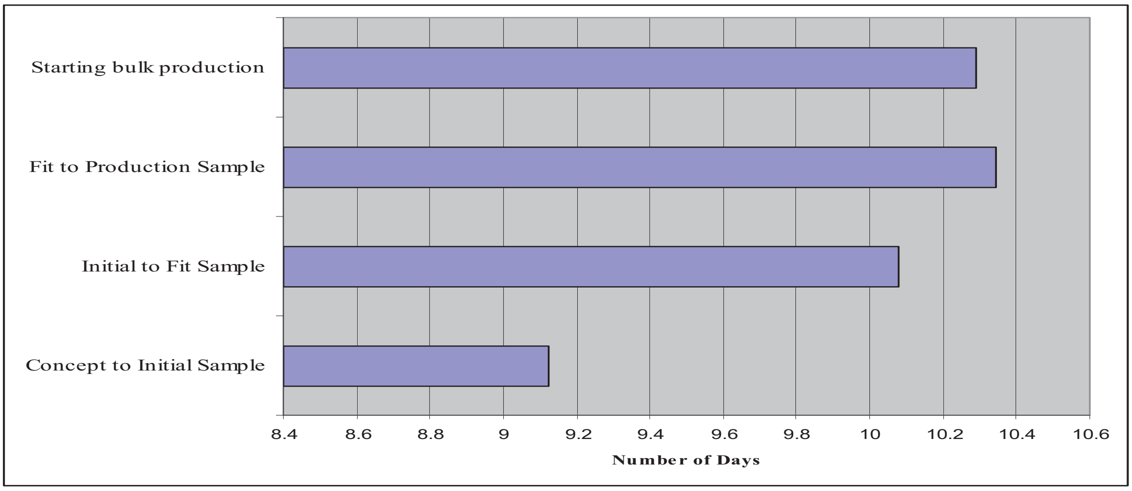
Figure 4.4 Importance of Different Operational Issues in Product Development



Sample Approval Time

While investigating time requirement at different stages of sample approval leading to the start of bulk production, respondents felt that the 'fit to production sample' stage took the maximum time followed by 'start of bulk production' and 'initial to fit sample'. respondents felt that 'concept to initial sample' took the least amount of time.

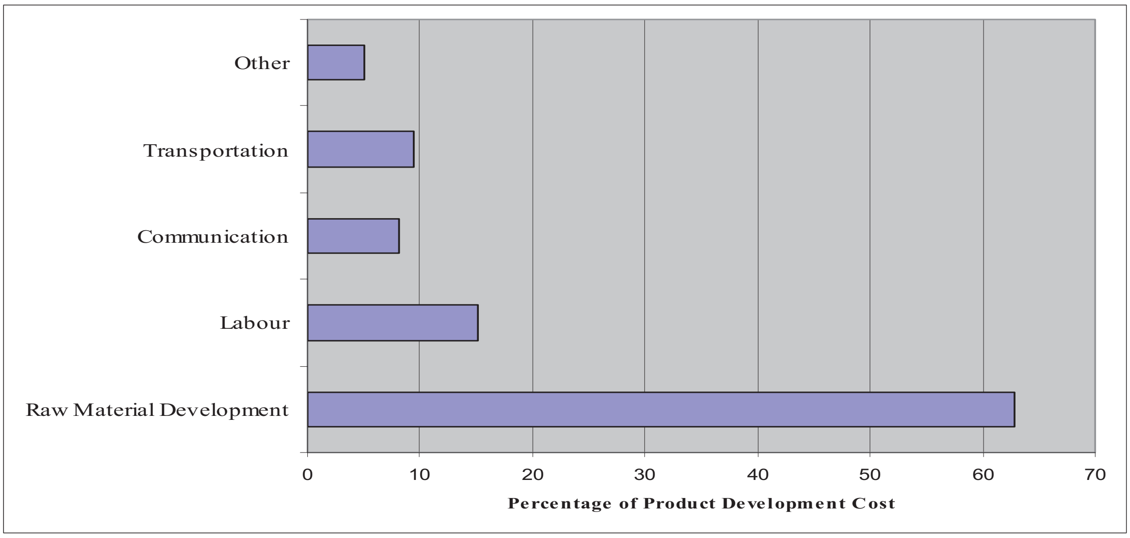
Figure 4.5 Sample Approval Time



Cost of Product Development

When reviewing different cost components of the product development process, respondents felt raw material consumed the major cost while labour, communication and transportation consumed the least.

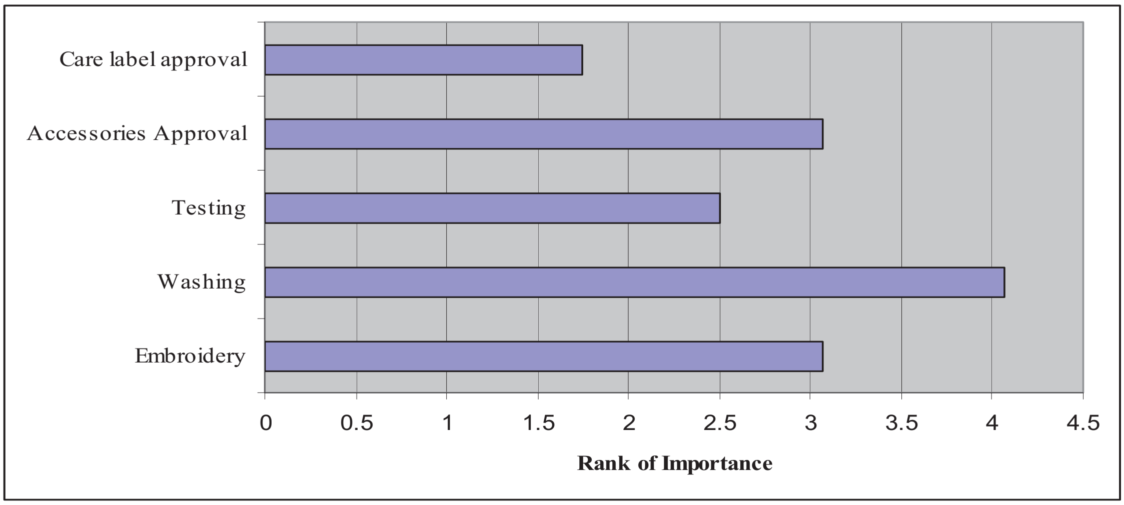
Figure 4.6 Cost of Product Development



Troublesome Pre-production Activities

When asked about most troublesome activities in the pre-production process, respondents put 'achieving washing standard' as the most troublesome, followed by the approval of embroidery and accessories. Care label approval came out as least problematic.

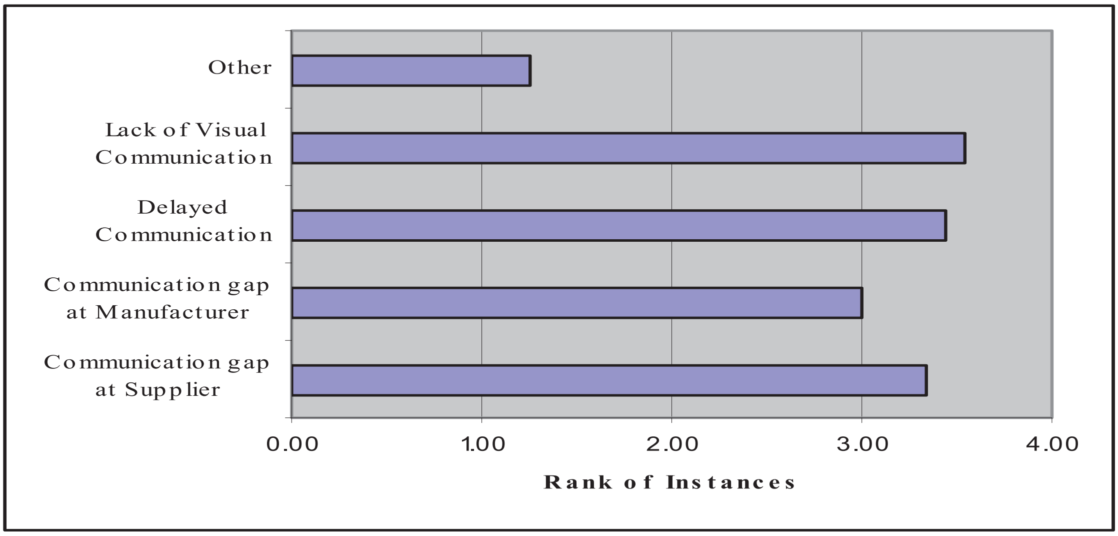
Figure 4.7 Troublesome Pre-production Activities



Communication Problems in Sourcing Accessories

India, regarded as a value added merchandise supplier, requires various accessories to be added to the merchandise. The types of problems faced while sourcing those accessories were then compared and ranked. Communication gaps between supplier-manufacturer, delayed delivery, and lack of visual reference were cited as the main obstacle.

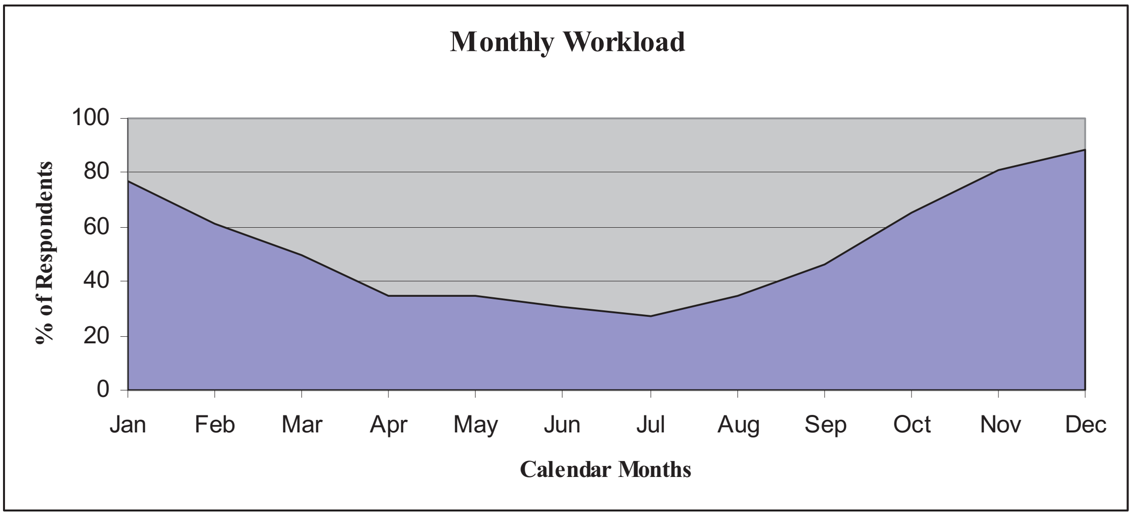
Figure 4.8 Communication Problems in Sourcing Accessories



Seasonality in Business

While enquired about which are the months the organizations work with up to 80% or above capacity, around 80%-89% of respondents reported three months; Nov-Dec-Jan are the busiest, while only 26% to 30% of respondents reported to be working with near full capacity during June-July. This seasonality in business reflected India's narrow range of product offerings, polarized workload in business.

Figure 4.9 Seasonality in Business



4.1.3 Data Analysis

While attribute-based data was collected for 2001 in the maximum number of cases, the turnover in millions of GBP varied from 0.4 to 8.67, a fact showing the highly de-fragmented nature of the industry (section 2.7). Even average unit value realisation is a consistent 2.7 GBP. Some companies work with a high number (maximum of 33) of customers to probably minimise the risk of putting all eggs in the same basket. This resulted in variations in the working process, specially in pre-production processes (section 2.7), as different customers are likely to follow different processes (section 2.7), Even though all of them produce the majority of the output in-house, it was seen that they worked with fabricators (for flexible capacity), a reflection of the seasonal nature of the business (section 2.7). Seasonality in business also another important factor to have flexible capacity thereby compensating the loss during lean season.

Product development (concept to style) time was identified as the prime area to be improved, followed by bulk fabric procurement and initial to production sample approval. As bulk fabric procurement is not directly controlled by the apparel manufacturer, the other two areas were identified as target areas for improvement. High emphasis on style and fabric forecast and low emphasis on production capacity indicates the emphasis on value added stylised garments rather than basic styles, where capacity is generally important. The low ranking of capacity parameters is also indicative of the presence of highly flexible (subcontractor-based) manufacturing infrastructure, which is also one of the characteristics of NCR-based manufacturers (section 2.7).

Although communication and transportation are important parameters in the product development process, the cost involved in those was ranked very low by the respondents, whereas raw material development was considered as the highest cost contributor in product development. Apart from raw material and labour, other cost parameters are difficult to measure and this fact is reflected in widespread variation in percentage; people simply had no idea! This could also be construed as non-availability of information or lack of awareness of techniques to measure such costs. Here was a classic case of pitting the traditional 'cost paradigm' against 'value of time' paradigm. People are simply unaware of how much money is being spent on communication and transportation. In all probability, the overwhelming cost of raw material overshadowed the cost of communication and transportation.

The average cost of raw material in a product is assumed to be around 65 percent followed by labour at 17 percent and communication and transportation approximately at 9 percent each. However, the most interesting observed is the variation of perception amongst respondents; raw material percentage varies from 45 to 80 percent, while labour varies from a minimum of 5 percent to a maximum of 30 percent. As the cost of transportation and communication are not separately maintained, the respondents have apparently inserted arbitrary figures varying from a minimum of 3 percent to a maximum of 20 percent.

The reason behind low sample conversion rate also reflects the 'cost-centric' mentality of the respondents. The respondents felt the two prime reasons behind poor conversion are high price and incorrect raw material with incorrect measurement/fit and late submission coming in third and fourth respectively.

The total time from concept to start of production is pegged at approximately 40 days, and divided into 4 different stages: concept to initial, initial to fit, fit to size-set and size-set to production. It is interesting to note that the later stages consume more time on an average than initial stages. Although average time for each stage ranges between 9 to 11 days, the variability among data is found to be very high; from a minimum of two days to a maximum of 40 days. Again, this wide variation of data reflects non availability of information, use of non-standard terminology and/or non-standard sampling procedures and quite probably, iteration.

4.1.4 Conclusion

It is interesting to note that while the respondents express their concern about the importance of time, they are equally concerned about controlling costs. Quite often, the intangible cost of submitting wrong measurement and fit and delayed approval are masked by the tangible cost of raw material and labour. The survey emphasised the communication problem during sourcing of material, the inordinately lengthy product development period and equally specially, the long sample approval procedure, all of which require immediate redress.

Product development, sample approval during fit and size set and management of the critical path are the most time consuming activities and need improvement. Subsequent operational measures taken are all focussed around cost reduction; control and time or customer service do not get enough importance. For example, cost of communication and late submission of samples are given negligible importance in cost of product development and sample approval respectively. Least importance is accorded to shipment time. This also suggests that Indian apparel manufacturers are mainly involved from the post-merchandising stage onwards, where price is more important than time (section 2.7).

The unanimous view expressed by industry was an investigation of internal activities which they could influence and control. The focus of any research should be on identifying parameters that are controllable and techniques which are universally applicable. Performance measures that rely on government policies or external infrastructure facilities, over which the apparel manufacturer has no control, need not be core areas of any investigation. Hence it was decided to investigate the product development and pre-production processes in greater depth. Non-availability of factual data was one of the primary reasons for incomplete feedback from factories; this is suggestive of the lack of documentation in industry.

4.2 Understanding of Product Development Process

As the outcome of the preceding survey suggests wider exploration of product development and pre-production processes, and literature (section 2.3.2) also mentions the parameters of variations in the process, it was decided to carry out a series of interviews and in-depth Focus Group discussions. The common areas of development are fabrics (texture, design and colour), patterns (silhouette and fit), and accessories and finishing or wash effects. Raw material was sourced either directly or indirectly through sourcing agents.

4.2.1 Methodology

The parameters of possible variations in product development and pre-production processes are retail distribution channel (2.1.3), geographical location of buyer (2.3.1), intermediaries in the chain (2.2.4), type of merchandise (2.1.2) and type of fabric (2.1.2).

While the approach and philosophy to be adopted was inductive and interpretive respectively, it was realised that experts from manufacturing organisations had very limited exposure to the product development process of different retail distribution channels as all manufacturing organisations (particularly small and medium enterprises) were unlikely to make different types of merchandise using different types of fabric and supply to different retail distribution channels, to different geographical locations, through different intermediaries. Whereas buying agents are generally found to cater to buyers of different retail distribution channels. Often small buying agents have a bias towards a particular geographical location due to the expertise they develop (section 2.2.4), whereas large buying agents are found to represent all variables described above. Therefore, it was decided to interview senior executives from buying agencies that represents buyers/brands/retailers of multiple distribution channels. A substantial volume of India's exports is to the EU and the U.S. (section 1.3), dictating the selection of the members of the focus group. Keeping the above factors in mind a five member focus Group representing four different organisations was identified through critical case purposive sampling.
The selection of experts was based on their educational background, previous work experience and current job description. The companies where the experts are currently working were selected based on the variety of retail distribution channel as well as the

customers of the different geographical locations they represent. The first expert is senior merchandising manager at Gap Inc[3]. India liaison office, a US based retailer. The second expert is the country manager of H&M[4] India liaison office, a Swedish retailer. Gap and H&M are considered competitors in similar product categories representing the U.S. and the E.U. The third expert was a merchandiser with Triburg Consultants[5], a buying house representing major U.S. customers as well as a few customers from the E.U. The fourth expert is a senior merchandiser from Li & Fung[6] India office, the Hong Kong based buying house. The fifth expert was selected for his previous work experience with Shahi Export House as merchandise manager, handling several customers sourcing mainly through importers. Shahi Export House is a manufacturing organisation[7] having production facilities in both north and south India, working with major U.S. and E.U. retailers, brands and importers. All experts involved with the Focus Group discussion were professionally educated and had 8-18 years of work experience. The type of interview was relatively unstructured and free-flowing (Zikmund, 2000) while the purpose was thus specific, focussed, and linked to the exploration, relevance and sequence of process steps for product development. The Focus Group discussion was documented as a series of parallel and sequential activities that happen as a precedence diagram. Every activity was discussed regarding its necessity.

4.2.2 Data Collection

During the lengthy deliberations with the Focus Group, the objective was to find similarity of processes while identifying the key differentiating steps. The difference lay in working through an importer and store or for a mail order. It transpired that though there were many similarities and common processes, the overall activity diagram could be classified into one of three basic types of supplier/manufacturer network. The product development process network through an importer has the maximum number of activities (refer figure 4.10). The product development process network for a Mail Order Catalogue and Brand is given in figures 4.11 and 4.12.

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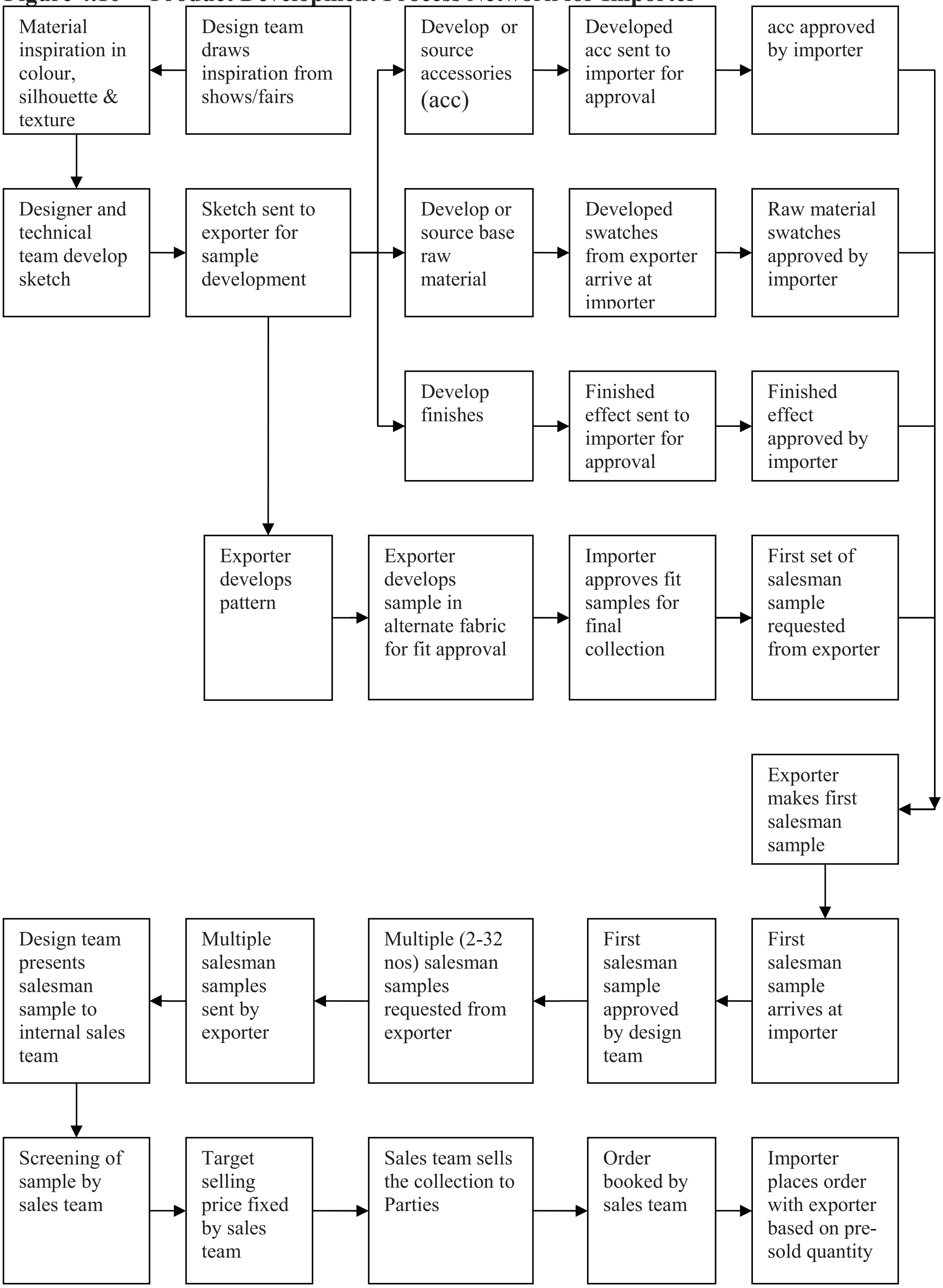
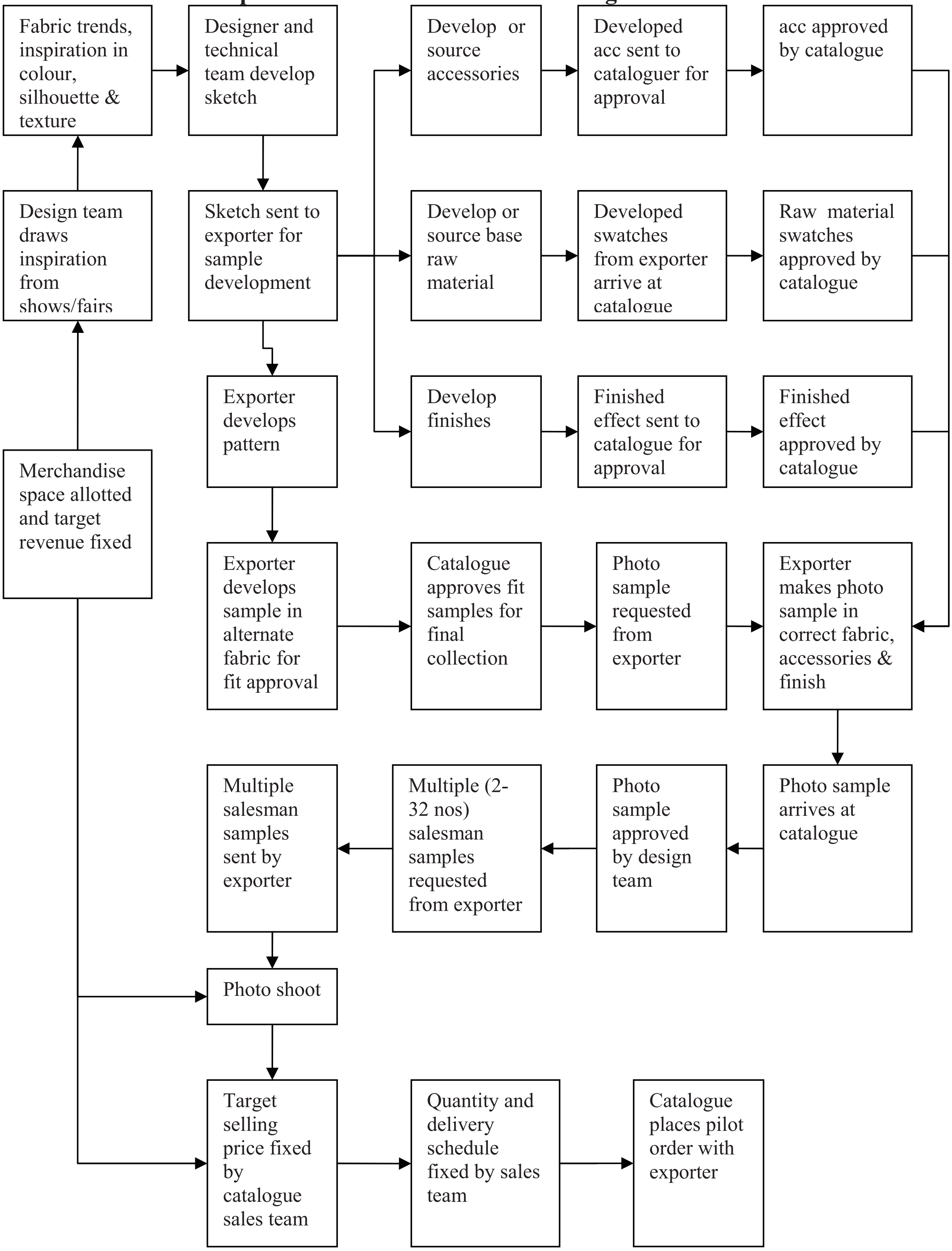
[3] www.gapinc.com
[4] www.hm.com
[5] www.triburg.com
[6] www.lifung.com
[7] www.shahi.co.in

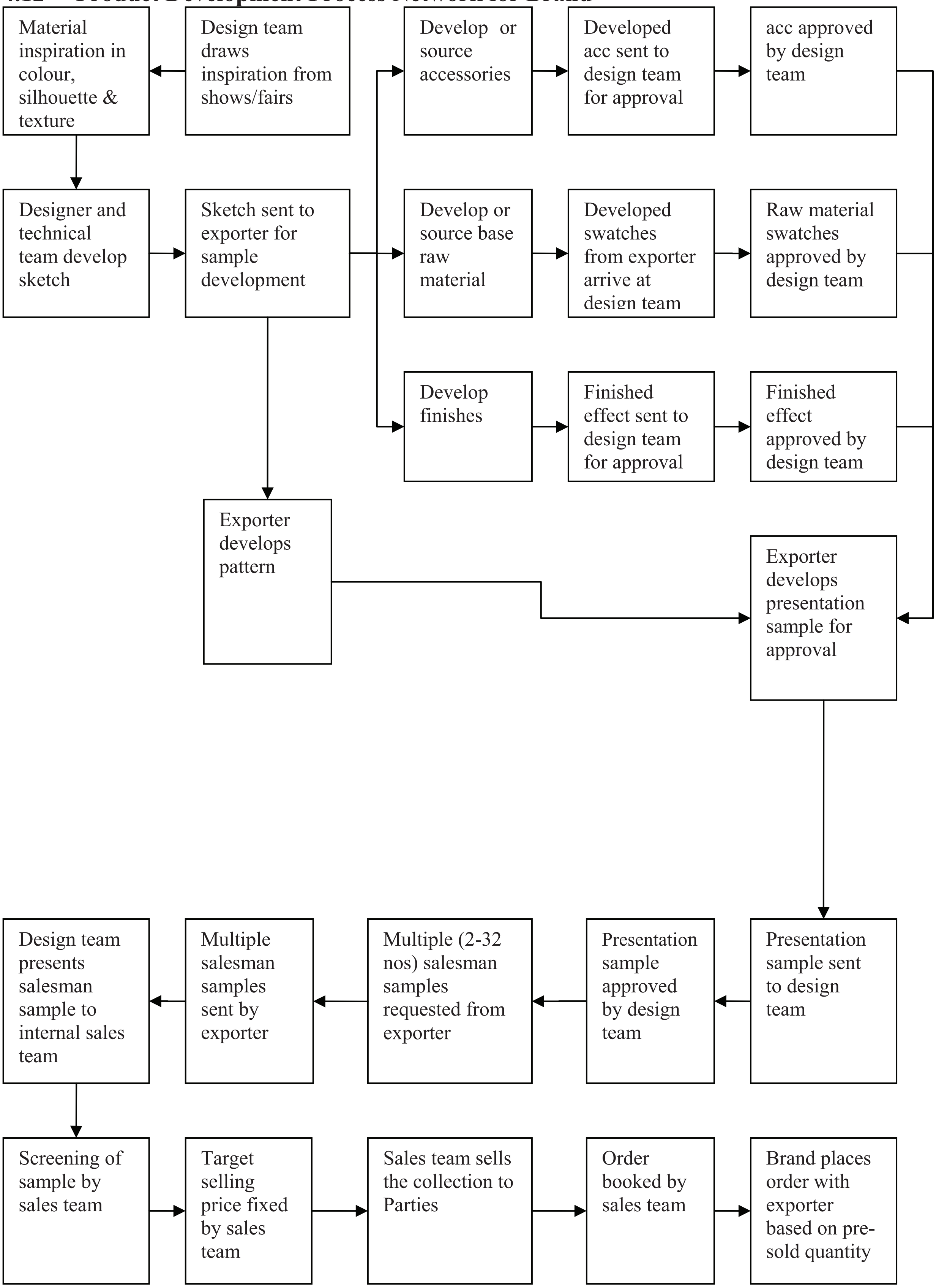
Figure 4.10 Product Development Process Network for Importer



4.11 Product Development Process Network for Catalogue



4.12 Product Development Process Network for Brand



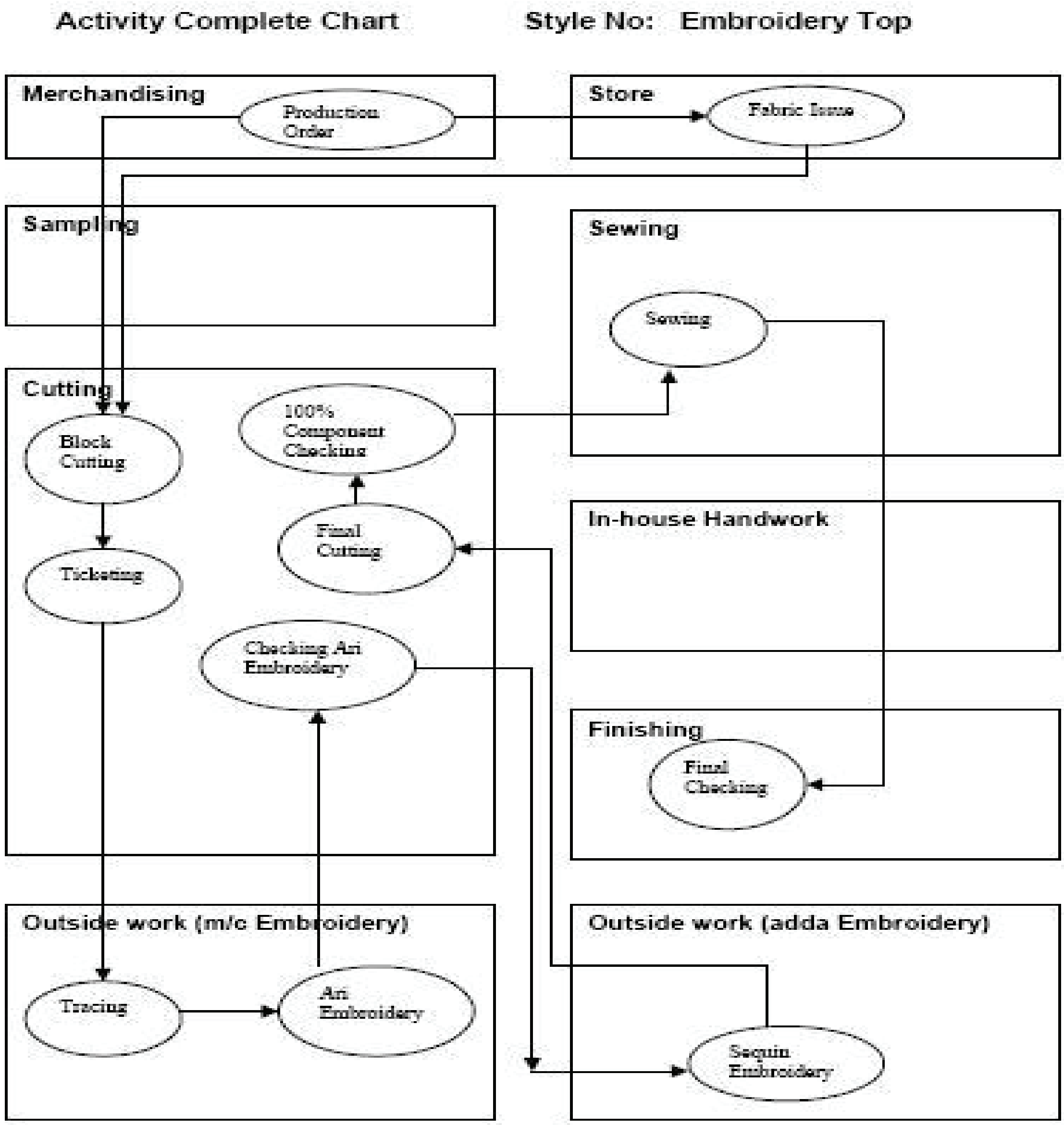
4.2.3 Data Analysis

Similar to Rochford and Rudelius (1992), it was found that product development process sequence for commodity garments are more or less a standardised combination of sequential and parallel processes. There were 18 sequential steps in the longest path for a store as well as importer, whereas mail order had 14 sequential steps. The fabric, accessories and fit sample development/approval process happen in parallel while the rest of the process is sequential. Rather than the sequential process models of Urban and Hauser, (1980), Gruenwald (1992) and Himmelfarb (1992), or the multiple convergent model of Bruce and Biemans' (1995) where R&D and customer involvement is a part thereof, the product development process in Indian garment industry involves design, industrial engineering, marketing and production quite similar to the integrated process models of Erhorn and Stark (1994).

It was observed in all three product development process flow chart that developed or sourced fabric, accessories, pattern and finish effect were sent to buyer's design team for approval was followed by the activity where approval/disapproval/approval with modification received from buyer. The actual process of approval/disapproval/approval with modification at buyer's end was not mapped in the process flow chart. If we compare product development process flow charts with Plumlee's (NICPPD) model model it was quite clear that while stage four activities are missing in above flow charts. This is quite interesting due to the fact that as the activities that are not being performed at manufacturers end will not require any manpower resource however there will be substantial time delay between the submission and approval received.

For the value added garments activity, steps in pre-production and production process sequences are quite different than standard cutting—sewing—finishing. Block cut parts are sent for embroidery/washing and/or printing and after embroidery/printing/washing, the final cutting is done; Half-sewn garments are sent for embroidery and/or printing and garments parts are assembled thereafter. Figure 4.4 shows one example of how production processes are different from the standard cutting—sewing—finishing operation. Often there is lot of hand work done in between the cutting—sewing—finishing processes requiring additional approval. There are additional steps for sample approval related to value added work like embroidery/printing/washing appearance/ colour/texture and/or trimming placement. Depending on the style detail, both the number of quality approval steps and their sequence was found to vary, and it was found that often certain approval steps followed were redundant and important approval steps missing. From Focus Group discussions it also emerged that different types of terminology, numbers of samples and sequence of steps were being followed by different buyers for the sample approval process. Hence it was decided to study the relevance of sample approval steps in the product development process.

Figure 4.13 Production Process for Value Added Garments



adda embroidery is a kind of hand embroidery where fabric is fixed in a wooden frame of approximately 44 inches X 88 inches under tension and multiple workers can embroider simultaneously using a kind of hand needle.

Any initiative and approach towards collaborative development with raw material vendors is absent in a majority of cases, which emphasises the need for an exploratory case study in the area of collaborative product development. The concept of salesman sample is dispensed with by a handful of fashion retailers like H&M and C&A. “The crucial time saved is worth taking a risk while bringing a product quicker to the market, especially for fashion items in relatively smaller quantity” – Country Manager, H&M India. (Chawla 2000)

4.2.4 Conclusion

The Focus Group concluded that due to continuous change and unpredictable trends in fashion garments, the product development process sequence may be the non-exhaustive type and continuously evolving. Thus it would be impractical to rationalise or standardise the product development process. Instead, rationalisation of the number of sample approvals may be a feasible step towards rationalisation of the process, thus shortening the product development and pre-production lead time.

4.3 Rationalisation of the Number of Sample Approvals

As concluded in para. 4.2.4 supra, rationalisation of sample approval process is possibly the answer to streamlining product development and pre-production processes. The objective of this study is to find out the rationale behind every sample approval process and examine the possibility of standardising it.

4.3.1 Methodology

The mode of investigation chosen was again a Focus Group survey (section 3.2.1) where an open ended questionnaire was sent to select experts. The choice of Focus Group members was based on judgemental critical case sampling as sample size should have cumulative experiences of product development and sample approval method encompassing different product types, different raw material types, different geographical locations, different retail distribution channels. Sample size (number was not important as long as all variables are covered) was decided as five. Members from earlier groups (section 4.2.1) were not considered in order to get a non-institutionalized and unbiased view. The Focus Group members included a senior merchandising manager from Gap Inc[8], India office, referred to hereafter as **[A]**, a merchandise manager from Li & Fung[9] India office **[B]**; the country manager, H&M[10], Bangladesh office **[C]**; a senior merchandiser from TMS Indonesia[11], a buying office from Indonesia **[D]**; a senior merchandiser from Ambatur Clothing Company[12], Chennai, India, a manufacturer of woven garments **[E]**, and a merchandiser from Texport Syndicate[13], Tirupur, India, a manufacturer of knitwear **[F]**. The Focus Group represented buyer/buying agent/importer/manufacturer exporter catering to different retail formats as well as different product ranges in woven and knitwear.

While the Focus Group meeting with the first three took place in the first round, a second Focus Group meeting was organised with the other three, based on their local availability. The agenda points deliberated upon with the Focus Groups were the requirement of different sample types and prevalent practices of sample approval in their respective organisations for different customers. Following the Focus Group discussion, each representative was given a tabular format to fill up (as a re-cap) assuming four standard sample approval processes, namely, prototype, fit, size set and pre-production take place for all orders. As the experts of this Focus Group were geographically separated from each other, answers (to the questionnaire) of one expert were shared with another expert to create a mock discussion scenario. The tabular format (Table 4.2) was administered through e-mail and each respondent was given time to interact internally in the organisation and fill in the form. While some members filled up the table soon after the discussion, some members took the form to their office and sent back the filled form after cross checking facts from their official records. The total study was completed in about 2 months.

8 www.gapinc.com
9 www.lifung.com
10 www.hm.com
11 www.tmsfashions.com
12 www.ambattur.com
13 www.texportsyndicate.com

Table 4.2 Agenda Points for Discussion

Parameters	Proto sample	Fit Sample	Size set	Pre production	Any other?
Number of samples asked for: Medium size/jumping size, etc. Including counters.					
Fabric to be used Alternate but same construction /sampling meterage/bulk fabric, etc.					
Whether actual accessories/ labels/ tags/embroidery were used in the sample.					
What is actually being checked in the sample?					
Whether the checked sample is returned to the manufacturer with comments? If yes, why? If no, why?					
Whether comments are sent by fax/e-mail/courier?					
Whether the approval process can take place electronically? i.e. without sample being physically couriered.					
Can the process be eliminated altogether?					

4.3.2 Data Collection

Data was collected in tabular format from each Focus Group member; however, it is presented here as a sample-wise summary.

<u>Prototype Sample</u>

Four out of six respondents **[A]** to **[D]** replied making 1 sample for buyer, **[E]** and **[F]** reported 2 and 3 samples respectively, and all six reported one counter for the factory. Five out of six reported using alternate fabric with similar construction whereas **[E]** reported actual bulk fabric for the same. Regarding accessories/labels/tags/embroidery used in the sample, four respondents reported using alternates; two reported use of actual (except labels & tags). Regarding what was actually being checked in the sample, respondents reported fit and look, commercial saleability, design and styling, construction, measurements and in some cases fabric quality as important parameters. Only two respondents reported that the actual sample is physically returned with comments while the other four said that the sample is retained with buyers for records and only comments were sent. The mode of intimating the sample feedback is e-mail with scanned picture for all respondents, while only one respondent reported using fax for pictures and sketches by courier. All respondents felt that the fit approval can neither be done electronically (i.e. without sample being physically couriered) nor the process can be eliminated; only **[A]** felt the proto approval could be clubbed with fit approval.

Fit Sample

Four out of six respondents replied making 1 sample for buyer, **[C]** and **[E]** reported 2 and 4 samples respectively, and all six reported one counter for factory. **[A]** & **[B]** reported that fit approval was often combined with size set using jumping size. Five out of six reported using same construction fabric (colour could be different). **[E]** reported that the actual bulk fabric was used. Regarding accessories/labels/tags/embroidery used in the sample, two respondents reported using similar or actual while four reported no use of accessories. When asked what was actually being checked in the sample, respondents reported construction, measurements, fit, shape and technical specifications (seams, stitches). Only two respondents stated that the actual sample is physically returned with comments while the other four said that the sample is retained with buyers for records and only comments were sent. The mode of intimating the sample feedback is e-mail with scanned picture for all respondents, while only one respondent reported using fax for pictures and sketches by courier. Regarding electronic fit approval, three respondents felt that fit approval could be done without sample being physically couriered by using either graded patterns or by tasking the staff, if they were technically competent to undertake the job.

Size Set Sample

While two respondents said one garment each in all sizes, two others asked for one garment in alternate (or jumping) sizes. One required pieces in medium size in addition to all sizes, and the sixth did not require size set at all. While two respondents specified using bulk fabric, the other four accepted alternate colours in actual fabric specification. All respondents (except the one who merged size set with fit sample) wanted actual accessories to be used, with special emphasis on embroidery, wherever required. In response to what was being checked, they cited various parameters like placement of accessories, grading of patterns, fitting, measurements, fabric shrinkage, lab test parameters, etc. While half the respondents did not return the physical sample (only comments), the other half returned the sample with seal to be followed in production.

The mode of communication was the same as for size set, however one respondent reported mandatory handwritten feedback. Regarding the relevance of the process, half the respondent felt that the process could be eliminated, while the other half disagreed.

Pre-production sample:

The pre-production sample replies showed that there was no uniformity amongst respondents: some asked for one piece in every colour, some in every size, some in any two sizes, some in the same size at fit sample while one respondent called this a sealer sample. Fabric, accessories and packing material to be used were the actual items. The parameters checked were aesthetics, packing material and proximity to the bought sample apart from details of accessories, specification and grading which was already checked earlier. While everyone felt that this process could not be eliminated, two respondents linked it with Fit sample performance; they felt that if the fit sample was approved at the first attempt without any comment, the production sample could then be skipped.

4.3.3 Discussion and Analysis

A discussion ensued on four aspects: basic processes and terminology, material and make up, quality control and communication, and value and best practice. Relevance of each step was discussed in the context of business. A serious complication realised during this discussion was the diversity in terminology used by the group members. For example, the typology of samples are multiple and confusing. While prototype sample, fit sample, size set sample, pre-production sample are standard and commonly used terms, others such as Presentation Sample, Pre-Proto Sample, Garment Process Test Sample, AD (Advertise) sample, top of production sample, bulk production sample, salesman sample, seal sample (gold, blue, red and green seal, etc.); terms like revised sealer sample, wash sample, embroidery position approval sample, etc., are also used frequently. It was found that the prototype sample is generally called for in a medium size with a counter piece ('counter' sample is an exact duplicate of the sample made and retained before sending any sample for approval, so that if a comment came by e-mail, it would be possible to interpret it easily, looking at the physical sample). For mail order business, instead of a prototype, a "photo shoot" sample is asked for. A salesman sample may be required for packing approval.

No electronic modes of approval took place. Instead, physical samples are couriered back and forth every time. Only in a few cases were graded patterns acceptable for size set approval. Approval/disapproval comments were often received by mail with accompanying pictures. Alternate fabrics and raw materials were being used even for size set leading to confusion for the counters kept. Some felt that fit sample and size set could often be combined for both the retail as well as catalogue businesses, while others felt that size set and pre-production could be combined. If fit sample/ size set had comments, then only some retailers called for a pre-production sample, otherwise this was skipped. While pre-production sample is defined as ‘representing bulk production in all aspects’, in some cases alternate accessories were allowed right up to the pre-production sample, defeating the purpose. Even though comments on sample were being received by mail, the remedial alteration (as per comment) could start only on the arrival of the sample by courier.

Everyone expressed apprehension about utility of electronic fitment as replacement of live model fitting. While two felt electronic fitment may reduce the number of attempts (iteration), the other four felt that it was far too early for technology to replace live model fitting (the discussion took place in 2002).

It is important to note that the fabric used for both proto and fit remain the same and also that the same parameters are being checked repeatedly. A striking similarity was observed here, in that those who retained the proto sample and sent only comments are the one who retained the fit sample. No substantial difference between proto and fit were found in terms of purpose. The group agreed that so many stages of sampling was probably designed to take care of mistakes at any stage, however when all was well with one stage, then all subsequent stages might not be necessary.

4.3.4 Conclusion

In summary of the discussion, it could be stated that irrespective of terminology, a minimum of three stages of sample approval appeared to be necessary. The first stage is to check the look, silhouette, overall proportion of measurement and construction details. In the second stage, the sample is checked for fit, measurement and balance (compatibility between fabric type, drape and measurements). In the third stage, the sample is checked for size grades, workmanship, all raw materials and accessories and proximity to the first sample. The fact that the concept of salesman sample is dispensed with by a handful of fashion retailers like H&M, C&A (section 4.2.3) reinforces the perception of lack of a standardised best practice.

4.4 Summary

This chapter addresses two objectives: firstly, to develop an understanding of the Indian apparel supply chain and secondly, to develop an understanding of the product development process. It was established that due to continuous change and unpredictable trends in fashion garments, the product development process sequence may be non-exhaustive type and continuously evolving. Thus it would be impractical to rationalise or standardise the same. Instead, rationalisation of the number of sample approvals and restricting it to three may be a feasible step towards shortening the product development and pre-production lead time.

Chapter Five: Case Studies

5.0 Case Studies

This chapter principally deals with two objectives:

- To evaluate and measure the delay-contributing activities in manufacturing cycles, analyse the reasons behind the delay and suggest means of reducing it.
- To identify and evaluate value-added and non-value-added activities in the manufacturing cycle.

The methodology used is primarily case studies and survey.

5.1 Identification and Measurement of Pre-production Activities (Case Study)

In order to identify and measure durations of delay-contributing activities in the manufacturing cycle, case studies of three organisations were followed by a survey through structured observation in a number of organisations. As the outcome of the case studies was used to finalise the methodology of subsequent survey, both are covered sequentially.

5.1.1 Methodology for Case Study

The qualitative requirements laid down for selection of organisations for the pilot study were that each organisation should have PD functions, pre-production activities executed by merchandisers, a reasonable number of orders in hand (seasonal business for number of organisations in NCR, section 2.7.2), and progressive mindset of the management to share data. The sample organisations would thus be amenable to purposive sampling, providing an illustration of what is typical of the industry.

Loyal Exports, Case-1, based in NCR with an approximate turnover of US$ six million, primarily exports to the Japanese market. Loyal Exports specialises in woven tops made out of yarn dyed fabrics. Delta Fashion, Case-2, an approximately US$ seven million turnover organisation has its own in-house manufacturing and buying division. Due to the buying arm, the organisation does a lot of PD. Silvershine Apparels, Case-3, is an approximately US$ five million turnover with exclusive in-house manufacturing facility.

One order from each organisation was mapped with activity dependency and expected time taken for each activity. Once an order was selected for mapping, description of all activities was listed with previous and next activity for each.

As clear demarcation of pre-production and production activities were needed (section 3.3), it was decided and any activity that changes form of raw material irreversibly will be considered as start of production. It was also necessary to ensure that such activities are being documented in any form, which can act as a possible source of information (section 3.3).

It was decided to use the standard formulae for measuring the duration of each activity (section 3.3). For every activity three different duration times (optimistic time = o, most likely time = m and pessimistic time = p) were calculated with assistance from executives from the organisation. Then, expected time duration for each activity was arrived at using the formula (o + 4m + p) / 6. PERT networks were drawn manually on MS-word and critical paths calculated for all three orders. The case studies were conducted concurrently over a period of one and a half months.

5.1.2 Data Collection

Activity data for each order listed all activities with activity no., activity duration and predecessor and successor activities. Activity data for Loyal Exports order is listed in table 5.1 and the PERT diagram shown in figure 5.2. A total of 64 activities were split into two major stages: 30 in PD (activity nos. 1-30), 25 in pre-production and manufacturing process (nos. 34 to 58). Three activities (nos. 31-33) fall in between, i.e. sample dispatch, comments thereon and exhibition in buyer's country, and six activities (nos. 59 – 64) appear in the post-shipment phase. Total number of activities in the critical path is 36 (shown in red colour), which provides the delivery lead-time of 189 days (from sample making to merchandise at store). It was decided to analyse activities only up to shipment and ignore the six post–shipment activities. Activity data for the Silvershine order is shown in table 5.2 and figure 5.3 is its PERT diagram. There are 14 activities in the critical path, delivery lead time being 59 days. In case of Delta Fashions (table 5.3 and figure 5.4), the activities are classified into internal, upstream and downstream activities. Out of a total of 42 activities, 19 are internal, 9 are upstream and 15 are downstream activities. The critical path has 22 activities with a lead time of 90 days.

Apart from order and organization-specific data collection, there were some interesting insights seen during the study of three organisations. It was found that the majority of the organisations used MS-Excel to schedule activities against target date, which they call TNA or critical path. Quite often, the buyer specifies target dates of key activities and based on those target dates, the manufacturing organisations create their own TNA calendar adding buffer days (to ensure that buyer target dates are not missed). It was found that Delta Fashion and Silvershine Apparels each maintained two separate TNAs; one with a few important activities suggested by the buyer, another one with a greater number of in between activities (mainly in-house) and brought forward target dates created by the manufacturer. For example, TNA calendar suggested by a buyer may have target dates for only five main activities, i.e. approvals for fit sample, size set, lab dip, bulk fabric, and production sample. A manufacturing organisation-created TNA calendar may have target dates for a total of 15−20 activities like pattern and grading approval, dispatch dates for all approvals, loading for bulk dyeing, receipt of fabric and accessories, etc.

Figure 5.1 shows a typical order follow-up sheet using MS-Excel for Delta Fashion. Five activities, namely labdip, technical sample (fit sample), photo sample, lab test report and production sample approvals are being monitored for all orders. For all five activities, there are two columns, one for submission date of sample (sent) and the other for approval date (approved). Apart from activities, other details of the orders are also mentioned in the same excel sheet. For every activity, two columns were to be filled up; actual date of activity starting and actual date of activity completion. Even then, some data was found missing in the format.

Figure 5.1 Order Follow-up Sheet Using MS- Excel

Picture 1 Typical Order follow up using MS-Excel

Supplier	Style No.	PO No.	Clr	Qty	Delvy Date	Descrp	Fabric	Labdip Sent	Labdip Aprvd	Technical Sent	Technical Aprvd	Photo Sent	Photo Aprvd	Lab Test	Production Intial	Production Final	Production W/Hus	Comments
ABC	19135	301091-	Noir	565	13/4	Bais Blouse				14/11	5/12*	5/12	24/12					
			Blanc	1290		Flouce Sleeves				15/12	31/12	15/12						Awaiting for photosample appro
ABC	19285	3E+06	Camel	555	13/4	Blouse		23/10	6/11	8/11	9/12	5/12	24/12					Bulk fabric will be inhoue by 10/
FGH			Noir	245									24/12					
IJK	19286	3E+06	Print	2830	13/4	T.Shirt	Prt Jersey	24/11	28/11*	8/11	5/12	2/1						Awaiting for photosample appro
ABC								4/12	9/12*									
ABC								17/12	23/12									
	19308	3E+06	Noir+Off-Wh	770	13/4	2 pcs set	70%A	4/11	7/11	10/11	10/11*	By 8/1						Will send the reviswed technica
			Off-Wht+Noi	420		CardigAN+1/2	30% MW			6/12	22/12*	By 8/1						by 6/1+Photo samples by 8/1
										By 6/1		By 8/1						
	19312	3E+06	Purple	905	13/4	Blouse crinkle	Poly Cot	11/12	16/12	12/11	2/12*	29/12						Awaiting for technical approva
ABC			Noir	610						17/12	Awating	29/12						
ABC	19352	3E+06	Blanc	205	13/4	Blouse				8/11	5/12	5/12	24/12					Awaiting for technical approva
BCD			Noir	795								5/12	24/12					
ABC	34872	3E+06	Brown	210	13/4	Trouser	L.Nappa	23/10	6/11	6/11	19/12	8/12	24/12					Have ordered the leather to the Tan
			Black	90		P/satin Lined						10/12	24/12					
ABC	36597	3E+06	Black	95	13/4	Skirt w/	L.Nappa			6/11	5/12	9/12	24/12					
			Brown	205		P/satin Lined		23/10	6/11	9/12		10/12	24/12					Have ordered the leather to the Tan
	58889	3E+06	Parma	1060	13/4	2 pcs set	100% A	4/11	7/11	25/11	10/12	4/12	24/12					
			Noir	510		cardigan + Pul		4/11	7/11			4/12	24/12					
ABC			Prune	630				4/11	7/11*			4/12	24/12					
			Prune					19/11	22/11			4/12	24/12					
	19288	321373-	Printed	800	13/4	T.Shirt	55%S	16/12	19/12*	10/12	Awating	By 20/1						Viscose Silk Yarn will be available
FGH							45%V	By 20/1										the fabric by 12/1 and will organzie
KLM	19293	3E+06	Printed	1560	13/4	T.Shirt	55%S	12/12		19/12	Awating	By 20/1						print strike off and samples together b
							45%V	By 20/1										
KLM	17476		Printed		13/4	T.Shirt	55%S			By 17/1		By 20/1						
							45%V	By 20/1										

Table 5.1 Activity Data for Loyal Exports Order

Code No	Description of Activities	Time in days
1	Fabric specification from buyer + proforma order	5.2
2	Fabric specification conversion for fabric vendor	0.04
3	Fabric specification courier to fabric supplier	1.08
4	Yarn sourcing by fabric vendor	10
5	Yarn dyeing	2
6	Yarn warping & weaving	5.3
7	Dyeing	2.1
8	Printing	3
9	Sample fabric transported to manufacturer	1.2
10	Sample fabric despatched to buyer	5.2
11	Buyers response to sample fabric	10
12	Trim specification sent from buyer	5.2
13	Trim specification conversion for trim supplier	0.04
14	Trim specification sent to accessories vendor	0.75
15	Trims developed by vendor	6.3
16	Trims despatched by vendor to manufacturer	0.7
17	Trims sent by buyer to manufacturer	5.2
18	Conversion of buyer order for fabric vendor	0.04
19	Courier order to fabric vendor	1.08
20	Yarn sourcing	10
21	Yarn dyeing	2
22	Warping	5.3
23	Weaving	2.1
24	Dyeing/ Printing	3
25	Fabric for exhibition samples sent to buyer	1.2
26	Paper pattern received from buyer	5.2
27	Quantity idea given by the buyer	0
28	Sewing & packaging spec. received from buyer	5.2
29	Price negotiations	0
30	Exhibition sample made	2.5
31	Exhibition samples and seal sample sent	5.2
32	Comment received on seal sample	5.2

Code No	Description of Activities	Time in days
33	Exhibition in buyer’s country	10
34	Purchase order with revised paper pattern received	5.2
35	Instruction to trim vendor to start bulk production	0.5
36	Trim production by vendor	7
37	Trim shipped to manufacturer	0.5
38	Instruction to fabric vendor to start bulk production	1.08
39	Bulk yarn sourcing	15
40	Bulk yarn dyeing	10.5
41	Warping	5.3
42	Machine setup	3.6
43	Weaving	11.3
44	Washing	5
45	Calendaring and packaging	5.3
46	Dyeing printing	3
47	Fabric shipped to processor	1.2
48	Fabric over dyeing	1.2
49	Production fabric sent to manufacturer	1.2
50	Sample made with production fabric	2.7
51	Sample sent to buyer	5.2
52	Buyers comments received	10.5
53	Cutting of fabric	1.7
54	Garment stitching	9.3
55	Garments finishing	2
56	Customs	20
57	Delivery to port	0.5
58	Delivery to buyer by sea	34.3
59	Customs clearance in importing country	2
60	Transport to warehouse	1
61	Rewashing process	2
62	Final Checking	2
63	Counting distribution and price tag attach	3
64	Delivery to each store	3

Figure 5.2 PERT Diagram for Loyal Exports Order

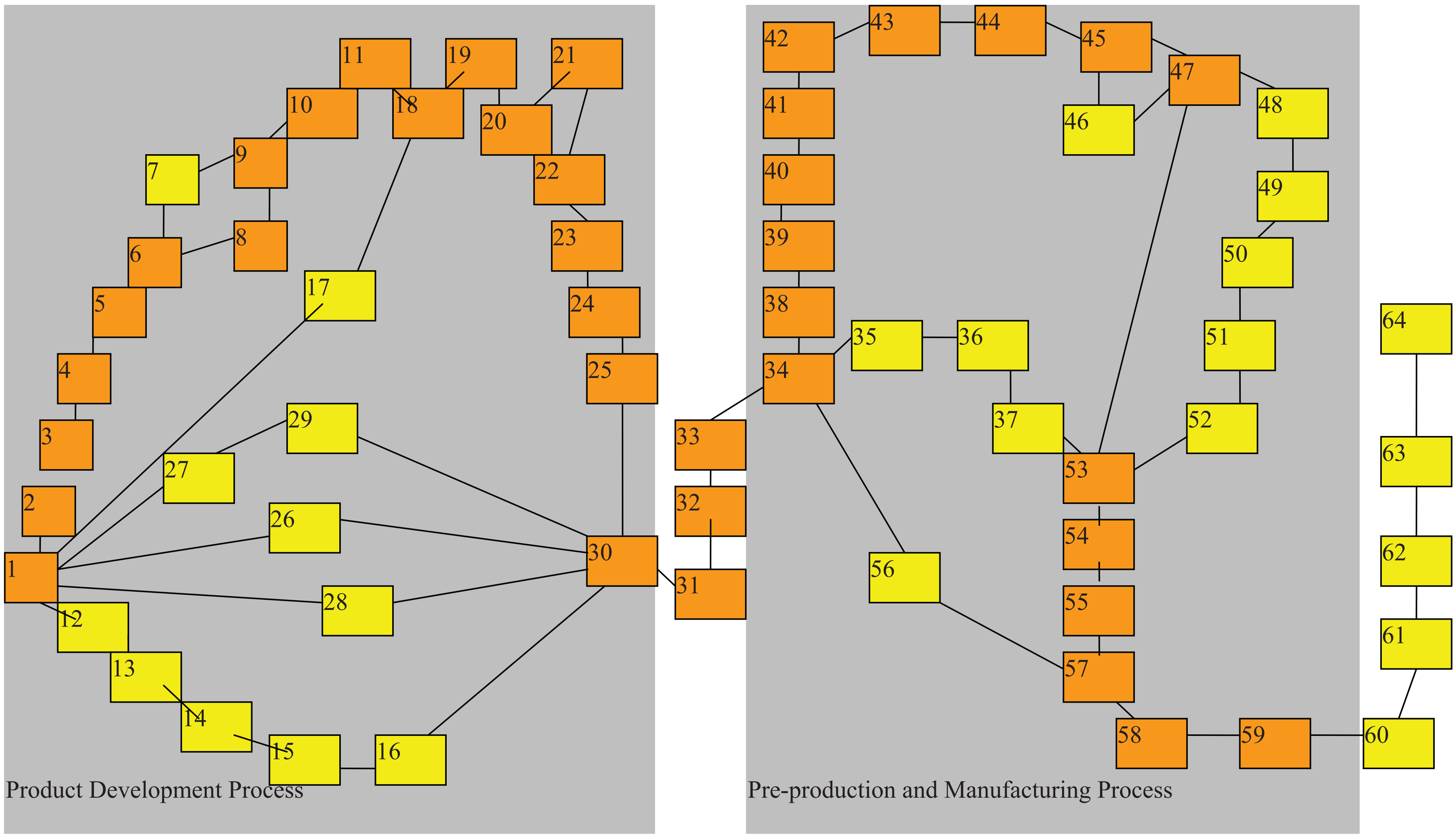


Table 5.2 Activity Data for Silvershine Apparels Order

		Silvershine Apparels		
Previous Activity		**Activity**	**Next Activity**	**Duration in days**
	1	Sampling	2	7
1	2	Range	3	3
2	3	Display to buyer	4	1
3	4	Make samples as per buyer specification (proto sample)	5,8,11,13	9
4	5	Order receipt	6,7	4
5	6	Fit sample submit	14, 17	3
5	7	Photo sample submit	14	3
4	8	Fabric order placement	9	2
8	9	Receive desk loom	10	11
9	10	Approval of desk loom	15	5
4	11	Measurement spec received	12	1
11	12	Size set making	16	3
4	13	Quota procurement	18	2
6	14	Approval of fit and photo sample	7	7
10	15	Bulk fabric approval	19	4
12	16	Size set approval receipt	20	5
6	17	Trims approval sought	21	5
5	18	L/C open	26	2
15	19	Bulk fabric ready	22	2
16	20	Production pattern make	22	1
17	21	Trims approved	22	3
14,19,20,21	22	Production	23	7
22	23	Mid inspection,	24	1
23	24	Final inspection	25	1
24	25	Packing	28	5
18	26	Get LC, quota etc.	27	1
25, 18	27	Ship out		1

Figure: 5.3 PERT Diagram for Silvershine Apparels Order

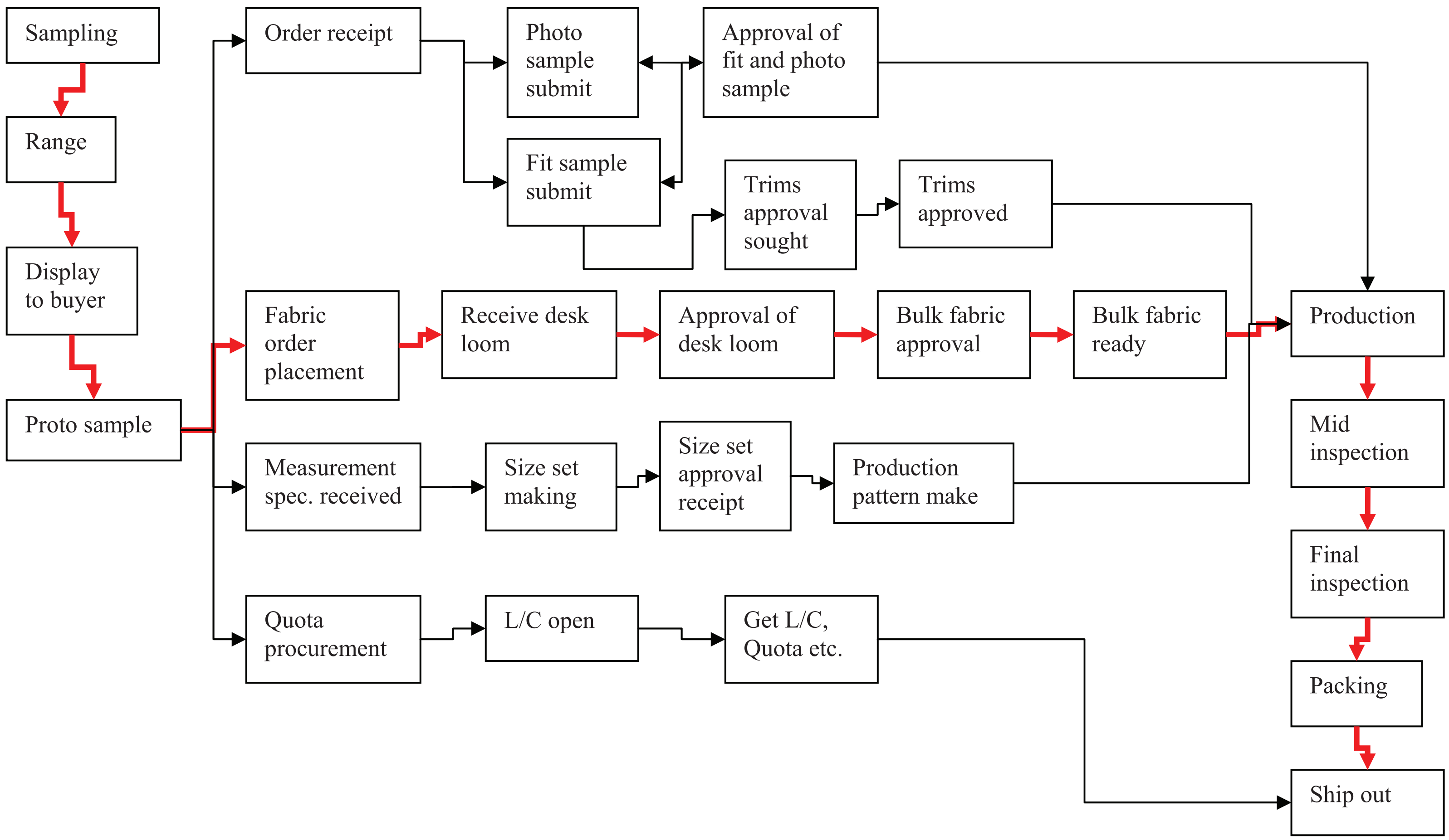
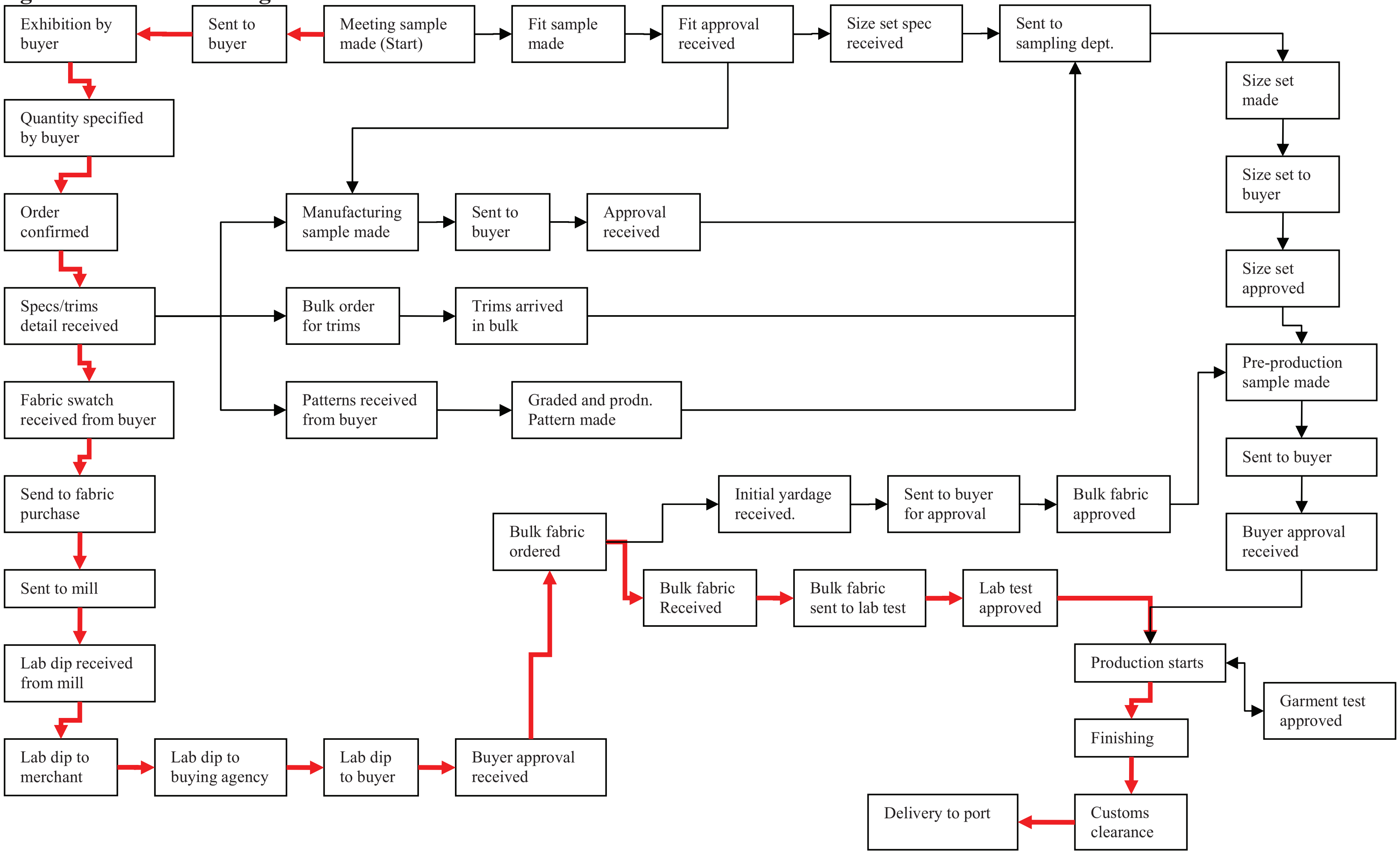


Table 5.3 Activity Data for Delta Fashion Order

Previous Activity		Activity	Next Activity	Duration in Days
	1	Meeting sample made (Start)	2, 30	7
1	2	Sent to buyer	3	3
2	3	Exhibition by buyer	4	1
3	4	Quantity specified by buyer	5	9
4	5	Order confirmed	6	4
5	6	Specs/trims detail received	7, 23,26,28	3
6	7	Fabric swatch received from buyer	8	3
7	8	Send to fabric purchase	9	2
8	9	Sent to mill	10	11
9	10	Lab dip received from mill	11	5
10	11	Lab dip to merchant	12	1
11	12	Lab dip to buying agency	13	3
12	13	Lab dip to buyer	14	2
13	14	Buyer approval received	15	7
14	15	Bulk fabric ordered	16	4
15	16	Bulk fabric Received	17	5
16	17	Bulk fabric sent to lab test	18	5
17	18	Lab test approved	19	2
18	19	Production starts	20	2
19	20	Finishing	21	1
20	21	Customs clearance	22	3

Previous Activity		Activity	Next Activity	Duration in Days
21	22	Delivery to port (End activity)		7
6	23	Manufacturing sample made	24	1
24	24	Sent to buyer	25	1
25	25	Approval received	33	5
6	26	Bulk order for trims	27	3
26	27	Trims arrived in bulk	33	3
6	28	Patterns received from buyer	29	3
28	29	Graded & prodn. Pattern made	33	2
1	30	Fit sample made	31	5
30	31	Fit approval received	32	3
31	32	Size set spec received	33	3
32,25,27, 29	33	Sent to sampling dept.	34	3
33	34	Size set made	35	5
34	35	Size set to buyer	36	5
35	36	Size set approved	40	5
15	37	Initial yardage received.	38	10
37	38	Sent to buyer for approval	39	5
38	39	Bulk fabric approved	40	5
36,39	40	Pre-production sample made	41	1
40	41	Sent to buyer	42	5
41	42	Buyer approval received	19	5

Figure: 5.4 PERT Diagram for Delta Fashion Order



5.1.3 Data Analysis

64 activities were recorded for Loyal, 42 for Delta and only 27 for Silvershine. The reason behind this could be multi-fold; the orders selected were fashion or basic merchandise, value addition in the merchandise and/or the distribution channel being used (to retail the merchandise). While Loyal Textiles received the pattern from the buyer, Delta developed their own pattern. While Loyal textile was working on yarn dyed fabric, Delta's order was solid colour and Silvershine worked on knits. Delta was involved in design development, Loyal was not. It was also found that while micro activities (of fabric development) were mapped in the Loyal order, only macro activities were mapped in the Delta and Silvershine orders. This depended on the companies' internal practice and convenience. For the Loyal order, the critical path time was 189 days spanning 36 activities; in the case of Delta Fashion, critical path time was 90 days with 22 activities and for Silvershine, only 14 activities were in the critical path of 59 days. In the case of Loyal Exports, it was found that the activities first diverged into many concurrent activities and then converged as the in-house PD activities got over. The activities again diverged into many concurrent activities as the pre-production began and again converged at 'cutting' activity.

The variability between organisations in maintaining details of activities could be attributed to the lack of record and hypothetical estimation. It was also observed that none of the three companies had ever drawn a PERT network for any of their orders. Executives rarely gave too much attention to the interdependency of activities, although it was found that all three organisations kept a tab on four to five milestone activities in every order. These milestone activities were generally suggested by the respective buyers. Although in two cases (Loyal and Delta), executives were aware about the term 'critical path method', no one actually knew the correct definition and method of calculation.

It was interesting to note that in all three cases, sample approval activities were not found in the critical path. Generally, bulk fabric development and sourcing activities were found in the critical path. However, amongst the variability of process steps between the three organisations, there were striking similarities in their PERT diagrams. In all three cases, it was found that activities first diverged to parallel activities and finally converged before production started. Fabric spreading and/or cutting could be considered as the beginning of ‘production’ process, differentiating the earlier process as ‘pre-production’. The number of activities in the production stage were barely four or five, depending on what level of detail the activities were recorded up to. In some companies cutting, sewing and finishing activities were separately recorded while in others, it was recorded as one activity followed by an inspection. Unlike the Loyal Exports order, where a clear distinction was observed between PD and in-house pre-production process, in the other two cases the PD and in-house pre-production activities were mixed. From sampling request till fabric cutting activity could thus be termed as the pre-production stage and cutting to shipment (out of factory) could be termed the production stage.

In the case of the Loyal order, only 14 days (4 activities) was ‘production’ process out of 189 days of manufacturing lead time. For Silvershine order production process was for 15 days (5 activities) out of 59 days and for Delta, 13 days (4 activities) out of 90 days of the manufacturing cycle. It was clear that time duration and number of activities in the pre-production stages were far more than in the production stages. Another important phenomenon observed during the case study was iteration in certain activities. While estimating duration of those activities, executives used to add extra time (buffering for possible iteration), resulting in longer target lead time. It was found that activities of upstream suppliers requiring approval by downstream customers generally went for iteration. Though iterations were prevalent in sample and accessories approvals, there was no record available which those activities were, the reason behind iterations and number of times iteration took place. Feedback by executives during the case studies suggested activities where approvals were needed were the primary reasons for delay, however no documented records were available to prove or disprove the facts. Iteration posed another possible phenomenon of dynamic shifting of the critical path. It was found (from the case studies) that fabric development-sourcing-approval process generally fell in the critical path and the other two concurrent process were sample (fit/size set) development approval and accessories development-sourcing-approval. As all ‘approval’ process are prone to iteration, depending on duration and number of times of iteration, any of the three concurrent processes could become the critical path. However the sample (fit/size set) development-approval route had very little (between 8-10 percent of the critical path time) slack time (section 2.4.2), which meant any delay in sample development-approval would convert the sample (fit/size set) development-approval path as critical path. To measure durations of delay contributing activities it was important to record the activity durations separately for each iteration (if any) during the subsequent survey.

Interestingly, the MS-Excel sheet (figure 5.1) was not used by Delta Fashion for any calculation of duration nor for any automatic visual alarm. The sheet was used merely as for record keeping and not for any analysis or decision making. Data maintained in Silvershine Apparel was also in MS-Excel, but not as detailed as Delta. Once the activity data and PERT networks prepared were shown to executives, they felt that the process was quite time consuming and apparently had no practical value during the actual progress of the order as the duration as well as precedence relationship between activities kept changing, making the whole exercise futile.

Even though the organisation's executives were aware of the term 'critical path method', it was surprising that none knew the correct meaning (definition as per operation research) of 'critical path'. The interpretation of term 'critical' by the executives varied; while some felt 'critical' meant 'possibility of non-conformance is higher' as per previous experience, others felt 'critical' meant 'most time taking'; some even linked 'critical' with cost involved with that activity. Everybody selected 'critical' activities hypothetically, based on intuition or previous experience or a buyer's milestones and no one actually made a PERT network of activities and then arrived at the CPM.

5.1.4 Conclusion

The fact that the number of activities in pre-production was higher than in production and time consumed in pre-production activities contributed more to the total manufacturing lead time suggested further exploration for identifying scope for lead time improvement. The above network analysis once again reflected the variability in processes. It was felt necessary to capture data with uniform level of detail for multiple orders across different organisations; thus, a structured method of data collection was felt necessary. As it was unlikely that any organisation would be able to draw PERT network diagram and map critical path themselves, a simpler method of capturing pre-production processes was required. However, it was clear from the case study that that PD and pre-production processes in the manufacturing cycle resembled project management. Multiple executives from different organisations worked in synchronicity to deliver the product in the pre-defined time. PERT/CPM was thought to be the appropriate project management tool for addressing the lead time (technically critical path time) reduction. However as the activities in apparel manufacturing cycle were primarily human-oriented functions (unlike machine-oriented tasks in other industries), the critical chain could be a more appropriate (section 2.4.2) optimisation technique to conduct a longitudinal study as the critical chain addressed both the human side and the algorithmic methodology side of project management in a unified discipline.

5.2 Identify and Measure Pre-production Activities (Survey)

As concluded in the earlier case study, there was a necessity to measure all activities from order receipt to shipment ex- factory, their durations and any instances of iterations. For the survey, data would be needed over a whole year to avoid any distortion due to several peaks and troughs of activity. Furthermore, data from several companies would make findings more generic, rather than inclined towards any individual organisation's practice. The steps involved were first development of a standardised format for order progress tracking which could be used across organisations, irrespective of the differences in merchandise type, distribution channel and methodology of record keeping followed by different organisations.

5.2.1 Methodology for Survey

As explained as necessity in section 3.3 and observed during pilot case study (section 5.1.4) it was established that a structured data collection format is necessary for conducting the survey. Also as anticipated in section 3.3 and concluded in pilot case study (section 5.1.4) it was also established that simpler yet flexible data collection format to capture the variability of data which can be easily filled up.

As explained in section 3.3 that one particular order is considered as one sample and information from multiple orders from multiple factories to be collected as representative data about the industry, selection of orders and selection of organisations should necessarily be heterogeneous. However as the data is considered confidential amongst industry, sample selection method was purposive (judgemental), and order selection method was random to ensure heterogeneity. The sample selection method would ensure that key themes were being observed (Saunders *et al.* 2007, page 193). Criteria of sample selection were coverage of north and south geographical location, mix of woven and knit product range, coverage of European and American buyers, procurement channels used and systems in place to ensure heterogeneity. Seven manufacturing organisations namely Kirat, USI, VO Enterprises, GI, ACC, Auric and Misami and two buying organisations namely Essel Inc. and H&M, India were selected. The selection of organisations was based on willingness to share info by the management and access to information. A brief of the organisations from where data was collected is given in appendix VIII and a summary of the organisations is given below:

Table 5.4 Summary of Organizations for Pre-production Time Analysis

Name of Organisation	Turnover $ million	MIS/ERP in place	Location	Separate style-wise file maintained	Source of business	Procurement channel used	Product range	Data collection process	No. of units of data accepted	No. of units of data collected
Kirat	$ 4 million	No	NCR	No	EU	Importer and Buying Agents	Ladies and Kids hi-fashion; woven	Personally	17	20
Unistyle Impex	$ 2.5 million	No	NCR	No	EU	Buying Agents and Direct	Ladies and kids hi-fashion, knits	Personally	11	17
Gokaldas Images	$100 million	No	Bangalore	Yes	EU & US	Importer, Buying Agents, Direct, Liaison Office	Ladies basic	Through student	11	14
Essel Inc	$ 5 million	No	Bangalore	Yes	EU and Asia	Buying Agent	Ladies and Kids hi-fashion; woven and knits	E-mail	14	14
H&M, India	$ 80 million	No	NCR	Yes	EU	Liaison Office	Ladies and Kids hi-fashion; woven and knits	E-mail	9	9
VO Enterprises	$ 8 million	No	NCR	No	EU & US	Importer and Buying Agents	Ladies and kids hi-fashion, knits	Personally	8	11
Misami	$ 8 million	No	Chennai	No	EU & US	Importer and Buying Agents	Men's basic	E-mail	2	2
ACC	$100 million	MIS	Chennai	Yes	US	Importer, Buying Agents, Direct, Liaison Office	Men's basic	Through student	0	5
Auric	$ 8 million	No	NCR	No	EU	Importer and Buying Agents	Ladies hi-fashion; woven	E-mail	0	8
									72	100

Except H&M India Liaison office, all other organisations were owner driven.

Product ranges indicated were company mentioned; this did not necessarily mean that data was collected for similar styles/similar fabrics.

A standardised data collection format was developed (table 5.5) and then pilot tested with 10 orders. Every activity was classified into two types, either the activity duration was less than or equal to one working day or more than one working day. For example, 'fit sample dispatched to buyer' or 'fit comment received from buyer' were activities indicated by one date. As 'fit sample making' or 'fit sample approval process by buyer' might take more than one day, two dates needed to be mentioned, the start and finish dates. For every activity there were two columns; the first captioned 'On/From' and the second captioned 'To'. For activity less than or equal to one working day, one date was entered in the first column. For activities spanning for more than one working day, start date was entered in the first column and finish date in the second column, thus capturing the duration of any activity.

The duration of iteration (if any) could be calculated first by deducting the 'To' column date from the 'On/From' column date and then adding the 'Days' column in case there was more than one iteration. The total lead time, pre-production time and production time was to be calculated by deducting the preceding activity date from the terminal activity date (and not by adding the activity durations), as this would automatically calculate the longest path and cancel out the problem of concurrence.

Table 5.5 Initial Order Progress Tracking Format

	Fabric description:			
	Order quantity/original delivery date:			
		On/From	**To**	**Days**
1	Date buyer meeting (sampling+specifications received)			
2	Date FIT samples were sent to the buyer			
3	Date comment (approval/rejection) received from the buyer			
4	Duration of FIT Iteration 1			
5	Duration of FIT Iteration 2			
6	Order Confirmation (Col+Qty+Delv+Price)			
7	Date size set were sent to buyer			
8	Date comment on size set from buyer			
9	Duration of size set Iteration 1			
10	Duration of size set Iteration 2			
11	Duration lab dip/strike off making by processor			
12	Date lab dip were sent to the buyer			
13	Date comment (approval/rejection) on lab dip from buyer			
14	Duration of lab dip Iteration 1			
15	Duration of lab dip Iteration 2			
16	Date grey fabric was ordered			
17	Wash Care instruction received			
18	Date W/C label were received in the store			

19	Date grey fabric sent to processors (bulk dyeing/printing)			
20	Date first lot finished fabric receive in store			
21	Duration: colour approval for fabric (first lot) sent to/from buyer			
22	Duration of fabric colour approval Iteration 1			
23	Duration of fabric colour approval Iteration 2			
24	Duration of lab test for processed fabric (first approved lot)			
25	Duration of lab test Iteration 1			
26	Duration of fabric colour approval Iteration 1			
27	Bulk embroidery thread sent to buyer for approval			
28	Bulk embroidery thread approval received			
29	Duration of embroidery thread approval Iteration1			
30	Duration of embroidery thread approval Iteration2			
31	bulk fabric inspection + PP meeting			
32	Initial inspection			
33	Duration Price ticket + carton sticker approval			
34	Duration Button approval			
35	Duration of cutting (first piece to last piece)			
36	Duration lot sent to sewing contractor (first to last piece)			
37	Duration lot recvd. from sewing contractor (first to last piece)			
38	Date production piece sent to buyer			
39	Duration washing			
40	Duration checking			
41	Duration finishing+packing			
42	Mid inspection			
43	Final Inspection			
44	Duration final inspection iteration 1			
45	Date goods out of factory			

To begin with, the initial order progress tracking format (table 5.5) had 45 activities to be tracked. During pilot testing it was observed that micro details of certain activities were generally not available (neither documented nor in memory), but did not really affect the objective of the study. Accordingly, to ensure data availability, authenticity and consistency, necessary modifications were done and the format was finalised for data collection (Table 5.6). However it was still necessary to maintain some flexibility in data collection, depending on some particular variation in order requirements, if style-specific. The final format had 20 activities to be tracked; a possibility of two iterations each were provided for six activities that were prone to iteration. Out of six activities for possible iteration, two were sample making-related and the other four were accessories-related. In case the number of iterations exceeded two, one more row was to be inserted in the respective activity.

Table 5.6 Final Order Progress Tracking Format

	Country of buyer	
	Type of Buyer: Store/catalogue/importer/other*	
	Garment description:	
	Fabric details - Knits/wovens/solid dyed/yarn dyed/print*	
	Fabric description:	
	Order quantity/original delivery date:	

		Date		
	Activity Description	On/From	To	Days
1	Date buyer meeting (sampling request+specifications received)			
2	Date FIT samples were sent to the buyer			
3	Date comment (approval/rejection) received from the buyer			
	Duration of FIT 1st iteration (steps 2 - 3)			
	Duration of FIT 2nd iteration(steps 2 - 3)			
4	Date Order Confirmation (Col+Qty+Delv+Price)			
5	Date size set were sent to buyer			
6	Date comment on size set from buyer			
	Duration of size set: 1st iteration (steps 5 – 6)			
	Duration of size set 2nd iteration (steps 5 – 6)			
7	Date lab dip were sent to the buyer			
8	Date comment (approval/rejection) on lab dip from buyer			
	Duration of lab dip 1st iteration(steps 7 - 8)			
	Duration of lab dip 2nd iteration(steps 7 - 8)			
9	Date first lot finished fabric received in store			
10	Date bulk fabric (from first lot) sent to buyer for colour approval			
11	Date bulk fabric colour (approval/rejection) received from buyer			
	Duration of fabric colour approval 1st iteration (steps 10 - 11)			
	Duration of fabric colour approval 2nd iteration (steps 10 - 11)			
12	Date processed fabric (first approved lot) sent for lab test			
13	Date lab test comment (approval/rejection) received			
	Duration of lab test 1st iteration (steps 12 - 13)			
	Duration of lab test 2nd iteration (steps 12 - 13)			
14	Date Bulk embroidery thread sent to buyer for approval			
15	Date Bulk embroidery thread approval/rejection received			
	Duration embroidery thread approval 1st iteration (steps 14 - 15)			
	Duration embroidery thread approval 2nd iteration (steps 14 - 15)			
16	Duration cutting			
17	Duration Sewing			
18	Duration washing (if applicable)			
19	Date production piece sent to buyer			
20	Date goods out of factory (in exporting country)			

Note:

Activities starting with ‘date’ please fill only first column
Activities starting with ‘duration’ please fill two columns, i.e. start and finish date
Activities marked with light green colour is mandatory
Activities marked with light yellow is applicable for iterations i.e. in case of rejection
Only actual date to be filled up
For orders with multiple fabric colours: fill up for any one colour as approval may happen at different dates
Please do not fill up for repeat orders (where lot of above activities are not required)

Data for total of 100 orders was planned to be captured with 12 orders each from nine organisations over a period of one year through different sources and through various means. Data from Kirat and USI was collected in person; from VO Enterprises, Misami, Essel Inc. and H&M, data was recorded and forwarded by the merchandise manager; data from GI was recorded by student associates as part of their directed research. Each data sheet was checked, query sent, if any, and only then was the final data sheet accepted. The collected data was then screened for completeness and obvious inaccuracy.

5.2.2 Data Collection

To ensure that all data was factual rather than the impression of merchandising manager, it was emphasised that all data was actually copied from written records (style/order file, data or communication file like fax, e-mail, etc.). As the emphasis was on actual data, even if one or two activity data (out of 20) for any style was missing from the records, that order was dropped for further calculation so that only complete data sets were used.

One filled up order progress tracking format from USI is presented in table 5.7 as an example. Basic order details and activity dates are recorded in the format. Missing data for some activities like size set, PP (pre-production) sample indicated that those activities were not present for that particular order. It was also seen that fit sample and lab dip were sent for one iteration each. Out of 100 units of data collected, styles/orders having incomplete and absurd data were removed and data for only 72 orders was accepted for final analysis. Further, in eight out of 72 orders, it was observed that the total approval time was more than total pre-production time; this was because more than one approval process took place simultaneously and the same time / duration was added. Data for those eight orders was also discarded and the remaining 64 orders analysed and the results summarised in table 5.8

Table 5.7 Filled up Progress Tracking Format

Country of buyer			
Type of Buyer:	AMC		
Garment description:	ladies top with embroidery		
Fabric details - Knits/wovens/solid dyed/yarn dyed/print*	Knit		
Fabric description:	Single Jersey		
Order quantity/original delivery date:	**960 pcs**		
Style	**us-102**		
	On/From	To	Duration
Date buyer meeting (sampling request+specifications received)	02/13/04		
Date FIT samples were sent to the buyer	03/11/04		27.00
Date comment (approval/rejection) received from the buyer	03/27/04		16.00
Duration of FIT 1st iteration	04/10/04	04/15/04	5.00
Duration of FIT 2nd iteration			0.00
Date Order Confirmation (Qty+Delv+Price)	02/13/04		
Spec+swatch+col reference received to start sampling	02/19/04		
Date size set were sent to buyer			
Date comment on size set from buyer			0.00
Duration of size set: 1st iteration (steps 5 - 6)			0.00
Duration of size set 2nd iteration (steps 5 - 6)			0.00
Date lab dip were sent to the buyer	03/08/04		18.00
Date comment (approval/rejection) on lab dip from buyer	03/09/04		1.00
Duration of lab dip 1st iteration(steps 7 - 8)	03/15/04	03/15/04	0.00
Duration of lab dip 2nd iteration(steps 7 - 8)			0.00
Date first lot finished fabric received in store	03/26/04		
Date bulk fabric (from first lot) sent to buyer for colour approval	03/27/04		
Date bulk fabric colour (approval/rejection) received from buyer	03/28/04		1.00
Duration of fabric colour approval 1st iteration (steps 10 - 11)			0.00
Duration of fabric colour approval 2nd iteration (steps 10 - 11)			0.00
Date processed fabric (first approved lot) sent for lab test	03/29/04		
Date lab test comment (approval/rejection) received	04/03/04		5.00
Duration of lab test 1st iteration			0.00
Duration of lab test 2nd iteration			0.00
Duration of lace approval	04/10/04	04/15/04	5.00
Duration of label approval	04/10/04	04/15/04	5.00
Date Bulk embroidery thread sent to buyer for approval	04/19/04		
Date Bulk embroidery thread approval/rejection received	04/19/04		0.00
Duration embroidery thread approval 1st iteration			0.00
Duration embroidery thread approval 2nd iteration			0.00
Send PP sample to buyer/photoshoot			
Go ahead for production			
Duration cutting	04/14/04	04/22/04	
Duration Embelishments/embroidery	04/14/04	04/28/04	
Duration Sewing	04/19/04	05/02/04	
Duration washing (if applicable)/finishing	04/20/04	05/02/04	
Date production piece sent to buyer (pp sample)	04/17/04		
Date goods out of factory (in exporting country)	05/03/04		

Table 5.8 Order Progress Analysis

Order code	Total lead time (sampling request to goods ship out)	Total production time (cut to ship)	Total pre-production time	% pre-production time out of total lead time	Total approval time	% approval time out of pre-production time	Total iteration time	% iteration time out of pre-production time
MP 615	262	31	230	88	194	84	96	42
H&M07	136	35	101	74	83	82	41	41
girls party shirt	109	45	64	59	53	83	22	34
short+shirt	180	110	70	39	39	56	23	33
sparkly t shirt	84	19	65	77	42	65	19	29
9109-CR	170	34	136	80	94	69	37	27
31300020	99	18	81	82	53	65	21	26
JDW-160	198	118	80	40	58	73	20	25
ELC-1136	82	26	56	68	30	54	13	23
ut-006	86	14	72	84	42	58	16	22
up-002	86	14	72	84	49	68	16	22
9109-CR	170	34	136	80	86	63	29	21
mg-11	68	21	47	69	30	64	10	21
9125-CR	170	34	136	80	130	96	26	19
Vichy-group	201	38	163	81	53	33	29	18
carnbey-6	78	6	72	92	47	65	11	15
9125-CR	170	34	136	80	112	82	19	14
29018	220	52	167	76	87	52	22	13
tt-614	79	17	62	78	41	66	8	13
I-04-2	138	37	101	73	24	24	13	13
I-04-1	152	51	101	66	24	24	13	13
K-04-123	154	104	50	32	16	32	5	10
K-04-123 Robe	154	104	50	32	16	32	5	10
SSD 127	183	32	151	83	51	34	15	10
SSD 127	183	32	151	83	51	34	15	10
MP 613	173	34	138	80	119	86	13	9
us-102	80	19	61	76	38	62	5	8
BN 101	149	12	137	92	55	40	11	8
Printed voil	137	37	100	73	29	29	7	7
RM04	199	60	139	70	129	93	9	6
S4r-356 dash	78	15	63	81	40	63	4	6
Dress	163	22	141	87	20	14	8	6
NJB 359	154	24	130	84	43	33	7	5
NJB 359	154	24	130	84	43	33	7	5
Emb Skirts	129	50	79	61	27	34	4	5
Dress	153	20	133	87	15	11	6	5
pd 24	176	10	166	94	61	37	5	3
pd 24	176	10	166	94	61	37	5	3
HNM-6	104	32	72	69	27	38	2	3
T-shirt	233	91	142	61	25	18	3	2
Skirts	175	92	83	47	16	19	0	0
Dress Set	180	102	78	43	28	36	0	0
474G	118	25	93	79	40	43	0	0

…contd

	Order code	Total lead time (sampling request to goods ship out)	Total production time (cut to ship)	Total pre-production time	% pre-production time out of total lead time	Total approval time	% approval time out of pre-production time	Total iteration time
400 H	127	34	93	73	50	54	0	0
CTR 6020	128	36	92	72	36	39	0	0
SW 149B	135	21	114	84	28	25	0	0
Lt 14	155	15	140	90	28	20	0	0
BNW 119	167	13	154	92	40	26	0	0
MH 046	177	30	147	83	75	51	0	0
CTR 6103	199	29	170	85	70	41	0	0
ELC-1137	85	22	63	74	6	10	0	0
474G	118	25	93	79	40	43	0	0
400 H	127	34	93	73	50	54	0	0
CTR 6020	128	36	92	72	36	39	0	0
BNW 119	167	13	154	92	40	26	0	0
MH 046	177	30	147	83	75	51	0	0
CTR 6103	199	29	170	85	70	41	0	0
SC00PJ	63	23	40	63	11	28	0	0
HNM-3	90	36	54	60	35	65	0	0
HNM-1	93	36	57	61	6	11	0	0
HNM-1A	93	36	57	61	26	46	0	0
HNM-4	102	35	67	66	51	76	0	0
HNM-4A	102	35	67	66	41	61	0	0
HNM-5	121	70	51	42	33	65	0	0
Average	142.1	37.1	104.9	73.5	49.5	47.7	16.0	15.2
SD	44.7	26.3	42.5	15.1	33.2	21.8	16.0	10.7
Max	262.0	118.0	230.0	94.3	194.0	95.6	96.0	41.7
Min	63.0	6.0	40.0	32.5	6.0	9.5	2.0	2.1

5.2.3 Data Analysis

The data was analysed using spreadsheet. The following conditions were assumed for ease of calculation.

- For calculating duration of any activity (from the start and finish date), calendar days were considered (not working days).
- ‘Order lead time’ (OLT) was calculated as duration between ‘date of goods out from the factory’ and ‘date of order confirmation’.
- ‘Total production time’ (TPT) was calculated as duration between ‘date of goods out from the factory’ and ‘date cutting started’.

- 'Total pre-production time' (TPPT) was calculated by deducting 'total production time' (TPT) from the 'order lead time' (OLT).
- 'Total approval time' was calculated by adding up all approval related times, including sample, raw material and accessories approval.
- All iteration activities were earmarked in the format and wherever any approval related activities were repeated (due to rejection in first attempt) the time duration was noted. Total iteration time was cumulative of all attempts, if any.
- Importantly, manufacturing cycle time for woven and knit merchandise will differ and cannot be compared with each other. In the above data, there is woven as well as knitted merchandise but instead of analysing the absolute time, for certain tasks percentage time out of total time was calculated and thus the effect of raw material type was nullified in the analysis. There was another important factor i.e. value addition like washing, embroidery, etc. These tasks and related approvals were not mandatory for all orders; such tasks were carefully omitted from the final analysis and only mandatory tasks irrespective of merchandise type (as defined in the format) were considered in data analysis.

In 24 out of 64 orders the iteration time was zero, meaning that in those 24 orders, all approvals were done right first time. Analysis was carried out separately for orders that had iteration and those that did not have (table 5.9).

Table 5.9 Pre-production Activity Time

Order Details	Total lead time in days (sampling request to goods ship out)	Total production time in days (cut to ship)	Total pre-production time in days	% pre-production time out of total lead time	Total approval time in days	% approval time out of pre-production time	Total iteration time in days	% iteration time out of pre-production time	% iteration time out of Total approval time
Average for 64 orders with or without iteration	142.13	37.14	104.94	73.50	49.5	47.70	16	15.19	29.43
Average for 24 orders without iteration	134.42	35.71	98.71	72.02	38.79	40.33	N/A	N/A	N/A
Average for 40 orders with iteration	146.75	38	108.68	74.38	55.93	52.13	16	15.19	29.43

N/A = Not Applicable

Iteration time for six different activities for different order groups are listed in table 5.10. Activities related to approval could be divided into three categories, namely sample approval, fabric development/procurement-related approval and accessories procurement-related approval. While iteration for fit sample and size set approval was found frequently, iteration for fabric and accessories was rare.

Table 5.10 Analysis of Iteration Times

	Order Group / Duration of Activities	USI-11	Shilpee-8	leela-14	Kirat	GI-11	Bangladesh	H&M-9	Total
1	FIT Sample - 1st iteration	42	21	20	55	20	9	0	167
	FIT Sample - 2nd iteration	21	17	0	17	0	0	0	55
2	Size set sample - 1st iteration	28	6	7	92	0	19	0	152
	Size set sample - 2nd iteration	16	0	0	32	0	0	0	48
	Size set sample - 3rd iteration	0	0	0	5	0	0	0	5
3	Lab dip approval - 1st iteration	0	7	11	14	0	5	0	37
	Lab dip approval -2nd iteration	5	0	0	5	0	8	0	18
4	Bulk fabric approval - 1st iteration	4	0	0	33	0	0	0	37
	Bulk fabric approval - 2nd iteration	0	0	0	0	0	0	0	0
5	Lab test - 1st iteration	0	0	0	14	0	0	0	14
	Lab test - 2nd iteration	0	0	0	0	0	0	0	0
6	Embroidery thread approval - 1st iteration	0	0	0	0	0	0	0	0
	Embroidery thread approval - 2nd iteration	0	0	0	0	0	0	0	0

In the earlier case study, it was observed that fabric development-sourcing-approval generally took the longest time (critical path). From this survey it was observed that iteration in sample making-approval was frequent. Average iteration time was found to be 16 days, approximately 12% of the total lead time (critical path time). This showed that there was a high possibility of the critical path being changed from fabric development path to sample development path for the average order during iteration.

To find out the interdependency between total manufacturing lead time, pre-production time, approval time and iteration time, data was illustrated using scatterplot, outliers[14] were removed, and coefficient of determination (indicated by R^2 in the graph)[15] was calculated.

[14] Data points that diverge from the overall pattern and have large residuals are called outliers.
[15] It is interpreted as the proportion of the variance in the dependent variable that is predictable from the independent variable.

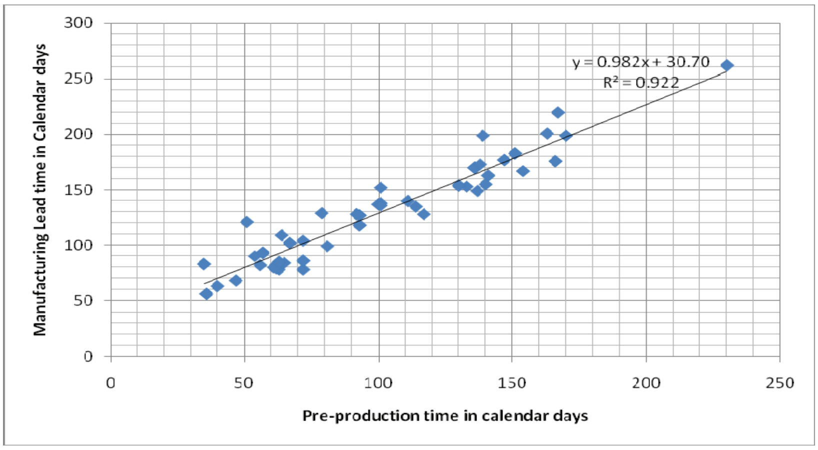
Average manufacturing lead time was found to be 136 calendar days. A strong positive correlation (0.96) between manufacturing lead time and pre-production time suggested that pre-production activity was the driver of total lead time, the following equation (figure 5.5) represents the dependency between them. A relatively high coefficient of determination (0.92) indicates nearly 92% of the variance in manufacturing lead time is predictable from pre-production time.

$Y = 0.98X + 30.70$

Where Y = manufacturing lead time

And X = pre-production time

Figure 5.5 Dependency between manufacturing lead time and pre-production time



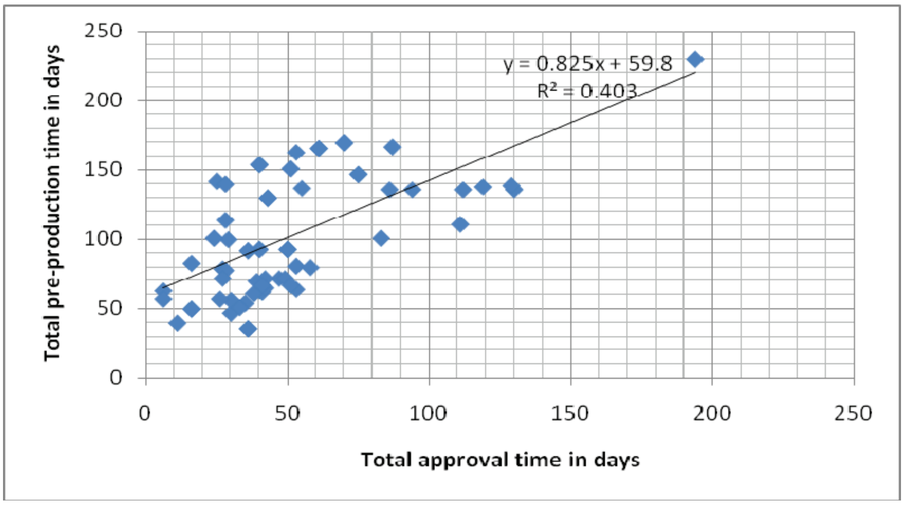
Similarly approval duration of sample and raw material positively influence the pre-production duration. The correlation between approval duration and pre-production duration was found to be 0.63. The following equation (figure 5.6) represents the mathematical relation between them. A moderate coefficient of determination (0.40) indicates nearly 40% of the variance in pre-production time is predictable from approval duration.

$Y = 0.83X + 59.8$

Where Y = pre-production time

And X = approval time

Figure 5.6 Dependency between pre-production time and approval time



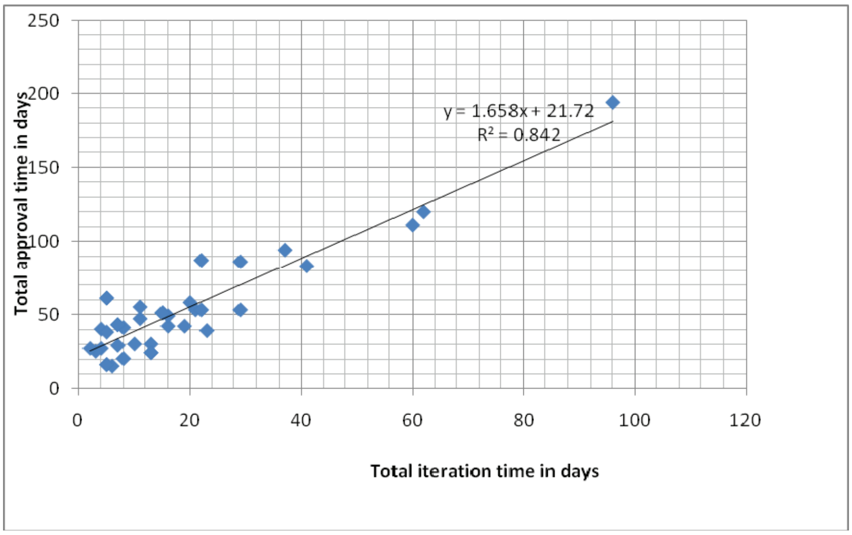
Similarly a relatively strong correlation (0.92) between total approval time and iteration explains that iteration was the main reason behind lengthy approval time. The following equation (figure 5.7) explains the relation between them. A relatively high coefficient of determination (0.84) indicates nearly 84% of the variance in approval time is predictable from iteration time.

$Y = 1.66X + 21.72$

Where Y = approval time

And X = iteration time

Figure 5.7 Dependency between approval time and iteration time



Out of 40 orders studied (that were having some kind of iteration), in 5 orders there was iteration during fit sample approval as well as during size set approval. Out of balance 35 orders In 24 cases iteration was during fit sample approval, while in only 11 cases iteration was during size set approval. The fit sample making requires in depth understanding of silhouette in context with the specification, while size set sample making merely use the grade rule (often supplied by buyer). This indicates either incapability of correct interpretation of the sketch and specification and/or due to changes asked by buyer.

It was interesting to find that no significant correlation (0.37) exist between manufacturing lead time and production time (fabric spreading till goods shipped out of factory). This explained the fact that while pre-production positively and significantly influence the manufacturing lead time, production time actually has no significant influence on total manufacturing lead time.

It was also found that approximately 41 percent of pre-production activities were externally dependent; this meant approximately 59 percent of pre-production time was dependent on internal resources and could be compressed by half through critical chain implementation. Iteration took up another 15 percent of pre-production time. As both sets of tasks were mutually exclusive, elimination of both could accumulate benefit. For example, elimination of iteration will reduce 15 percent of externally dependent time and critical chain will result a further 29.5 percent reduction (half of 59 percent) of internal activity. Therefore, overall reduction in pre-production time due to elimination of iteration and implementation of critical chain was 44.5 (29.5 + 15) percent. It was also found that in a 100 day lead time, pre-production consumed 73 days and production time was 27 days. A 44.5 percent reduction of 73 percent means 33 percent in overall lead time. So it could be conclusively stated that elimination of iteration and implementation of critical chain had inherent potential to reduce manufacturing lead time by 33 percent. Iteration in fit and size set sample approval was frequent, which corroborated the theory that *"Indian product development team is strong in fabric development, sourcing, pricing, etc….but they are very poor in knowledge of fit and pattern details (Malik 2009)"*

5.2.4 Conclusion

It was clearly established that delay contributing activities in the manufacturing cycle were pre-production activities, specifically sample making approval-related activities. Apart from the scheduled activities that could be eliminated, compressed or made concurrent, as much as 29 percent of approval time, or 15 percent of pre-production time or 12 percent of total manufacturing lead time could be saved by ensuring right first time (eliminating iteration). Poor record maintenance, commonplace in most factories, was the main problem in data collection. Even though these were routine activities for every order in every factory, record for the actual dates of completion or duration of activities were not always available. It was observed that even in the best managed factories, all relevant data (of selected 20 activities that were listed in the above format) were not available at a single source. In some cases, it was quite often observed that data of one or two activities of some style were simply not recorded.

One interesting but important observation was that all activities that involved movement of material or paper outside the company were recorded religiously in some register or another, whereas activities involving movement of material or information within the factory/company premises were often not recorded anywhere. For example, 'date fit comment received from buyer' could easily be found in fax/e-mail records or courier dispatch/receipt register. But the exact date/time when 'date fit comment was conveyed to sampling in charge (to re-make fit sample)' was not found anywhere as the same was probably conveyed verbally. In some cases, comments were handed over immediately but in a number of cases, the merchandiser took 1-2 days before handing over comments. The fit comments held up for 1-2 days before being handed over to the next person was tantamount to 'non-value added waiting time' and generally added as such to the next activity.

Towill (1996) explained how lead time reduction was possible through elimination (removal of an activity), compression (removal of time within an activity), integration (re-engineering interfaces between successive activities) or concurrence (activities operated in parallel). As elimination, integration or concurrence could sometimes be organisation or product-specific, it was evident that general benefit to industry as a whole would accrue from compression techniques such as collaborative product development (section 2.3.3), vendor managed inventory (2.5.1.1), critical path and/or critical chain concept (2.4.2), which could be universally applied across organisations.

While comparing between the trend lines it was obvious that pre-production and approval process has strong influence on total cycle time and pre-production time respectively. Iteration, which is not a mandatory but an occasional sub-set of approval process, and found to have strongest influence on approval time. This also establishes that iteration delays, whenever happens have telling affect on approval time and subsequently on total cycle time.

While more than 84% of the cases approval time is explained by iteration time and more than 92% of the cases manufacturing lead time is explained by pre-production time; a moderate 40% of the variance in pre-production time is predictable from total approval duration. This is probably due to the fact that approval of sample is only part of the total approval duration which is generally found to be delayed; the colour and accessories approval form the rest of the approval process which is generally not delayed.

5.3 Value Added and Non-Value Added Activities

While some literature reported 17 percent (Bruce et al. 2004) to 33 percent (GEAC 1999) value added time in the apparel supply chain, other studies on Indian apparel manufacturing organisations (Agarwal and Sahani 2007, Nagar *et al.* 2008) reported merely 1-4% value added time in thee manufacturing activities of a supply chain (section 2.5.4.1). The substantial difference in percentage of value added time could be attributed to the fact that while GEAC (1999) and Bruce *et al*. (2004) categorised activities into only two categories: value added and non-value added. Presumably, the necessary non-value added (NNVA) activities were clubbed with ‘value added’ activities in the former study, while Agarwal and Nagar had considered ‘necessary non-value added’ (NNVA) as a separate category. Further, it was observed that in the earlier studies, VA and NVA was measured using value stream mapping (section 2.5.4.1), the format of which was probably designed for measuring in-house activities. It was clear from literature (sections 2.3.1 and 2.3.2) and the case study (sections 4.3 and 4.4) that PD and pre-production activities involved many out-of-workplace activities (involving upstream and downstream players). The purpose of this longitudinal study was to measure value added activities in pre-production activities in an apparel manufacturing scenario by improvising on the classification given by Monden (1993) and Womack and Jones (1996).

5.3.1 Methodology

Typical case purposive sample selection method was followed and data was collected through structured format (section 3.4). Two manufacturing organisations, Kirat and UniStyle Impex (USI) were selected for the longitudinal studies based on the parameters explained in section 3.4. The sample organisations also had young management team; thus open to ideas, which would help categorising VA, NVA and NNVA activities.

For the purpose of this longitudinal study (better understanding, interpretation and appreciation by the executives in the factory) the non-value added activities were re-christened as:

- NNVA = Value Addition (by other than conversion e.g. transportation)
- NVA = Non-value Addition (Inventory e.g. stock fabric in store)

The initial format used for data collection was improvised from the one used earlier in tracking pre-production activities (table 6.10). The format for capturing order progress data had a list of 20 activities. First, an effort was made to identify any activity and classify it as one of the existing 20 activities. But, while classifying manufacturing activities into value added and non-value added, it was realised that the old formats were designed to capture dates or duration of certain activities and it was not possible to segregate value added and non-value added activities using the same format. For example, *duration FIT samples (with counter) were made* was a value added activity due to conversion. Start date was 03 March and finish date 05 March. But it was not possible to segregate the time duration when actual conversion took place and the time duration the sample/half finished sample was waiting for the next process during that time span.

Table 5.11 Excerpt of Initial Format for Value Added and Non-value Added Activities

Activity Description	Conversion	Transport	Inventory/ Waiting
	VA	NNVA	NVA
Date sampling & specifications received from buyer			
Duration patterns were developed			
Duration fabric being sourced			
Duration Proto samples (with counter) were made			
Duration Proto sample being couriered to buyer			
Duration buyer takes to comment (modification) on the sample (fax or e-mail)			
Duration Proto sample being couriered to manufacturer			
Duration patterns were modified			
Duration fabric being sourced			
Duration FIT samples (with counter) were made			
Duration FIT sample being couriered to buyer			

Next, a typical value stream mapping (VSM) data collection format (appendix IX) was analysed for its suitability in collection of data for the longitudinal study.

Table: 5.12 Calculation of Time in VSM Format

	Date	Time	Time taken	VA/NNVA/NVA
Processes				
Activity 1	06 Feb 2007	1:00:39	0:11:46	NNVA
Activity 2	06 Feb 2007	1:12:25	0:00:28	NVA
Activity 3	06 Feb 2007	1:12:53		

In VSM, data collection format clock time was recorded at the start of every activity. Then actual time taken for an individual activity was calculated by deducting that start time from the start time of the next activity (table 5.12). It was, however, found that these VSM formats were suitable for collecting data where all activities took place in- house. As the emphasis of the longitudinal study was on pre-production activities, where a lot of activities were third party dependent, material and information had to flow in and out of the organisation frequently.

Also, typical VSM formats (appendix X) were found suitable where only one particular order/style was being tracked by one researcher. In the longitudinal study, data for multiple orders was to be tracked simultaneously. An improvised data collection format was then developed to suit the requirement. Table 5.13 below shows a portion of the modified format.

Table 5.13 Modified VA/NNVA/NVA Data Collection Format

Activities	Value added time (in min)		In days	Non-value added (in min)	Waiting time
	Conversion (VA)	Transportation (NNVA)	Actual time	Waiting (NVA)	In %
Activity 1					
Activity 2					
Activity 3					

Three time durations for each and every activity were being noted in the new format; namely conversion (Value Added Time), transportation time (Necessary Non Value Added time) and Actual Time. Non Value Added (waiting) Time was calculated by deducting the sum of VA and NNVA from total actual time. In first two columns Value Added time (VA) and Necessary Non Value Added time (NNVA) were recorded in minutes. The third column recorded the actual time elapsed in 'days'. The waiting time was expressed as percentage of total time. Waiting time was calculated as *(actual elapsed days x hours per shift x 60 minutes) − (total conversion time + total transportation time).*

The format was designed in MS-Excel and calculations were done by formulae. As visible from the modified format, activities were mostly classified into conversion and transport types. True segregation of waiting time from conversion and transportation activities was possible only when activities were occurring, like the 'relay race' approach (explained in chapter 2.2.5), where everyone was pulling his/her work from the preceding activity. However, in real life, this did not happen in pre-production and production activities. Toyota Sewing System was an exception. After an activity was over, things were simply put aside and the instruction sheets/ half finished merchandise waited for the next activity to begin. This waiting time was 'unaccounted for' and recorded accordingly.

Then, different cost centres in the organisation were identified and classified and an activity cost centre matrix was developed by mapping all activities against any one or more cost centres. Cost centres are classified into three categories; in-house (activities done by company executives inside the organisation, for example **sampling**), out-of-workplace (activities executed by company executives outside the organisation, e.g. embroidery) and third party (activities executed by outside executives outside the organisation, e.g. fabric lab dip making).

5.3.2 Data Collection

For in-house activities, 8 hours per shift was taken for calculation whereas for activities like couriering sample abroad and getting comments from buyer, 24 hours per shift was taken for calculation. Bulk fabric procurement could depend on type of fabric and sewing conversion time would depend on the manufacturing system being followed. Here, time for micro activities was to be recorded for running (ongoing) orders. Data could not be collected from orders executed in the past. As the organisations were already selected based on heterogeneous parameters like working with multiple procurement channels, working with small and medium buying offices, importers abroad as well as direct export (section 5.3.1), all ongoing orders were selected for data collection. Using the improvised format, data was collected and calculated for total 35 orders, 14 being studied at USI by a student researcher (Mr. George) under guidance of the researcher and another 21 being studied at Kirat personally by the researcher himself. Data for 35 orders were considered representative enough for providing an illustrative profile (Saunders *et al.* 2007, page 193). An example of one such filled up format (with detailed micro activities) for knitted garments being manufactured in make through system is given in appendix X and a summary of same is given in table 5.14

Table 5.14 Value Added and Non-Value Added Activity Tracking

Activities	Style no		s4r 1147		
	Buying agency		AIE		
	Destination		London		
	Value added time (in min)		Actual time in days	Non-value added in min	Waiting Time in %
	Conversion	Transportation		waiting	
Fit Sample Making	216	45	45	21339	99
Comments Of The Buyer	15	5760	31	38865	87
Size Set Sample Making	1005	0	7	2356	70
Comments Of The Buyer	75	2880	9	10005	77
Requisition For Lab Dips From Supplier	464	960	5	976	41
Comments Of The Buyer	15	2880	12	2865	50
Bulk Fabric Manufacturing	3969	960	29	8991	65
Bulk Fabric Approval	16	90	4	1814	94

Lab Test Approval	**15**	**645**	**4**	**1260**	**66**
Sourcing Of Trims	**116**	**525**	**8**	**3199**	**83**
Photo Shoot Sample Making	**251**	**45**	**1**	**184**	**38**
Cutting Of Fabric	**2166**	**0**	**8**	**1674**	**44**
Embellishments	**170905**	**0**	**18**	**4415**	**3**
Embroidery	**0**	**0**		**0**	
Sewing	**31500**	**0**	**17**	**6900**	**85**
Finishing	**34335**	**0**	**16**	**813**	**11**
Packing	**546**	**0**	**2**	**414**	**43**
	245609	**14790**	**216**	**39768**	**38**
None of the activities are considered in critical path	(total conversion time)	total transportation time	Actual no of days (**not in critical path**)	waiting time	% waiting time

Inventory or waiting time (NVA) between different value-added activities was basically non-value added duration and it was very important that it was eliminated/minimised where-ever possible.

5.3.3 Data Analysis

Order wise conversion time, transportation time and waiting times for all 35 orders are produced in table 5.15 below.

Table 5.15 Order-wise Value Added and Non-value Added Time in Manufacturing

Style no	Conversion Time (min) VA	Transportation Time (min) NNVA	Waiting Time (min) NVA	Actual Elapsed Time (min)	% NVA Time
313000200	21463	6930	34967	63360	55.18
mg-11	46477	6930	33953	87360	38.86
carnbey-6	16317	6810	26313	49440	53.22
S4r-356 dash	45255	6810	42495	94560	44.93
tt-614	20807	5850	22783	49440	46.08
Us-102	94372	5850	38978	139200	28.00
sparkly t shirt	28667	6810	17803	53280	33.41
Ut-006	56194	6810	175076	238080	73.53
Up-002	20444	6810	38026	65280	58.25
tt-347	17633	4890	43237	65760	65.74
girls party shirt	13346	5805	41809	60960	68.58
Ng-2252	13050	5805	43065	61920	69.54
474G	9359	2925	31396	43680	71.87
400 H-56	28637	4455	24508	57600	42.54
S4R-1147	45608	14790	43282	103680	41.74
ELC-1136	26880	5760	33600	66240	50.72
ELC-1137	30240	6810	30150	67200	44.86
I-04-2	48480	5760	18720	72960	25.65

JDW-060	53280	5805	14835	73920	20.06
I-04-1	48480	5805	19635	73920	26.56
BN 101	26400	5760	39360	71520	55.03
BNW 40	17280	9600	10000	36880	27.11
SB 123	42720	8080	21520	72320	29.75
474G	19200	8080	29360	56640	51.83
400 H	24000	6810	30150	60960	49.45
CTR 6020	17280	6810	37350	61440	60.79
SW 149B	13440	8080	43280	64800	66.79
NJB 359	20640	8080	45200	73920	61.14
Lt 14	13440	7200	53760	74400	72.25
BNW 119	19200	6240	54720	80160	68.26
Pd 24	29280	4800	50400	84480	59.65
MH 046	36000	7200	41760	84960	49.15
SSD 127	24480	7200	56160	87840	63.93
CTR 6103	33600	7200	54720	95520	57.28
S4R-1147	45608	14790 **6975.71**	43282 **39590.09**	103680 **77067.43**	38.35

On an average, 50.57% of the actual elapsed time in garment manufacturing (from order confirmation to goods trucked out of factory) was waiting or non-value added time. A very high positive correlation (86.35) was found between waiting time and actual elapsed time. Also, moderate positive correlation (63.41) found between conversion time and actual elapsed time. However no correlation (12.52) was found between transportation time and actual elapsed time.

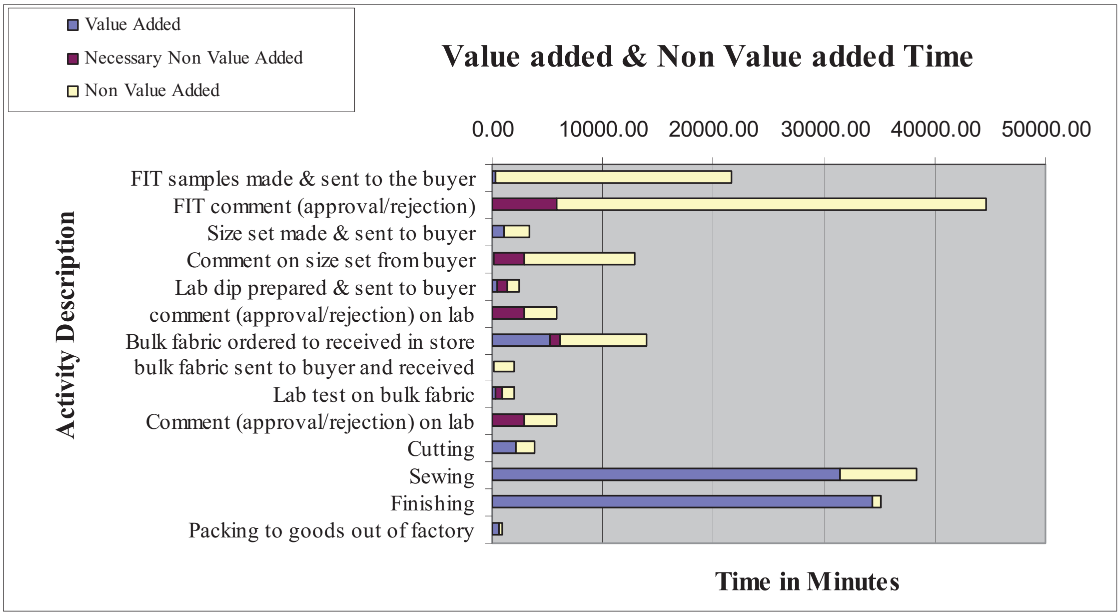
Activity wise conversion, transportation and waiting time was analysed for total 21 orders (studied in Kirat) following the above format. Averages for the same is shown in table 5.16. Out of 26 activities, only 14 selected activities were analysed for average conversion, transportation and waiting time. Iterations, if any were left out. While the conversion time depended on fabric type (woven or knits, yarn dyed, solid dyed or printed etc.), style (work content), order quantity (number of units per style), the transportation time depended on country of export, approval policy (i.e. whether approval was done by the head office in the importing country or liaison office/agent in the exporting country), mode of transport and communication.

Table 5.16 Activity-wise Value Added and Non-value Added Time

	Activity Description	Conversion time (min)	Transportation time (min)	Waiting time (min)	Actual elapsed time (days)
1	FIT samples made and sent to the buyer	322.40	45.00	21233.60	45.00
2	FIT comment (approval/rejection) received from the buyer	30.00	5760.00	38865.00	31.00
3	Size set made and sent to buyer	1004.50	45.00	2311.50	7.00
4	Comment on size set from buyer	90.00	2880.00	9990.00	9.00
5	Lab dip prepared and sent to the buyer	464.00	960.00	976.00	5.00
6	Comment (approval/rejection) on lab dip from buyer	30.00	2880.00	2850.00	12.00
7	Bulk fabric ordered to received in store	5169.00	960.00	7791.00	29.00
8	Bulk fabric sent to buyer and received colour approval	46.00	90.00	1784.00	4.00
9	Lab test on bulk fabric	315.00	645.00	960.00	4.00
10	Comment (appval/reject.) on lab test from buyer	30.00	2880.00	2850.00	12.00
11	Cutting	2165.63	0.00	1674.38	8.00
12	Sewing	31500.00	0.00	6900.00	17.00
13	Finishing	34335.00	0.00	813.00	16.00
14	Packing to goods out of factory	546.00	0.00	414.00	2.00

Activity-wise value added time (conversion and transportation) and non-value added time (waiting) is plotted graphically in Figure 5.5. From the graph it was clear that in fit sample and size set sample activities, a huge percentage of time was non-value added time (waiting time) whereas in fabric sourcing, cutting, sewing and finishing activities, maximum percentage of time was value added time (conversion time). It was also obvious that wherever comment/decision was awaited, a sizable percentage of time was spent on necessary non-value added time (transportation).

Figure 5.8 Activity-wise Value Added and Non-value Added Time



Another very important insight from the study was interruption in work. Activity time increased due to such interruptions. While some interruptions were simply non-value added time, others led to Intermittent Work Interruption. When any activity was in progress, there could be a sudden request/instruction from a competent authority to stop that activity halfway and start another. Such phenomena were frequent in pattern making, sample making, specification sheet making, inspection, and other skill-based activities. Other types of interruptions during any activity were telephone calls and calls from the boss. Peers seeking clarifications were difficult to segregate and were absorbed within activity time.

5.3.3.1 Activity Mapping with Cost Centres

A total of eleven cost centres were identified as in-house and three out-of-workplace. All third party activities were clubbed onto one category and indicated separately. Table 5.17 shows how each individual activity is linked with one or more cost centres. Store, sampling and merchandising departments were found to be involved in the maximum number of activities. Incidentally, just four departments, store/purchase, design, sampling and merchandising together accounted for 60 percent of the total number of activities.

Table 5.17 Activity Mapping with Cost Centres

	Activity	(In House)											(Out House)			Third party
		Marketing	Store/Purchase	Design	Sampling	Merchandising	Cutting	Sewing	Finish	Dispatch	Industrial Engg.	QA	Embroidery	washing	Testing	
	1) Buyer meeting	Y				Y										
2) Fit sample making	requisition making		Y													
	finalised design making			Y												
	tracing design into butter paper			Y												
	tracing design into garment			Y												
	pattern making/cutting				Y											
	cutting of fabric				Y											
	Embellishment				Y											
	embroidery				Y								Y			
	sewing				Y											
	finishing								Y							
	Inspection & packing					Y			Y			Y				
	sending the sample to buying house									Y						
	3) Third party activities															Y
	4) Received comments from buyer					Y				Y						
5) Size set sample making	requisition making		Y													
	tracing design into butter paper			Y												
	tracing design into garment			Y												
	pattern grading n cutting				Y											
	cutting of fabric				Y											
	embellishment				Y											
	embroidery				Y								Y			
	sewing of garments				Y											
	finishing								Y							
	Inspection and packing				Y	Y						Y				
lab dip & bulk fabric purchase	Requisition for lab dips from supplier					Y										
	Making swatch card					Y										
	sending to the supplier					Y										
	making of lab dip															Y
	Costing of the fabric		Y		Y	Y										

	rate/lead time discussions with fabric suppliers					Y										
	making purchase order		Y													
	sending to the supplier		Y													
	Bulk fabric manufacturing															Y
	Receive bulk fabric from supplier		Y													Y
Sending bulk fabric for colour approval	making shade card		Y			Y										
	sending to the buyer/buying agency					Y				Y						
	sending for lab test to testing centre		Y			Y										
	lab tests done														Y	
	sending reports back to exporter														Y	
	sending the report to buyer/buying agency		Y			Y										
Ordering of Trims	making requisition for threads labels beadings					Y										
	sending to different suppliers		Y			Y										
	Consumption of trims										Y					
	Sourcing of trims		Y			Y										
	making swatch card		Y			Y										
	sending trim to buying house for approval					Y										
	garment break down, work aid requirement										Y					
	machine & operator allocation										Y					
Prepare to sew	preparatory for spreading						Y									
	spreading						Y									
	marker making (manual)						Y									
	cutting						Y									
	stretching the fabric in the frame												Y			
	making design on the fabric												Y			
	beading work												Y			
	hand embroidery (if applicable)															
Sewing	Sewing of garments							Y								
Finishing and packing	thread cutting								Y							
	measurement checking								Y							

	ironing								Y							
	packing n tagging								Y							
	Inspection								Y			Y				
	packing into cartons	1	12	5	12	19	4	1	Y 9	3	3	3	5	0	2	4

5.3.4 Conclusion

Before the time compression methodology was explored to reduce pre-production process time, it was imperative to measure the potential for improvement, i.e. how much time could be compressed. Even though VSM technique was a tried and tested methodology (section 2.3), a slightly improvised format was used in this longitudinal study for value stream analysis of pre-production activities. Value added and non-value added analysis of activities in PD and pre-production quantified the potential of improvement through elimination of waiting time. During the study it also found that waiting time could further be classified into three different types:

First, when the goods were waiting to be processed for the next activity by the same person and within the same department/cost centre, e.g. pattern master had made the pattern and fabric was waiting to be cut by the pattern master himself. These non value added times were nearly invisible and most difficult to measure. Second, when the goods were waiting to be processed for the next activity within the same cost centre but by a different person; for example, fabric cut components were waiting to be sewn by sampling tailors. These were also difficult to measure as the goods were still within the same cost centre. Third, when the goods were waiting to be processed for the next activity at a different cost centre to be executed by different persons. For example, sewn garments were waiting to be taken to the embroidery department for embroidery. These were comparatively easy to measure as goods were being transported from one cost centre to another. It was realised that first two types of waiting times were more prevalent among pre-production activities but were not captured in the study. The nearly 50 percent waiting time that was measured in the study was attributed to the third type of waiting time and could be easily eliminated. The first and second type of waiting time could only be minimised and or eliminated if the preceding and succeeding activities were carried out in 'relay-race' approach, where after completion of any activity, it was handed over to the executive responsible for the next activity (and not waiting to be picked up for the next activity). The 'relay-race' technique is a part of an optimisation technique called critical chain (section 2.4.2).

Another important factor behind the long cycle time in receiving sample approval comment from buyer is the batch processing pattern. It was prevalent practice by customers to organise live model fitting session weekly once or twice depending on the volume of work. Thus in a five working day week (in buyer's country) if live model fitting session happens twice, there will be maximum three days of waiting time for the samples depending on date of arrival of samples in relation with date of subsequent date of live model fitting session.

The activity-cost centre matrix clearly proved the fact that pre-production processes were centred around only a few departments like store/design/ sampling/merchandising, thus emphasising the skewed workload towards a few departments in the beginning of a manufacturing cycle.

5.4 Summary

It was established that pre-production activities contained a significant amount (73 percent) of the total manufacturing cycle and moreover a major contribution to knowledge was that approval process (52 percent) and iteration process (15 percent) took up a sizable portion of the pre-production time. It was decided to further identify reasons behind the delay and suggest different optimisation techniques to reduce the pre-production lead time. Contrary to perception during the first survey about SME characteristics that sample conversion rate was low due to price and raw material problems, the survey clearly established that wrong measurement/fit and delay in submission were the main reasons behind low sample conversion rate. It was also found that occurrence of iteration during fit sample and size set sample approval was very high, which again corroborated the perception (initial survey) that 'fit to production sample' stage took the maximum time. Non-value added times were found inbuilt within several activity times, thus it was decided to identify and measure value added and non-value added time in pre-production activities.

The VA and NVA study established that nearly 50 percent of the time spent in a manufacturing cycle was NVA (waiting time) and a substantial portion of the same could be minimised by adopting a critical chain approach which was subject to further longitudinal study. The activity cost centre matrix established that pre-production processes were centred around only a few departments like store/design/sampling/ merchandising resulting in a possible resource constraint which required further study.

Chapter Six: Longitudinal Studies

6.0 Longitudinal Case Studies

This chapter primarily deals with applicability of different optimisation techniques to reduce lead time in the manufacturing cycle. From the case studies conducted earlier, it was clear that longitudinal studies were required to explore the potential of optimisation techniques like collaborative product development (CPD), critical path/critical chain and avoiding intermittent work interruptions to compress pre-production time. Available literature talked about reduction of lead time (Li 2007) and bullwhip effect (Paik, *et al.* 2007) through the elimination of echelons. Towill (1996) talked about four different options of lead time reduction, namely elimination, integration, concurrence and compression. However, elimination, integration or concurrence was pointedly specific to an organisation and its supply chain. For example, whether an approval process can be done away with (elimination), or prototype and fit sample can be combined together (integration), or costing and size set approval can be done in parallel (concurrence) depends on the buyer/style/distribution channel and many more specific parameters (section 4.2.5), where a generic solution is impossible to implement. It was also realised that pre-production processes resembled project management (2.4.2). In order to explore time compression possibilities in pre-production processes, it was decided to use both project management tools, namely critical path and critical chain, as a case study while comparing suitability. It was also observed in the earlier study (section 5.4) that product development and pre-production activities concentrated on storage, design, sampling, merchandising and procurement departments, resulting in the possible imposition of constraints on resources. Critical Chain is defined as the longest chain of tasks that consider both task dependencies and resource dependencies. VA and NVA studies conducted earlier concluded that a relay race approach in executing the activities would possibly minimise the NVA component in activities (section 5.3.4). Relay race is an approach being followed in the critical chain technique; hence the critical chain was considered as the most appropriate tool for lead time optimisation.

Another human tendency was to stop working on one order midway and start another in response to a shrill demand from another customer. This tendency is referred to as multitasking in project management literature (section 2.4.2) and should be avoided to reduce project completion time. The earlier focus group and case study (section 5.3.3) indicated presence of intermittent work interruptions in many activities in product development and pre-production process. It was thus decided to conduct a longitudinal case study to identify, understand and quantify the lead time improvement potential by minimising intermittent work interruptions.

6.1 Collaborative Product Development

Literature suggested that use of collaborative product development (CPD) saved development time (section 2.3.3). It was also felt during the case study (section 4.2) that the initiative and approach towards CPD was absent in Indian small and medium apparel enterprises. It was therefore decided to explore why CPD was not being practised regularly by many manufacturing organisations. The case study was done through a focus group interview with the apparel buyer, apparel manufacturer, fabric manufacturer and supplier, sewing thread manufacturer and supplier, sewing needle manufacturers and suppliers, zipper manufacturers and suppliers. Personal interviews were done with the apparel manufacturer, fabric supplier, sewing thread manufacturer and supplier and the garment processor.

6.1.1 Methodology

Methodology was decided as focus group interview followed by exploratory case study (section 3.5.1). The focus group sample selection was based purely on critical case purposive sampling, as the idea was to select those few who are either practicing collaborative and concurrent product development (CPD) concept or at least aware about it. The focus group should, also, represent all trading partners, have a progressive mindset and more importantly, the person representing the organisation should be knowledgeable and willing to share data and have worked in the same sector for at least five years. Keeping the above factors in mind, a nine-member focus group representing nine different organisations was identified.

The expert panel comprised of a merchandiser with Triburg Consultants[16], a large buying house representing major U.S. and a few EU customers; the Director Asia, Tukatech Inc.[17], a CAD/CAM solution provider; the Manager, Marketing at Coats

[16] www.triburg.com
[17] www.tukatech.com

India[18], a sewing thread manufacturer and supplier; the Manager, Marketing, Groz Beckert Asia Limited[19], a sewing needle supplier; the Manager PD, from Vaman Mills, a yarn dyed circular knit fabric manufacturer; the owner of Able Processors, a garment processing house in Mumbai, India; the R&D Manager from Tex, a zipper manufacturer from NCR; the General Manager, Operations, at ABC Fashions, a vertically integrated knitwear facility from NCR, with a turnover of approximately US$ sixteen million, exporting primarily to the EU and U.S.A. and the Manager Operations from PQR Fashions, an approximately US$ nine million turnover organisation from Mumbai with its own in-house manufacturing facility and specialising in washed garments. Pseudonyms were used for the last five organisations (fifth to ninth) to anonymise their identity (section 3.8) as desired by the organisations.

As it was difficult to get all experts together in one place at one time, the focus group was done in the first stage and 'expert knowledge elicitation' in the second stage. Thus, in the first stage, discussions took place with three experts in conclave and in the second stage, the researcher visited the experts personally to discuss, understand and record their observations and views.

During focus group interview information was also sought about any case example where the principle of collaboration and concurrency was followed and what was the result. Two cases were found worthwhile for exploration. ABC Fashions, Case-1, was based in NCR and has a vertically integrated knitwear facility. PQR Fashions, Case-2, was based in Mumbai with its own in-house manufacturing facility and specialising in washed garments. In both cases, the studies involved orders placed by Triburg Consultants. Triburg Consultants is a buying agent for premium US labels like Liz Claiborne and PVH, among others. Both case studies were conducted using historical data. The information was gathered by personally interviewing key executives from the manufacturer as well as the buying organisation and from company records, i.e. a secondary source of information.

6.1.2 Data Collection

Development or sourcing was carried out in two ways: either apparel manufacturers sourced or developed raw materials (fabrics and accessories) from different vendors and

[18] www.coatsindia.com
[19] www.groz-beckert.com

the buyer's office only approved the quality; or buyers collaborated directly with 'a set of vendors' to develop or source raw materials/accessories and approve quality. The apparel manufacturers were then required to source materials from that 'set of buyer approved vendors'. Either way, an approved or preferred supplier could be given the opportunity to develop a new product in parallel with the purchasing company.

The focus group unanimously agreed that buying organisations could take the lead in initiating development of three key ingredients directly with suppliers; fabrics, accessories and garment finishes. While large buyers commonly practiced such an approach and had a set of nominated (or buyer approved) vendors, small buying organisations and importers did not follow such a practice. Elaborating the distinction between large and small buyers, the group defined large buyers as agencies placing a large order quantity, primarily basic styles, whereas small buyers were involved with primarily high fashion merchandise in low quantity. [There are two reasons why small buyers do not follow the nominated vendor route. Firstly, either the quantity of raw material is not large enough to attract raw material vendors to participate and secondly, the raw material (especially fabric) is often sourced from the unorganised power-loom sector that is simply unaware of, and not really progressive enough to understand the concept].

Another important observation was that when a large order quantity was distributed to multiple apparel manufacturers, the 'nominated vendor' approach was widely followed, whereas even if a large order quantity was placed with a single manufacturer, vendor selection was often left to the manufacturer. The focus group also felt that apart from large order quantity, raw material vendors often agreed to collaborative development if the buyer was conceived as a respected name in the industry. The reason behind having a nominated vendor was further investigated. Although 'collaborative', 'higher efficiency', 'lesser number of approvals', 'reduced iteration' were cited as common reasons, concurrence and resultant reduction of time were mentioned by only two member of the group.

Lastly, another factor that came out as a possible hindrance to practicing 'collaborative' and 'concurrent' development was the socioeconomic aspect. Collaboration and concurrence is common within an organisation or between organisations from one country and/or countries with a similar socioeconomic environment (section 2.3.3).

However practicing 'collaborative' and 'concurrent' development between organisations of one developed and another developing country (dissimilar socioeconomic environment) requires co-ordination and levels of trust which, quite probably, are absent.

Many buyers and manufacturers have started to develop partnerships at the global level. For example, Gap Inc. shared its colour forecast for the current and forthcoming seasons with Coats worldwide for development of embroidery thread. All Gap vendors were directed to source all their embroidery thread need from local Coats suppliers. While some focus group members felt that an awareness programme of these best practices would help bringing in more and more organisations to practice collaborative and concurrent product development, other group members felt unless a commercially sustainable business model was created, an awareness programme simply would not help. One Focus group expert discussed outsourcing pattern making and sample approval activities to expert organisations to avoid iteration. Once the expert organisation developed and got the pattern/sample approved directly by the buyer, the apparel manufacturer simply sourced the pattern/sample from the expert organisation and duplicated it. Some US buyers were now following a similar approach.

6.1.3 Case Studies

Triburg Consultants, headquartered in New Delhi, wanted to place a huge order of yarn-dyed T-shirts with ABC Fashions. The buying agent decided to place the order with two different manufacturers; ABC Fashions in Delhi and another manufacturer in Ludhiana. ABC Fashions contacted a textile mill, Vaman Mills, a yarn dyed circular knit fabric manufacturer, to develop the knitted fabric made of dyed yarn, but this textile mill was unwilling to meet specified quality and delivery parameters due to the low volume of the order. ABC Fashions requested the buying agent to intervene; the buying agent contacted the mill and offered sourcing the total fabric quantity (combined orders of two manufacturers) from the mill if they were willing to collaborate in the fabric development. Vaman Mills collaborated with Triburg Consultants from the stage of yarn quality approval till the finished fabric approval. Once the dyed yarn lots were approved, garment manufacturers were advised to source yarns only from the 'nominated yarn supplier' or source knitted fabric from the 'nominated' fabric supplier.

The buying agent felt that both colour and quality consistency increased while fabric development lead time reduced by approximately 40 percent.

Triburg also wanted to place an order of a special enzyme-washed programme with PQR Fashion, Mumbai. Triburg contacted an enzyme supplier, Able Processors, to develop the recipe with a promise to guarantee business provided the wash effect was approved. While fit and size set approvals were going on with the apparel manufacturer, the enzyme supplier concurrently developed and had the wash effect approved. Then PQR Fashion directed all the manufacturers to source the enzyme from Able Processors who would set the washing parameters for different manufacturers, resulting in improved consistency in washed effects and reduced (43 percent) development time.

6.1.4 Data and Case Analysis

The CPD effort for basic versus fashion merchandise showed more weightage (percentage cost of product) given to fabric in basic merchandise whereas the cost of fashion merchandise depended more on value addition (either accessories or labour content). The current practice of collaboration and concurrence seemed primarily due to convenience and isolated commercial benefit rather than reduction of manufacturing lead time or the supply chain cost as a whole. While large order quantities were distributed to multiple apparel manufacturers, buyers resorted to nominated vendors to avoid multiple approvals. The raw material vendors agreed on collaborative development with a buyer if the deal was either commercially large enough to be profitable and/or the buyer was a respected name to be associated with.

Ignorance about time saved through collaborative and concurrent product development was a direct reflection of how important time was in the contract manufacturing environment. It may be recalled that a similar view was also expressed during the first survey about characteristics of the Indian apparel export manufacturing (section 4.1.3). The missing coordination between trading partners could probably be attributed to their dissimilar socio-cultural background and the same apprehension was felt by Tyler (section 2.3.3).

Regarding commercially sustainable business models − it was clear that trading partners were aware of and appreciated the merit of the approach but simultaneously wanted assurance that the benefit generated out of the practice was distributed amongst the trading partners. Currently, raw material vendors (as well as apparel manufacturers in some cases) were apprehensive about whether the money saved in the process was being pocketed by the buyer. It was clear from product development analysis (section 4.2.2) and pre-production network analysis (section 5.1.2) that there were generally three concurrent routes; first, the sample approval route; second, the fabric development and approval route and third, the accessories approval route. Tyler's concurrent product development model (figure 2.14, Section 2.3.3) mentioned convergence of ideas from design, production and material management teams within or between organisations. It was found that design, merchandising, production, industrial engineering and purchase (equivalent to material management) executives regularly met and discussed simplification, material optimisation and resource availability issues during every new product development. The focus group also mentioned similar practices between executives of buying and apparel manufacturing organisations, between executives of buyers and raw material suppliers and between apparel manufacturers and raw material suppliers. However no structured format or check list was followed during any meeting, thereby risking omission of some important points either during discussion or in implementation.

It was concluded from an earlier analysis (section 5.2.3) that sample development and approval route (which, otherwise, is generally not the critical path) would, in all likelihood, become the critical path (longest lead time) due to iterations in the actual scenario. Outsourcing of all sample approval-related activities to an expert organisation could bring twofold benefits; on the one hand, it could make some activities concurrent (thus reducing developmental lead time) and on the other, reduce the sample approval time by compression (eliminating/minimising iteration). However the other group members felt that the concept was new, unproven and not many organisations were ready for it yet.

6.1.5 Conclusion and Reflections

In both the focus group and case studies, the unanimous feeling was that reduction and consistency of lead time was a must. The 40-43 percent reduction was achieved in the fabric approval process and not in overall order lead time. As the cases were not documented either at the buyers' or manufacturer's end, the quantities were determined from the interview.

Pre-production activities varied from manufacturer to manufacturer as well between orders for a single manufacturer. While some started at pre-production stage, others started at the PD stage. (Some orders may even start from the pre-production stage but involve development activities later). Due to this hybrid nature of PD, activity in the Indian supply chain could not be ascertained accurately. In the operational sense, collaborative product development ultimately led to a 'buyer approved vendors' (also called 'nominated vendors') scenario, which has several perceived advantages and disadvantages for Indian manufacturers, vendors and buyers. From the case studies, it was clear that collaborative product development is easy to implement by large organised buyers (or buying agent) or large influential manufacturers, firstly due to sheer volume of potential business and secondly, sheer clout, which small buyers and/or manufacturers could not currently counter or exercise. This explains the crucial role of the dominant supply chain leader (section 2.2).

It was observed that buyers and small buying agents sourcing low volume fashion merchandise were apprehensive about sharing information during PD, whereas high volume basic merchandise buyers did not find any problem. This fully correlated with information sharing problems mentioned by Lamming (Lamming *et al.* 2000) and Fisher's supply chain classification (refer chapter 2.3). The two cases analysed clearly show how volume (due to consolidation of orders) and power/name could initiate the change. In the 'buyer approved vendors' or 'nominated vendor' concept there were perceived or notional advantages from the buyers', manufacturers' and vendors' point of view. Vendors enjoyed focussed development, higher development to business ratio, association with big buyers and also the possibility of high volume orders due to consolidation. From the manufacturers' point of view, no searching for vendors, assured merchandise quality, no hassle of repeated iteration and no requirement of special expertise were the added benefits. The process made the development cycle faster as buyers approved merchandise quality only once with the vendor and there was no need for any further approval with the individual manufacturer; the buyer also enjoyed the benefit of minimum variability between lots.

There were disadvantages too; vendors felt a loss in bargaining power and lack of variety while manufacturers felt curbed in their freedom of choice of vendors and often alleged a higher cost of procurement. There was an added responsibility of selection and development for the buyer who was also often caught in payment and delivery-related conflicts between manufacturers and vendors. Finally, there was the inevitable concern of putting all eggs into one basket.

6.2 Critical Chain Implementation

As explained in section 2.4.2, the critical path is commonly used for monitoring pre-production activity. However, the critical chain has some subtle advantages over the critical path technique, making it more suitable for human co-ordinated and controlled activities like pre-production activities in apparel manufacturing. Unlike the critical path, the critical chain also considers resource availability during optimisation. Moreover, the critical chain is a compression technique and can be generically applied to any process. The Critical Chain technique has, therefore, been selected for the longitudinal case study.

6.2.1 Methodology

As this study was to provide an illustrative profile using a representative case (section 3.5.2), a typical case purposive sampling would be ideal. The case study would require one company to be selected where the management was open to new ideas and ready to experiment with at least one actual ongoing order. The organisation was to permit the researcher to evaluate the current method of scheduling of activities, order tracking, access to data, and would allow the scheduling of activities to be done as per Program Evaluation and Review Technique (PERT) / CPM network. The organisation was to also allow the researcher to brief, train and guide executives as necessary to complete the case study. Silvershine Apparels was chosen because the managers/employees were committed to co-operate during the experimentation and also as the company had earlier participated in the research for delay contributing activities. The executive team was fully committed to the study. The duration of this case study would be around 142 days (section 5.2.3) depending on the actual lead time of the order chosen for the study. A student research team was stationed in the organisation for round-the-clock monitoring and carrying out instructions from the researcher during the study.

One style, named Dolores Top, was selected for experimentation. Pre-production activities starting from fabric quality approval (activity no. 1) till production start (activity no.39) were selected for monitoring. The structured observation format was designed as per data required for preparing PERT/CPM diagram. Before the order actually started, estimates of the activity durations were called for from concerned executives, the relationship between each activity was established (activity data table made with preceding and succeeding activity), and activities scheduled (PERT network diagram was made) both as per critical chain as well as critical path methodology. The critical chain concept was briefed to all team members of the organisation and time estimated for each task and pooled buffer positions. Once the order started everyone was encouraged to work according to the tenets of 'Relay Race'. Every one was briefed to finish the activity as early as possible and hand it over to the next person for the next task. As the order activities moved forward, respective executives were pre-informed and prepared for tasks to arrive, thus ensuring manual prioritisation and speedy execution of tasks. As and when any activity was completed, data was recorded in the table.

6.2.2 Data Collection

Data collection was done in two modes, the Set Up Mode and the Tracking Mode. In the Set Up Mode order selection, estimation of activity time, activity data table making, PERT network making and actual data collection format were prepared. In the Tracking Mode, as the order progressed, the actual start and end date were recorded in the format.

Set Up Mode:

The activity data for Dolores Top was recorded with activity no., activity duration, previous activity and next activity and is presented in table 6.1. The activity duration for critical path and critical chain was estimated separately for internal activities. However, for external activities (not under direct control of the organisation), the duration was estimated as equal (section 2.4.2). The activity duration was calculated from information collected from three resources (concerned executive, merchandise manager in the manufacturing organisation and merchandise manager at the buying organisation). The activity code numbers in the table are not in serial order as some additional activities were added in between preparing the PERT Chart and planning the style. The actual number of activities were 49.

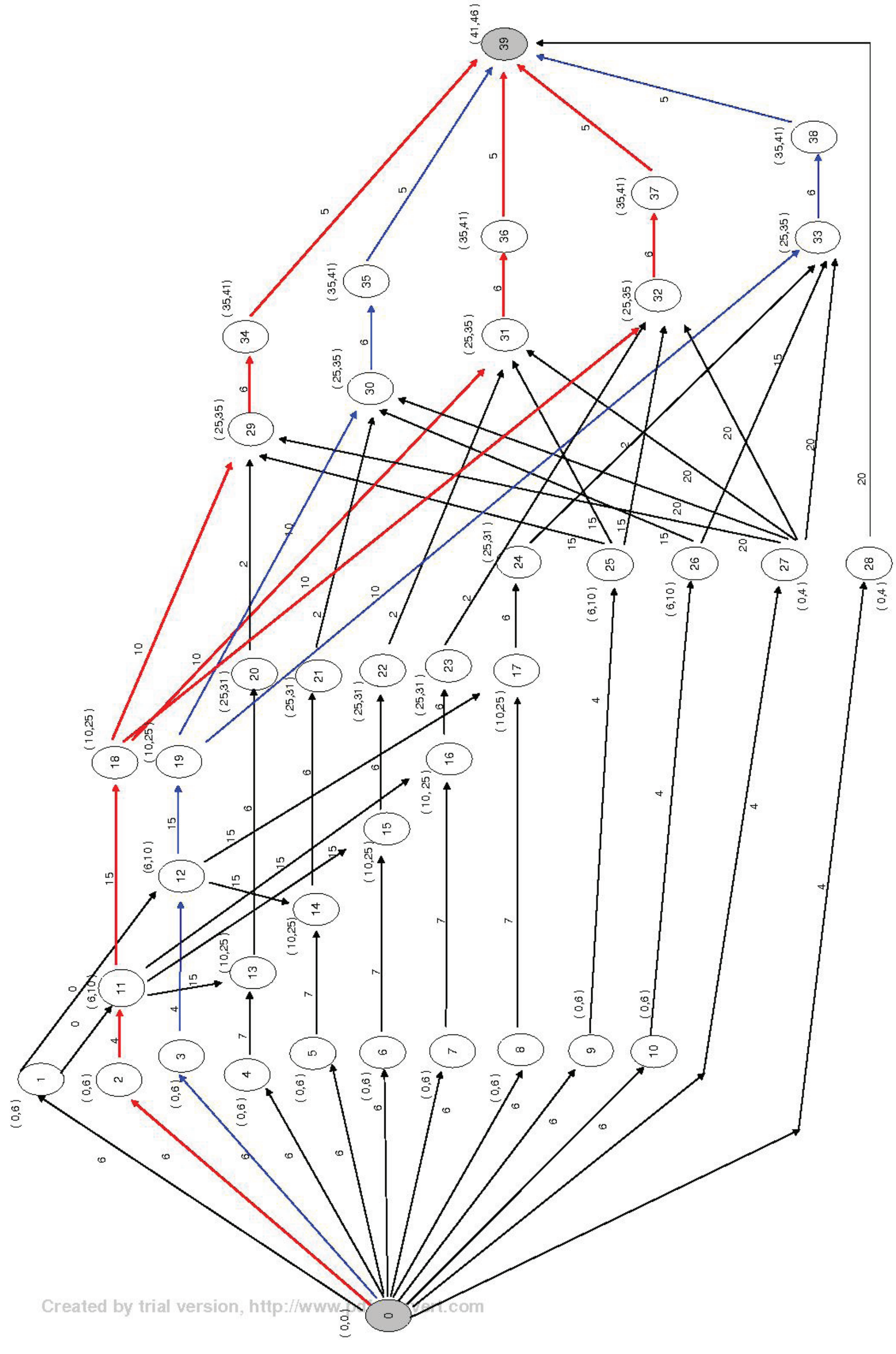
Table 6.1 Activity Data for Dolores Top Style

	Previous Activity	Code No.	Activity Description	Next Activity	Duration in Days	
					Critical Path	Critical Chain
		0	Order Confirmed (event)	0-1/2/3/ 4/5/6/7/ 8/9/10/ 27/ 28		
1	0	0-1	Fabric quality for approval	21	6	6
2	0	0-2	Lab dip for approval - petal pink	2	6	3
3	0-2	2-11	Lab dip approval - petal pink	22	4	4
4	0	0-3	Lab dip for approval - margerita green	3	6	3
5	0-3	3-12	Lab dip approval - margerita green	23	4	7
6	0	0-4	Fit for approval - L/SL – IG	9	6	3
7	0-4	4-13	Fit approval - L/SL – IG	24	7	7
8	0	0-5	Fit for approval - L/SL – TG	10	6	3
9	0-5	5-14	Fit approval - L/SL – TG	25	7	7
10	0	0-6	Fit for approval - L/SL – LG	11	6	3
11	0-6	6-15	Fit approval - L/SL – LG	26	7	7
12	0	0-7	Fit for approval - S/SL – TG	12	6	3
13	0-7	7-16	Fit approval - S/SL – TG	27	7	7
14	0	0-8	Fit for approval - S/SL – LG	13	6	3
15	0-8	8-17	Fit approval - S/SL – LG	28	7	7
16	0	0-9	Embroidery colour approval - petal pink	16	6	3
17	7	16-23	Embroidery design approval - petal pink	47	4	4
18	0	0-10	Embroidery colour approval - margerita green	17	6	3
19	8	17-24	Embroidery design approval - margerita green	48	4	4
20	0	0-27/ 28	Accessories ordered	19, 20	4	2
21	0-27	27-29/ 30/31/ 32/33	Main label, loop label, wash care in-house	37, 38, 39, 40, 41	20	10
22	0	28-39	Hanger hangtag in-house	50	20	20
23	0	1-11	Fabric quality approved	23	0	0
24	2-11	11-13/15/ 16/18	Initial processed dyed fabric in-house petal pink	24, 26, 27, 34	15	7
25	3-12	12-14/17/ 19	Initial processed dyed fabric in-house margerita green	25, 28, 35	15	7
26	4/11-13	13-20	Size set sample for local approval - L/SL – IG	29	6	3
27	13-20	20-29	Size set sample local approval - L/SL – IG	37	2	2
28	5/12-	14-21	Size set sample for local approval - L/SL – TG	30	6	3

	14					
29	14-21	21-30	Size set sample local approval - L/SL – TG	38	2	2
30	6/11-15	15-22	Size set sample for local approval - L/SL – LG	31	6	3
31	15-22	22-31	Size set sample local approval - L/SL – LG	39	2	2
32	7/11-16	16-23	Size set sample for local approval - S/SL – TG	32	6	3
33	16-23	23-32	Size set sample local approval - S/SL – TG	40	2	2
34	8/12-17	17-24	Size set sample for local approval - S/SL – LG	33	6	3
35	17-24	24-33	Size set sample local approval - S/SL – LG	41	2	2
36	11-18	18-29/ 31/ 32	Bulk fabric in-house - petal pink	37, 39, 40	10	10
37	12-19	19-30/33	Bulk fabric in-house - margerita green	38, 41	10	10
38	18/20/ 25/27-29	29-34	Pre-production sample for approval -L/SL– IG	42	6	3
39	19/21/ 26/27-30	30-35	Pre-production sample for approval-L/SL– TG	43	6	3
40	18/22/ 25/27-31	31-36	Pre-production sample for approval-L/SL– LG	44	6	3
41	18/23/ 25/27-32	32-37	Pre-production sample for approval-S/S –TG	45	6	3
42	19/24/ 26/27-33	33-38	Pre production sample for approval -S/SL–LG	46	6	3
43	29-34	34-39	Pre production sample approval - L/SL – IG	50	5	5
44	30-35	35-39	Pre production sample approval - L/SL – TG	50	5	5
45	31-36	36-39	Pre production sample approval - L/SL – LG	50	5	5
46	32-37	37-39	Pre production sample approval - S/SL – TG	50	5	5
47	33-38	38-39	Pre production sample approval - S/SL – LG	50	5	5
48	9-25	25-29/ 31/32	Bulk embroidery in-house - Dolores Top petal pink	37, 39, 40	15	7
49	10-26	26-30/33	Bulk embroidery in-house - Dolores Top margerita green	38, 41	15	7
	34/35/ 36/37/ 38-39	39	Production Start (event)			

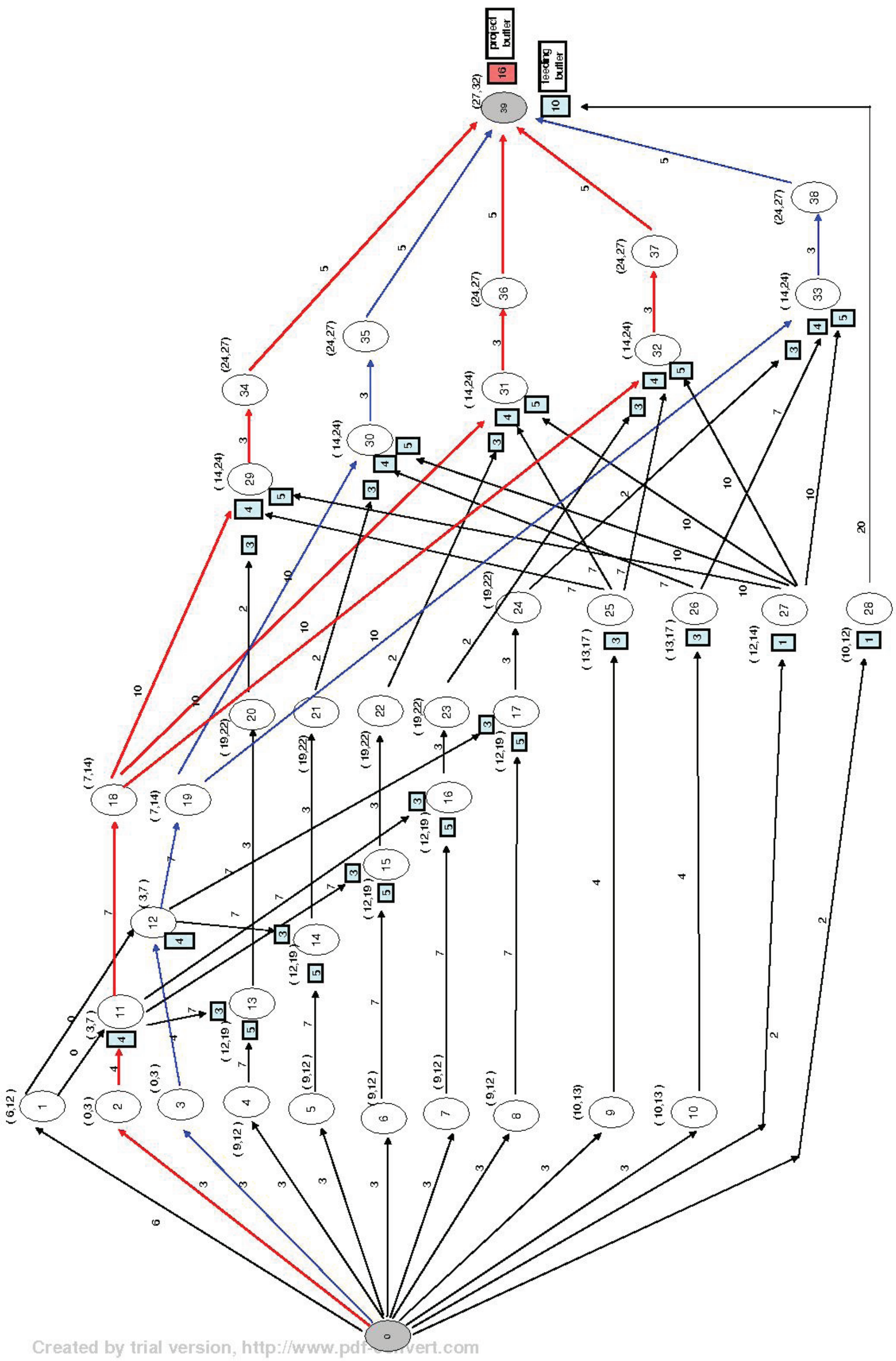
A PERT diagram (figure 6.1) for critical path was prepared based on AOA (activity on arrow) principle and started with an event named *Order Confirmed* and ended with an event named *Production Start*. These ‘events’ have a duration of zero (0). Then each activity was drawn as an arrow that started after *Order Confirmation* (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 27, 28 in this example) and led to an event. Similarly, all successive activities were drawn as arrows coming from preceding activities. The pre-production sample approval was the last activity in the pre-production process (activity 34, 35, 36, 37, 38) and production started next. The event P*roduction Start* is numbered as 39. Out of a total of 49 activities, only 10 activities were found to be in the critical path and the critical path time was 46 days. There were three parallel paths having the same time as the critical path. As the activities are in AOA, they are referred to as 0-1, 1-2, etc. and the duration of activity is written on the arrow. The earliest start and earliest finish days of any particular activity was written inside the first parenthesis with a comma; for example activity 0-2 could start earliest on day 0 and finish by Day 6; similarly, activity 11-18 could start earliest on Day 10 and finish on Day 25. The critical path was 0-2-11-18-29-34-39 and indicated in the diagram by red arrows.

Figure 6.1 PERT/CPM Diagram for Dolores Top Style



The PERT diagram for critical chain was also prepared (Figure 6.2) based on the AOA principle and followed the same dependency relationship. According to convention (section 2.4.2), the duration of activities were reduced to half for calculating the critical chain. However, during the study it was realised that only durations of internal activities (where control was with the organisation) should be reduced to half while durations of external activities (where control was not with the organisation) should remain the same. For example, duration of activity 0-5 was reduced to 3 days from 6 days (table 6.1) as 0-5 was an internal activity but duration of 5-14 (table 6.1) remained as 7 days as it was an external activity. Two types of buffers were calculated for the critical path; the feeding buffer was inserted at different milestone activities where the feeding chain intersected with the critical chain and the project buffer was inserted at the last activity of the critical chain. Buffer duration at any milestone was calculated as 50 percent of the length of the chain preceding that activity. The critical chain time was 32 days and therefore project buffer was 16 days. Feeding buffers at all feeding points were calculated similarly. While the critical chain is indicated in red arrows, the numbers written in sky colour boxes before the nodes indicate the buffer time for the activity in number of days. In the critical chain diagram, the latest start and latest finish days of any particular activity are written inside first parenthesis with a comma; for example activity 0-9 could start latest on Day 10 and finish by Day 13, meaning that this activity had 10 days of lag time. The total number of activities in both the critical path and critical chain network was 49. While in the critical path plan, *production start* could take place after Day 46, the same could take place in the critical chain plan on Day 32. This effectively means that in the critical chain plan, the first activity could start on Day 1 and the last activity finish by Day 32, i.e. 14 days earlier than required. Alternatively, one could start the first activity on Day 14 and finish on Day 46. In a practical scenario, planning generally is done end-to-start and in Silvershine Apparels, for the Dolores Top order, enough lead time was available, so it was decided to anchor *production start* on Day 46 (similar to the critical path schedule) and schedule all activities as late as possible (ALAP) in the critical chain. Figure 6.2 shows the critical chain network with all activities scheduled ALAP to start production on Day 46.

Figure 6.2 Critical Chain Network for Dolores Top Style



The calendar date for *order confirmed* was 04 March and considered as Day Zero. Based on the critical path and critical chain networks earliest start/end and latest start/end days were also calculated and tabulated in a tracking format. For every activity there were four possible days; for example, activity 2-11 (Lab dip approval - petal pink) could either start as early as on Day 6 and end on Day 10 or as late as Day 17 and finish on Day 21. In both cases, as per plan, the order would meet the scheduled *production start* on Day 46. In the order tracking format (table 6.2) the critical path and critical chain columns indicate planned start-end date; the last two columns were left blank for recording actual start-end date in tracking mode.

Table: 6.2 Tracking Format: Actual Days vs. Critical Path and Critical Chain

NO	ACTIVITY	CRITICAL PATH ASAP		CRITICAL CHAIN ALAP		ACTUAL START DAY	ACTUAL END DAY
		START	END	START	END		
0-1	Order confirmed	DAY 0 - 4 MARCH					
0-2	Fabric quality approval	0	9	5	14		
2-11	Lab dip for approval - petal pink	0	6	3	6		
0-3	Lab dip approval - petal pink	6	7	6	10		
3-12	Lab dip for approval - margerita green	0	6	3	6		
0-4	Lab dip approval - margerita green	6	7	6	10		
4-13	Fit for approval - L/SL – IG	0	6	8	11		
0-5	Fit approval – L/SL – IG	6	13	11	18		
5-14	Fit for approval - L/SL – TG	0	6	8	11		
0-6	Fit approval – L/SL – TG	6	13	11	18		
6-15	Fit for approval - L/SL – LG	0	6	8	11		
0-7	Fit approval – L/SL – LG	6	13	11	18		
7-16	Fit for approval - S/SL – TG	0	6	8	11		
0-8	Fit approval – S/SL – TG	6	13	11	18		
8-17	Fit for approval - S/SL – LG	0	6	8	11		
0-9	Fit approval – S/SL – LG	6	13	11	18		
9-25	Embroidery colour approval - petal pink	0	6	10	13		
0-10	Embroidery design approval - petal pink	6	10	3	17		
10-26	Embroidery colour approval - margerita green	0	6	10	13		
0-27/28	Embroidery design approval - margerita green	6	10	3	17		
27-29/ 30/31/ 32/33	Accessory ordered	0	2	13	15		
28-39	Main label, loop label, wash care in-house	4	24	16	26		
1-11	Hanger hangtag in-house	4	24	9	29		
11-13/ 15/16/18	Initial processed dyed fabric in-house - petal pink	10	25	14	21		
12-14/ 17/19	Initial processed dyed fabric in-house - margerita green	10	25	14	21		
13-20	Size set sample for local approval - L/SL - IG	25	19	23	26		
20-29	Size set sample local approval - L/SL - IG	31	33	26	28		
14-21	Size set sample for local approval - L/SL - TG	25	19	23	26		
21-30	Size set sample local approval - L/SL - TG	31	33	26	28		
15-22	Size set sample for local approval - L/SL - LG	25	19	23	26		
22-31	Size set sample local approval - L/SL - LG	31	33	26	28		
16-23	Size set sample for local approval - S/SL - TG	25	19	23	26		
23-32	Size set sample local approval - S/SL - TG	31	33	26	28		
17-24	Size set sample for local approval - S/SL - LG	25	19	23	26		
24-33	Size set sample local approval - S/SL - LG	31	33	26	28		
18-29/ 31/32	Bulk fabric in-house - petal pink	25	35	21	31		
19-30/ 33	Bulk fabric in-house - margerita green	25	35	21	31		
29-34	Pre-production sample for approval - L/SL - IG	35	41	31	34		
30-35	Pre-production sample for approval - L/SL - TG	35	46	31	34		
31-36	Pre-production sample for approval - L/SL - LG	35	41	31	34		
32-37	Pre-production sample for approval - S/SL - TG	35	46	31	34		

33-38	Pre-production sample for approval - S/SL - LG	35	41	31	34		
34-39	Pre-production sample approval - L/SL - IG	41	46	34	39		
35-39	Pre-production sample approval - L/SL - TG	41	41	34	39		
36-39	Pre-production sample approval - L/SL - LG	41	46	34	39		
37-39	Pre-production sample approval - S/SL - TG	41	41	34	39		
38-39	Pre-production sample approval - S/SL - LG	41	46	34	39		
25-29/ 31/32	Bulk embroidery in-house - Dolores Top p pink	10	25	20	27		
26-30/ 33	Bulk embroidery in-house - Dolores Top margerita green	10	25	20	27		
39	Production start	46		39			

Tracking mode:

Once the order was started, actual start and end times were noted against every activity in the format above. During the tracking mode, executives were instructed to treat the specific order as a relay race approach; however, no special treatment was given to the Dolores Top order in terms of activity completion.

Table: 6.3 Tracking Format: Actual Days vs. Critical Path and Critical Chain

NO	ACTIVITY	CRITICAL PATH ASAP		CRITICAL CHAIN ALAP		ACTUAL START DAY	ACTUAL END DAY
		START	END	START	END		
0-1	Order confirmed	**0 DAY - 4 MARCH**					
0-2	Fabric quality approval	0	9	5	14	N/A	N/A
2-11	Lab dip for approval - petal pink	0	6	3	6	0	4
0-3	Lab dip approval - petal pink	6	7	6	10	4	10
3-12	Lab dip for approval – margarita green	0	6	3	6	1	4
0-4	Lab dip approval - margerita green	6	7	6	10	4	11
4-13	Fit for approval - L/SL – IG	0	6	8	11	1	7
0-5	Fit approval – L/SL – IG	6	13	11	18	7	7
5-14	Fit for approval - L/SL – TG	0	6	8	11	1	7
0-6	Fit approval – L/SL – TG	6	13	11	18	7	7
6-15	Fit for approval - L/SL – LG	0	6	8	11	1	7
0-7	Fit approval – L/SL – LG	6	13	11	18	7	7
7-16	Fit for approval - S/SL – TG	0	6	8	11	1	7
0-8	Fit approval – S/SL – TG	6	13	11	18	7	7
8-17	Fit for approval - S/SL – LG	0	6	8	11	1	7
0-9	Fit approval – S/SL – LG	6	13	11	18	7	7
9-25	Embroidery colour approval - petal pink	0	6	10	13	5	12
0-10	Embroidery design approval - petal pink	6	10	3	17	12	30
10-26	Embroidery colour approval - margerita green	0	6	10	13	5	12
0-27/28	Embroidery design approval - margerita green	6	10	3	17	12	30
27-29/ 30/31/ 32/33	Accessory ordered	0	2	13	15	N/A	N/A
28-39	Main label, loop label, wash care in-house	4	24	16	26	N/A	N/A
1-11	Hanger hangtag in-house	4	24	9	29	N/A	N/A
11-13/ 15/16/ 18	Initial processed dyed fabric in/h - petal pink	10	25	14	21	12	28
12- 14/17/19	Initial processed dyed fabric in/h - margerita green	10	25	14	21	12	28
13-20	Size set sample for local approval - L/SL - IG	25	19	23	26	37	39
20-29	Size set sample local approval - L/SL - IG	31	33	26	28	39	45

14-21	Size set sample for local approval - L/SL - TG	25	19	23	26	37	39
21-30	Size set sample local approval - L/SL - TG	31	33	26	28	39	45
15-22	Size set sample for local approval - L/SL - LG	25	19	23	26	37	39
22-31	Size set sample local approval - L/SL - LG	31	33	26	28	39	45
16-23	Size set sample for local approval - S/SL - TG	25	19	23	26	37	39
23-32	Size set sample local approval - S/SL - TG	31	33	26	28	39	45
17-24	Size set sample for local approval - S/SL - LG	25	19	23	26	37	39
24-33	Size set sample local approval - S/SL - LG	31	33	26	28	39	45
18-29/ 31/32	Bulk fabric in-house - petal pink	25	35	21	31	28	45
19-30/33	Bulk fabric in-house – margarita green	25	35	21	31	28	45
29-34	Pre-production sample for approval - L/SL - IG	35	41	31	34	30	37
30-35	Pre-production sample for approval - L/SL- TG	35	46	31	34	18	37
31-36	Pre-production sample for approval - L/SL- LG	35	41	31	34	17	37
32-37	Pre-production sample for approval - S/SL- TG	35	46	31	34	16	37
33-38	Pre-production sample for approval - S/S - LG	35	41	31	34	16	37
34-39	Pre-production sample approval - L/SL - IG	41	46	34	39	37	45
35-39	Pre-production sample approval - L/SL - TG	41	41	34	39	37	45
36-39	Pre-production sample approval - L/SL - LG	41	46	34	39	37	45
37-39	Pre-production sample approval - S/SL - TG	46	46	34	39	37	45
38-39	Pre-production sample approval - S/SL - LG	41	46	34	39	37	45
25-29/31 / 32	Bulk embroidery in-house - Dolores Top p pink	10	25	20	27	N/A	N/A
26-30/33	Bulk embroidery in-house - Dolores Top margerita green	10	25	20	27	N/A	N/A
39	Production start	46		39		N/A	N/A

There were three longest paths in the network; namely 0-2-11-18-29-34-39, 0-2-11-18-31-36-39, and 0-2-11-18-32-37-39. Any delay beyond buffer time in any of these activities would mean delay in overall lead time. The start and end days for these critical activities were tabulated separately for comparison (table 6.4).

Table: 6.4 Critical Activities

No	Activity	Critical Path ASAP		Critical Chain ALAP		Actual Start Day	Actual End Day
		Start	End	Start	End		
0-2	Lab dip for approval - petal pink	0	6	14	17	0	4
2-11	Lab dip approval - petal pink	6	10	17	21	4	10
11-18	initial processed dyed fabric in/h - petal pink	10	25	21	28	10	22
18-29	bulk fabric in/h - petal pink	25	35	28	38	22	34
18-31	bulk fabric in/h - petal pink	25	35	28	38	22	34
18-32	bulk fabric in/h - petal pink	25	35	28	38	22	34
29-34	Pre production sample for approval - L/SL – IG	35	41	38	41	34	37
31-36	pre production sample for approval - L/SL – LG	35	41	38	41	17	37
32-37	pre production sample for approval - S/SL – TG	35	46	38	41	16	37
34-39	pre production sample approval - L/SL - IG	41	46	41	46	37	45
36-39	pre production sample approval - L/SL - LG	41	46	34	39	37	45
37-39	pre production sample approval - S/SL - TG	46	46	34	39	37	45

Apart from collecting order-specific data, several other practices/ conventions were observed during the case study. It was common practice in Silvershine to make individual time and action (TNA) calendar for every order that was being processed.

These TNA calendar were the same as the critical path in purpose (section 2.4.2). At any given point of time, any one executive typically followed up 8-10 orders; that meant, 8-10 separate TNA calendars. On any given day, there were different activities from different TNA calendars to be executed, and executives typically follow a ‘to-do’ list (based on memory) to accomplish the tasks one by one. As no prioritising of activities was done, every one used to pick up activities from the to-do list at random, resulting in frequent changeover and intermittent work interruption. However, while the order was being tracked, it was observed that executives were trying to give priority to the Dolores Top order to ensure the order was executed in the relay race approach. It was felt necessary by the executives to automatically prioritise activities as per PERT network sequence for smooth handover and less interruption.

6.2.3 Data Analysis

Out of six activities in the critical path/chain, only two were internally dependent, while the other four were externally dependent. While comparing actual time taken against planned in the critical path, it was found that in four out of six critical path activities, work started earlier than planned and in only two activities, work started on time as planned. However, in three out of four external activities, time was lost. While comparing actuals with the critical chain schedule, it was found that in five activities time was lost and one activity was on time. Even though the first activity was started 14 days early, the last activity finished only one day early, resulting in overall network loss of 13 days. Another important indication to emerge was that activities depending on external factors were likely to eat into the buffer time, while internally dependent activities made up for the loss.

Table: 6.5 Comparison between Critical Path and Critical Chain

		Critical Path vs. Actual			**Critical Chain vs. Actual**		
Activity	Type of activity	Start day	End day	Status	Start day	End day	Status
0-2	Internal	On time	Early 2	Gained time	Early 14	Early 13	Lost time
2-11	External	Early 2	On time	Lost time	Early 13	Early 11	Lost time
11-18	External	On time	Early 3	Gained time	Early 11	Early 6	Lost time
18-29	External	Early 3	Early 1	Lost time	Early 6	Early 4	Lost time
29-34	Internal	Early 1	Early 4	Gained time	Early 4	Early 4	On time
34-39	External	Early 4	Early 1	Lost time	Early 4	Early 1	Lost time

Once the comparative days from table 6.5 were plotted in graphs (figures 6.3 and 6.4), the results suggested that while activities were being planned by the critical chain method (where target date was earlier than critical path method), there was a high chance of completion as per the critical chain target. When the actual working pattern (i.e. the actual start and end dates of all the activities) in Silvershine Apparels was correlated with that of planned dates, the critical chain approach showed very strong positive correlation between actual start of tasks (0.83) and finish of tasks (0.80). Critical path scheduled dates also showed strong correlation with actual dates and thus it could be concluded from the above study that both critical path and critical chain have good correlation with human behaviour and these approaches may be used for lead time reduction. Assuming that there could never be early delivery, the study also showed that critical chain could actually reduce lead time by 12 percent.

Figure 6.3 Critical Chain, Critical Path and Actual Start

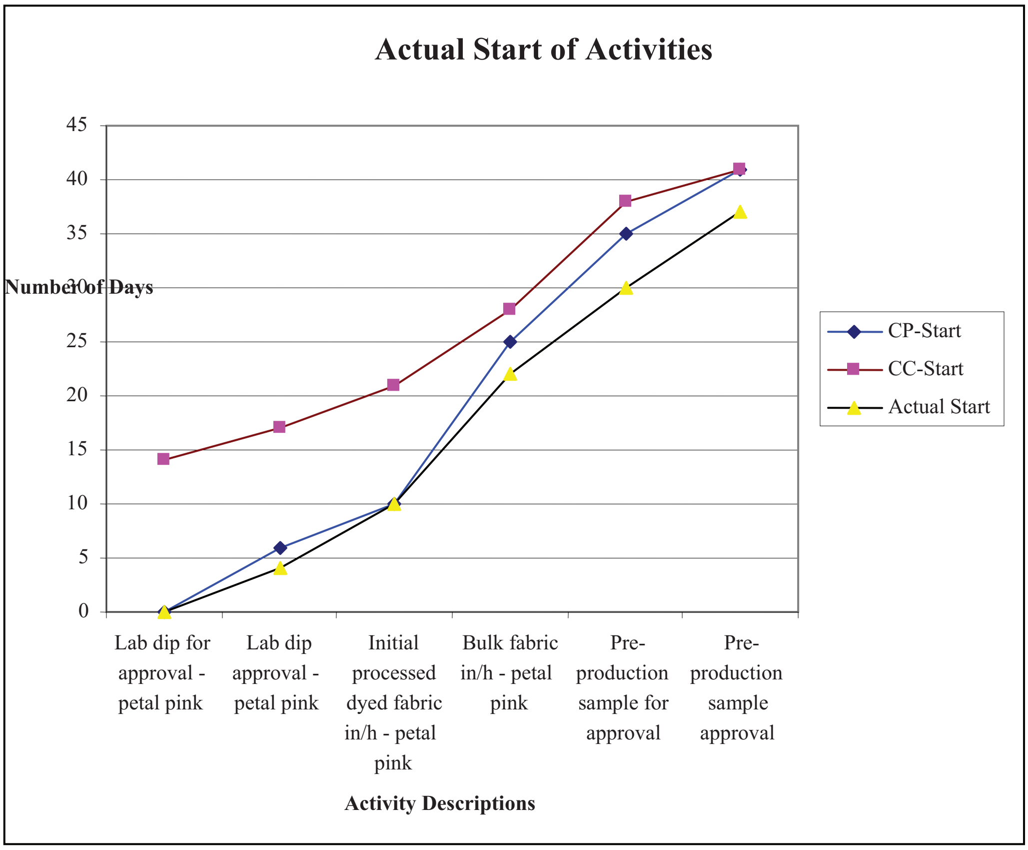
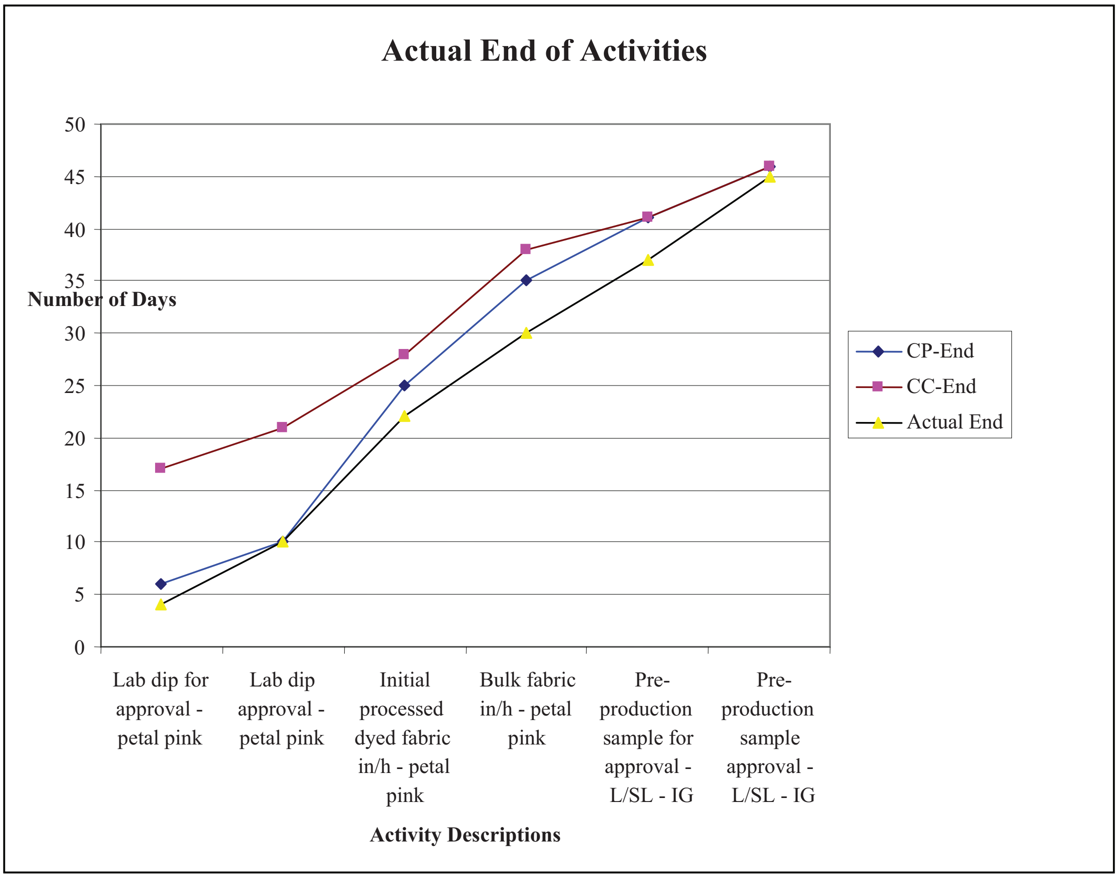


Figure 6.4 Critical Chain, Critical Path and Actual Finish



Intermittent work interruption was found common among pattern making, sampling, quality checking and specification sheet preparation activities. If a dedicated set of executives was made responsible for the Dolores Top order, then activities could have been executed in a synchronised manner in a relay race approach. However, as all executives were working on numerous other orders also (along with Dolores Top order), it was not possible to implement relay race.

It was realised that the critical path method (CPM) network made on a spreadsheet was static. When the order was in progress (in tracking mode), the duration of activities changed, but these changes were not automatically reflected in the CPM network; instead, one had to take note and change figures manually, which was very cumbersome. A single change of duration of activity could result in the change of earliest and latest start/end times of all the linking chains (in Dolores Top case study, sometimes 8-9 activities), buffer time, maybe even the critical path. Incorporating these changes manually was impossible in the factory scenario as it was tiresome, time consuming and error prone. It was thus decided to use specialised CPM software for longitudinal study.

Flaws in Logic of Current Practices

While analysing the reason behind why critical chain implementation in organisation was not smooth and free flowing, it was realised that there was a logic flaw in current practices. While making a network (PERT) of dependent activities, the time duration of activities was assigned in days or hours but surprisingly never in man-days or man-hours! As there were only 5-6 executives expected to carry out 50-60 activities of any order, there would be a practical constraint of timely availability of executives. Depending on availability of executives, lots of parallel operations would become sequential if the same executive was supposed to carry out both, and this phenomena was overlooked while making the TNA calendar, a constraint on the actual execution (during tracking mode) resulting in a delay. On any given day, there would be different activities from different TNA calendar to be executed, as no combined prioritisation of activities was possible (either manually or in MS Excel), everyone set their own priority, conflicts arose, priorities were shuffled repeatedly and frequently, executives moved between tasks leaving them half-finished, ultimately resulting in more delay. Generally better organised executives are known for their foolproof follow-up. To-do lists of activities were either maintained in diaries, hand-phone schedulers or in aide-memoires to ensure timely reminders and no gaffes in the follow up of activities. But no one realised that these to-dos lists in isolation offered no synchronisation between the working of two executives, which was of utmost importance.

To cross check how executives schedule and followed their daily activities, the pattern maker and sample master of Silvershine Apparels were asked to prepare a to-do list for one working day based on the current orders running at that time. While both executives were following up the same group of orders, they were asked to prepare to-do lists without consulting each other.

Table 6.6 To-Do List of Activities for Pattern Maker Chandar Kumar on 12/09/2002

Serial	Order No.	Activities	Activity type
1	AT009	Making patterns for fit sample	Critical
2	AT013	Grading patterns for size set sample	Non-critical
3	AT0021	Making patterns for fit sample	Critical
4	BZ0013	Making production pattern from size set comment	Non-critical
5	BZ0015	Grading patterns for size set sample	Non-critical

Table 6.7 To-Do List of Activities for Sample Master Surinder Singh on 12/09/2002

Serial	Order No.	Activities	Activity type
1	BZ0013	Making production sample	Non-critical
2	BZ0015	Making size set sample	Non-critical
3	LZ003	Fit sample making	Critical

While pattern maker Chandar Kumar knew that he had to complete the 5 activities on 12 September, he did not know in what sequence. Anyone would start with the activity listed first (if printed) or remembered first (if memorised), so Chandar Kumar also started with AT009. Similarly Surinder Singh would also like to follow his to-do list as per serial number, but he would not be able to start production sample (first thing in the morning) for BZ 0013 as production patterns were not yet prepared by his predecessor (listed as the 4th activity in Chandar Kumar's list; may start only in the afternoon).

Ideally, there has to be sychronisation of priorities so that pattern maker took up production sample making of BZ0013 first in the morning and sample making of same could be scheduled later on the day for sample maker Surinder Singh. Instead there was interruption in both activities, as the pattern maker had to stop AT009 halfway and take up BZ0013 on an urgent basis.

It was realised that these prioritising problems occurred as the to-do lists were prepared picking up date specific activities from separate CPM network of AT and BZ orders in isolation, and not according to any combined CPM network. If a combined CPM network was made for AT and BZ, then prioritising of activities would have occurred automatically. Interestingly the idea of combining multiple CPM network into one and then executives following only one integrated network was never thought of by any merchandising executives. Finally, apart from being complex, the CPM network making for scheduling activities was very cumbersome and time consuming. Once durations of activities and activity relationships were established, making of the network diagram (using MS-Excel) for Dolores Top took 4 man hours (for critical path) and 9 man hours (for critical chain) respectively. Making of the critical chain took longer time because calculation of start and end time and corresponding buffer time was very onerous and prone to error.

6.2.4 Conclusion and Reflections

The basic philosophy of critical chain was reduction of individual activity time to half while adding buffer time of 50 percent of the critical path. From the earlier study (section 5.2.4) it was evident that nearly 41 percent of the pre-production time was externally dependent. Assuming that durations of externally dependent activities could not be compressed, adoption of critical chain would theoretically reduce the pre-production lead time by 30 percent. This pilot case study using critical chain showed up potential of lead time reduction by compressing internal activities. Actual result was constrained by two factors; first, inability to make multi-style critical chain (for common resources), leading to inability to synchronise and prioritise activities, leading to inability to follow the relay race approach. Secondly, lack of synchronised priorities among certain skill- based activities resulted in interruptions and loss of precious time, which needs to be addressed in future studies.

The network diagrams for individual orders were manually prepared in MS-Excel. This was time consuming and prone to error. Although the researcher and associates themselves prepared the network, it was felt by the company executives that total time required for making critical path or critical chain network would be prohibitive in adopting MS-Excel network diagrams in an actual factory scenario. Moreover, it was unlikely that the understanding and knowledge of critical path/chain would be available with the organisation's executives to prepare such a network. Also, during the course of progress of orders, often changes were required in activity sequences and durations (one common cause was iteration, section 5.2.3). Incorporating such changes in Excel had to be done manually. Once the date of actual execution of any activity was entered, MS-Excel datasheet could calculate the variation, however there was no link between the data sheet and the PERT network. Thus it was felt necessary to use specialised software for critical chain implementation, where automatic update of a network was possible once durations of activities were entered in the data table.

Another shortcoming felt during the case study was linking of resource availability with PERT network. As time availability of executives could not be linked with activities using MS-Excel, it was difficult to calculate resource utilisation and schedule activities to resources scientifically. In such circumstances, there appeared to be inefficient stop/start tasks as priorities changed and people tried to multi-task. While shifting from one activity to another (multitasking) was natural for management-level decision-related activities, the same in skill-based activities could cause efficiency loss due to intermittent work interruption. It was also realised that if multiple PERT networks were integrated for a group of executives, then combined priorities could be easily worked out, which would minimise work interruption and resultant stretching of lead time.

Therefore it was felt mandatory to use specialised software for future longitudinal study where a simple automatic network could be made based on activity duration and relationship. Quick/accurate re-calculation and dynamic updates were then possible, resource availability catered for and multiple order networks combined to develop an integrated network based on resource constraints.

6.3 Multi Project Gantt Chart Implementation

The case study of critical chain application (section 6.2.4) had concluded that specialised project management software would be required to demonstrate dynamic changes of plan due to even a single change of a task duration, to conduct a longitudinal feasibility study for integrating multiple critical path/critical chain (for multiple orders) at the organisation level to observe its effect on activity prioritisation and work interruption. The objective of this longitudinal study was to first identify a generic critical path/critical chain software which had all required features to take care of constraints faced in earlier studies using MS-Excel and, secondly, actual scheduling of multiple orders (multiple critical path networks) in one integrated network and follow-up workload distribution of executives to analyse how computerised scheduling could help prioritisation of activities and actually carry out day-to day task for executives.

6.3.1 Methodology

The methodology could be divided into three stages; selection of appropriate software, implementation of the software in a single order to understand the feature and capabilities, and use of the software to make a multi-order Gantt chart and evaluate how the software capabilities offer additional advantages (over manual and/or MS-Excel) to executives involved in executing the tasks.

In the first stage, neither was any sample size decided nor any sampling method followed for searching and selection of the software. Through contacts in and guidance of Project Management Associates (an association for promoting project management throughout the world, http://www.pma-india.org/), a suitable software was identified, which was found (from brochure and website information) to meet all the necessary parametric requirements for the longitudinal study.

In the second stage, the necessary features of the software were understood by installing the software in an organisation and planning a sample order using critical path methodology and most importantly, understanding the software's capability to overcome earlier shortcomings. Basically, any software could offer an advantage in two ways: helping the direct user in decision making while inputting the parameters and indirectly through various outputs (reports) it could generate to enable/guide executives to carry out the tasks in a better informed manner, which otherwise was not possible. The objective of the second stage was to ensure satisfactory application of the software features and select the appropriate reports that could be used for executives as a guide/checklist/reminder. Sample selection method for selecting the organisation was typical case purposive (section 3.5.2) and data collection was through structured format. A manufacturing organisation, Kirat, was selected based on firstly the management co-operation received during the earlier two case studies on measuring durations of delay-contributing activities in manufacturing cycle (section 5.2) and to identify and measure value added and non-value added time in preproduction activities (section 5.3) and secondly, their willingness to allow planning and executing of selected actual orders through implementation of specific software and a directive to its executives to follow the instructions of the researcher during the longitudinal study.

The third and final stage involved preparation of a multi-project Gantt chart by combining more than one order to see how different software features/reports guided/facilitated executives to carry out their work during actual running of orders. Selection of orders to combine was typical case purposive sampling from those orders that were planning to be shipped during the timeframe, i.e. before Jan 2004. Progress of the combined orders was monitored over a period of 6 months (July 2003 to December 2003) to complete the life cycle of the three selected styles. The order entry in the software, planning and scheduling was done by the researcher, while all concerned executives were given software generated workload related reports to check relevance thereof and what advantages / benefit could accrue in carrying out their activities based on these reports.

6.3.2 Data Collection

Stage One: Selection of the Investigative Tool

The following criteria were laid down for selection of project management software. The requirements of software functions were first identified as under:

- Ability to create PERT network/Gantt chart automatically
- Ability to indicate critical path and critical chain in the network
- Ability to switchover between critical path and critical chain mode during planning as well as tracking of orders.
- Ability to calculate resource availability once work content for each activity is defined and a resource (executive) is allocated to an activity.
- Ability to combine/integrate more than two Gantt charts with resource constraints automatically reflected.
- Ability to show the planned and completion status of activities.
- Ability to provide different options of task relationships like start-start, finish-finish

During detailed evaluation, it was found that PS8 from Sciforma Corporation, US satisfied all listed criteria and was selected for the study. A one-year evaluation version of PS8 was made available gratis by the software vendor and user support was provided through e-mail, another important reason for its selection for the longitudinal case study.

Stage 2: PS8 Software Implementation in Single Order

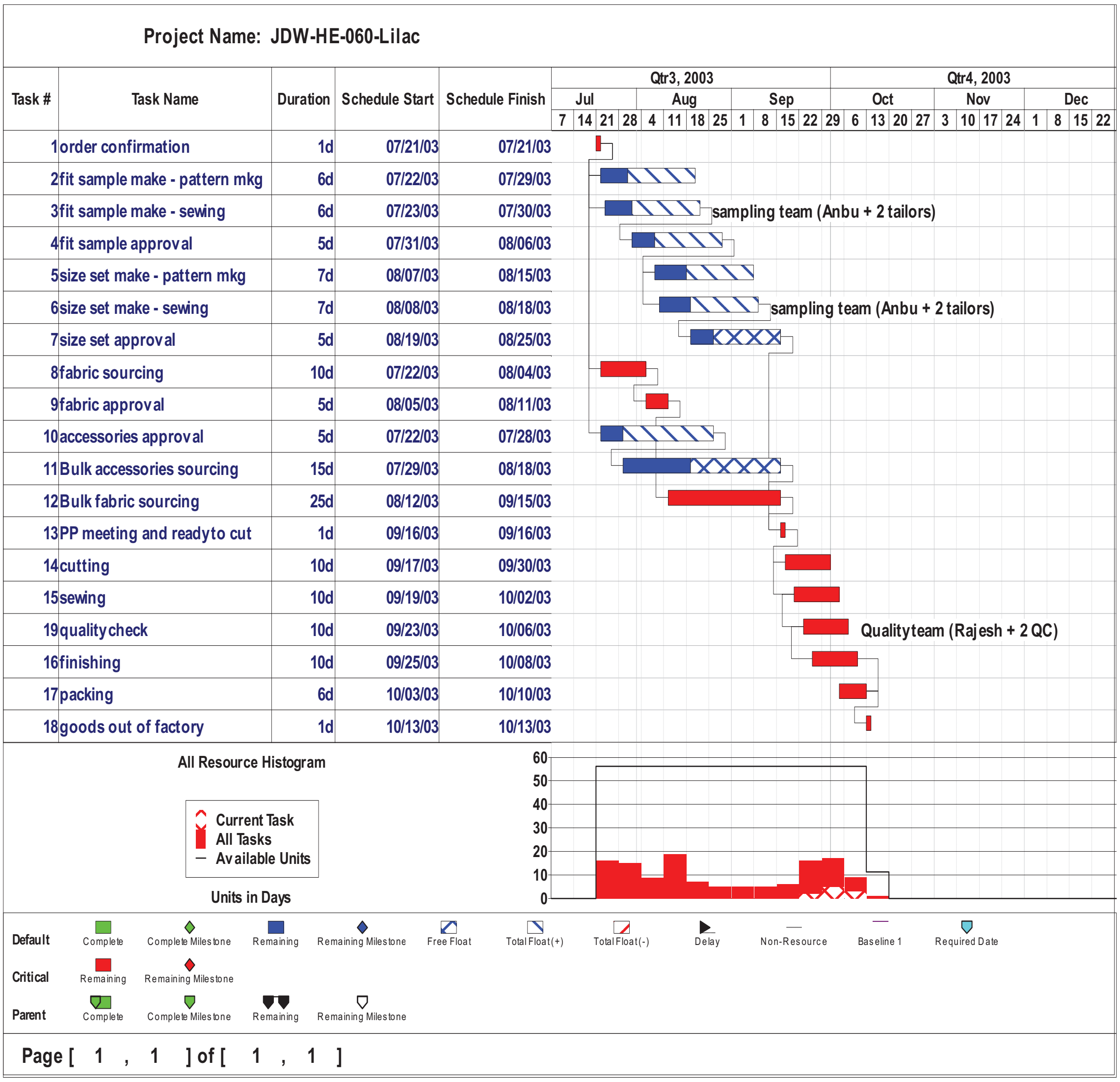
Every order of a garment was treated as a project in PS8 software. One order, JDW-HE-060-LILAC was selected for PS8 implementation. First, resources were defined in the Resource List and then assigned to the tasks. A list of 10 resource persons/groups (termed as executives hereafter) were identified (table 6.8) who could be assigned activities and/or sub-activities related to the order. All resource persons are classified as LABOUR, but time availability varied from eight to ten hours per day depending on the job, i.e., whether it was a desk job or skill-based job.

Table 6.8 List of Resource Persons for Gantt Chart

Resource #	Resource Name	Type	Availability	Email Address
1	merchandiser - Suman	LABOR	8h/d	
2	merchandiser - Rupa	LABOR	8h/d	
3	Sample master - Zakir	LABOR	10h/d	
4	sampling team (Anbu + 2 tailors)	LABOR	10h/d	
5	fabric executive - Vineet	LABOR	8h/d	
6	production executive - Saugat	LABOR	8h/d	
7	spreading & cutting resource	LABOR	10h/d	
8	sewing resource	LABOR	10h/d	
9	finishing & packing resource	LABOR	10h/d	
10	Quality team (Rajesh + 2 QC)	LABOR	8h/d	

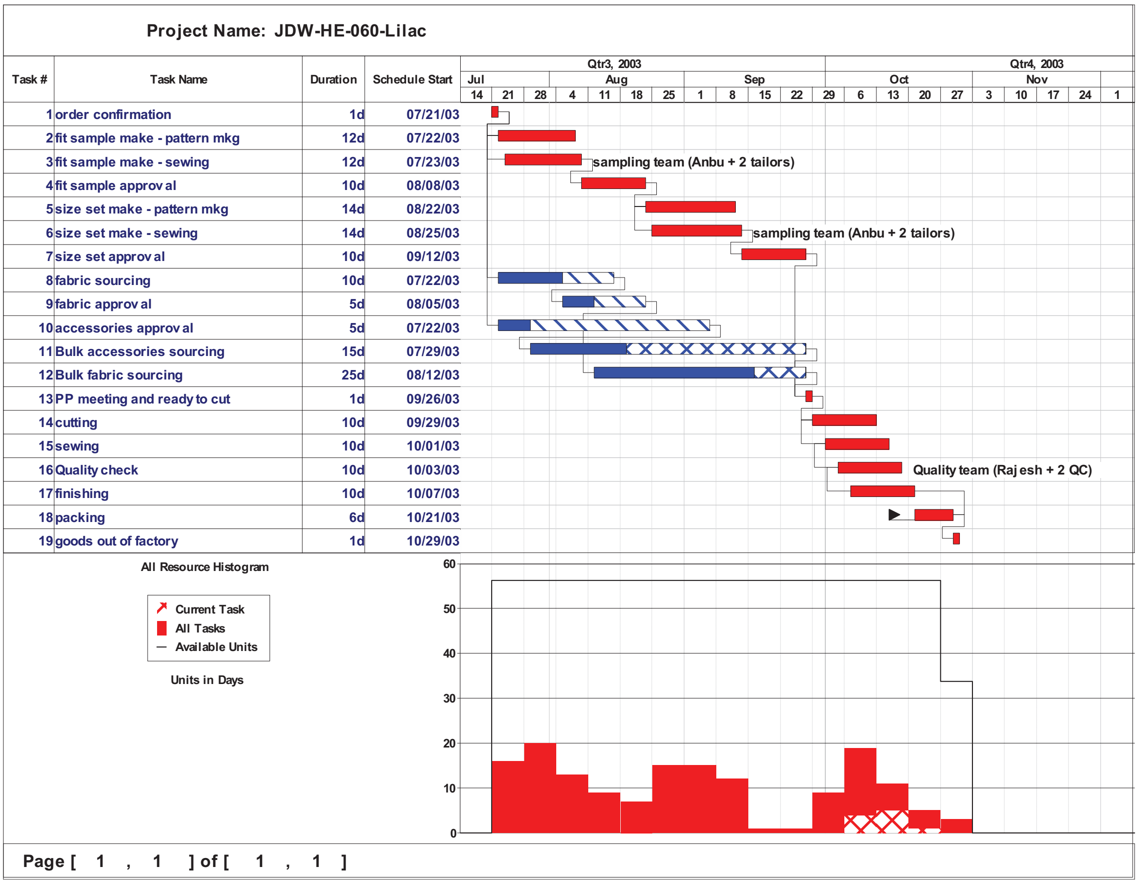
The Gantt chart and resource histogram for JDW-HE-060-LILAC order are shown in figure 6.5. The order had 18 main tasks and a manufacturing lead time of 61 days (which is effectively the critical path duration). All internal tasks were assigned one resource executive and tasks linked to predecessor and successor activities by S-S (start to start), F-S (finish to start) or F-F (finish to finish) relationship. For example 'fit sample make' was a 7 day task earlier divided into two tasks 'fit sample make – pattern mkg' and 'fit sample make – sewing', both working in parallel with starting lag of 1 day. 'Pattern master –Zakir' and 'sampling team' were assigned the two tasks of 6 days duration each.

Figure 6.5 Gantt Chart of JDW-HE-060-LILAC



The Gantt chart showed the scheduled start and finish dates and duration, critical tasks in red colour bar and free floats in non-critical tasks. Free float is the amount of time a non-critical task could be delayed or extended without affecting the start of a successor task, indicated in the Gantt chart as blue cross-hatching at the right end of a task bar. Positive Total Float is that amount of time a non-critical task could be delayed or extended before the task became critical. The bottom of the picture showed weekly utilisation of resources in the form of a histogram (the current task by a red cross in the histogram only indicates the selected task by a cursor at any given point). The requirement of dynamic change of plan (Gantt chart) due to a single change of task duration was checked and found to be working satisfactorily. Figure 6.6 shows how change of duration of fit sample and size set (in case of iteration) dynamically changed the critical path, the duration of critical path from 61 to 73 days and the resource workload pattern in the histogram.

Figure 6.6 Dynamic Change of Gantt Chart



After all the required predetermined features were found to be working satisfactorily, the various report options were studied. The software could generate 60 different types of reports. After analysing all the reports generated by PS8, five reports were selected to be used as a guide to executives while working on the multi-project Gantt chart. The reports are titled Resource Assignments, Resource Project Task Effort, Weekly Resource Utilization, To Do List and Resource Levelling Analysis.

Weekly Resource Utilisation report (figure 6.7) listed executive-wise allocated, percentage used and unallocated (available) hours for every week the order is planned to run. Tasks like approval of fit sample, size set, etc. were done by external resources like the buying office, thus no internal resources from Kirat were assigned for those tasks. However, while observing other orders in progress in the same organisation, it was realised that often more than one type of resource was involved in the execution of a single task and needed to be split into further sub-tasks for better allocation of resources.

Figure 6.7 Weekly Resource Utilisation

Project Name: JDW-HE-060-Lilac

Res ID	Resource Name														
38A5ILQ	merchandiser - Suman		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	40h	8h											
		% Used	100%	20%											
		Available		32h	40h	40h	40h	40h	40h	40h	40h	40h	40h	40h	8h
38A5ILY	merchandiser - Rupa		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated		32h	40h	40h	8h								
		% Used		80%	100%	100%	20%								
		Available	40h	8h			32h	40h	40h	40h	40h	40h	40h	40h	8h
38A5ILR	Sample master - Zakir		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	32h	16h	16h	40h									
		% Used	64%	32%	32%	80%									
		Available	18h	34h	34h	10h	50h	50h	50h	50h	50h	50h	50h	50h	10h
38A5ILZ	sampling team (Anbu + 2 tailors)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	24h	24h	8h	40h	8h								
		% Used	48%	48%	16%	80%	16%								
		Available	26h	26h	42h	10h	42h	50h	50h	50h	50h	50h	50h	50h	10h
38A5ILS	fabric executive - Vineet		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	32h	40h	8h	32h	40h	40h	40h	40h	8h				
		% Used	80%	100%	20%	80%	100%	100%	100%	100%	20%				
		Available	8h		32h	8h					32h	40h	40h	40h	8h
38A5ILT	production executive - Saugat		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									8h				
		% Used									20%				
		Available	40h	40h	40h	40h	40h	40h	40h	40h	32h	40h	40h	40h	8h
38A5ILU	spreading & cutting resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									24h	40h	16h		8h
		% Used									48%	80%	32%		80%
		Available	50h	50h	50h	50h	50h	50h	50h	50h	26h	10h	34h	50h	2h
38A5ILV	sewing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									8h	40h	32h		
		% Used									16%	80%	64%		
		Available	50h	50h	50h	50h	50h	50h	50h	50h	42h	10h	18h	50h	10h
38A5ILW	finishing & packing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated										16h	48h	64h	
		% Used										32%	96%	128%	
		Available	50h	50h	50h	50h	50h	50h	50h	50h	50h	34h	2h	-14h	10h
38A5ILX	Quality team (Rajesh + 2 QC)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated										32h	40h	8h	
		% Used										80%	100%	20%	
		Available	40h	40h	40h	40h	40h	40h	40h	40h	40h	8h		32h	8h

The objective of stage 2 was to accurately and realistically map the workload of internal resources using software, so that clear priorities could be worked out. Accordingly all pre-production tasks were further subdivided into sub-tasks keeping in mind how different resource executives and/or external resources were involved. It was also realised that sometimes one executive was involved in a task in a phased manner, thereby it was important not to assign that resource at one go. For example 'fit sample make' was divided into 4 sequential sub-tasks; pattern making - material conformity - cut & sew - fit check. Pattern Master Zakir was involved in the first and last sub tasks i.e. pattern making and fit check, while merchandiser Suman and the sampling team were assigned to material conformity & cut and sew respectively.

Figure 6.8 Gantt Chart with Sub-tasks

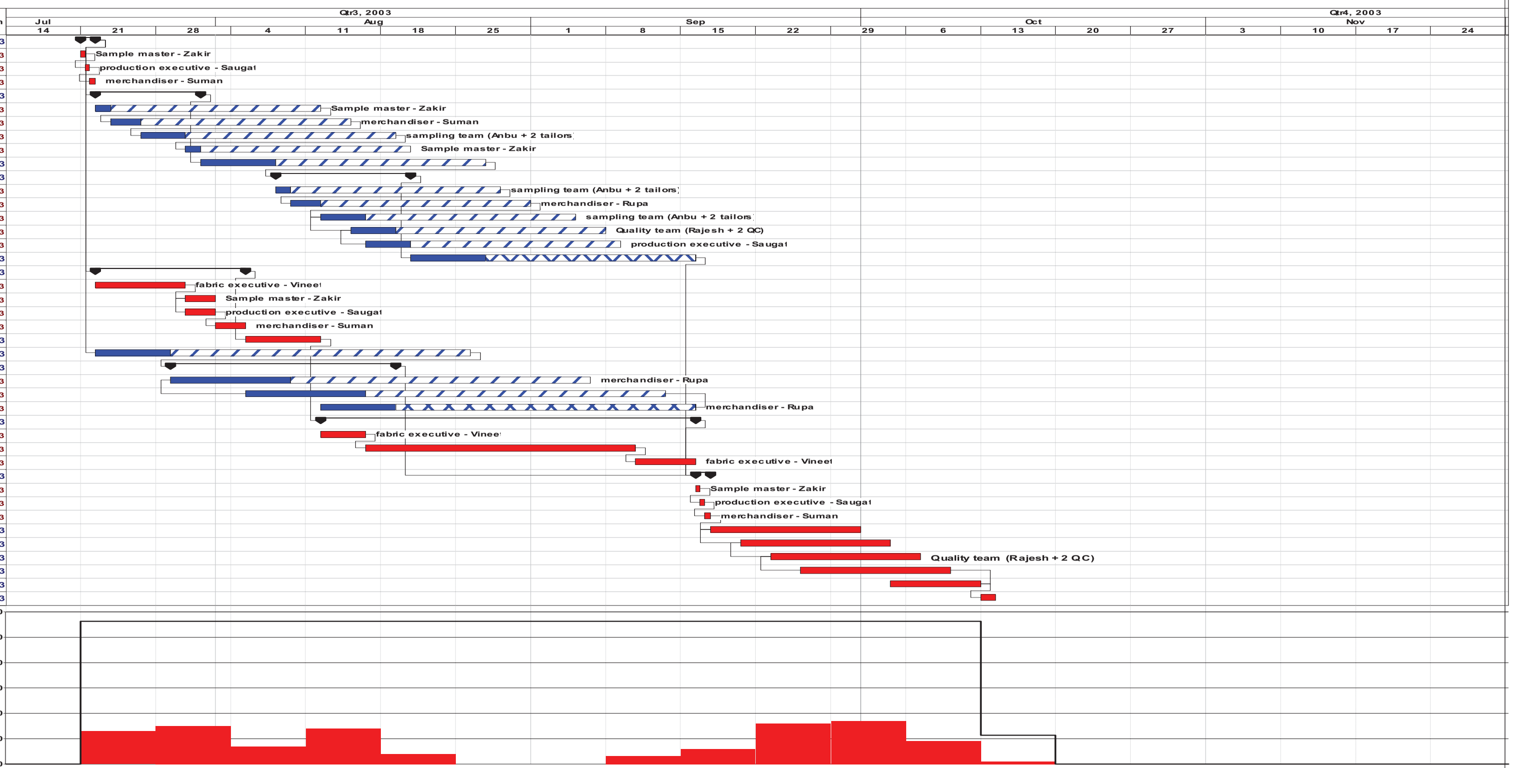
Project Name: JDW-HE-060-Lilac

Task #	Task Name	Duration	Schedule Start	Schedule Finish
1	order confirmation	1d	07/21/03	07/21/03
2	sample - feasibility check	0.3d	07/21/03	07/21/03
3	production - feasibility check	0.3d	07/21/03	07/21/03
4	merchandiser - BOM check	0.4d	07/21/03	07/21/03
5	fit sample make	7d	07/22/03	07/30/03
6	pattern mkg	1d	07/22/03	07/22/03
7	material conformity	2d	07/23/03	07/24/03
8	cut and sew	3d	07/25/03	07/29/03
9	fit check	1d	07/30/03	07/30/03
10	fit sample approval	5d	07/31/03	08/06/03
11	size set make	9d	08/07/03	08/19/03
12	pattern mkg	1d	08/07/03	08/07/03
13	material conformity	2d	08/08/03	08/11/03
14	cut and sew	3d	08/12/03	08/14/03
15	quality check	3d	08/14/03	08/18/03
16	reproducibility check	3d	08/15/03	08/19/03
17	size set approval	5d	08/20/03	08/26/03
18	fabric sourcing	10d	07/22/03	08/04/03
19	sourcing sample fabric options	6d	07/22/03	07/29/03
20	compatibility check -pattern	2d	07/30/03	07/31/03
21	compatibility check - reproduci	2d	07/30/03	07/31/03
22	finalising fabric option	2d	08/01/03	08/04/03
23	fabric approval	5d	08/05/03	08/11/03
24	accessories approval	5d	07/22/03	07/28/03
25	Bulk accessories sourcing	15d	07/29/03	08/18/03
26	communication & follow up	8d	07/29/03	08/07/03
27	accessories make source	8d	08/05/03	08/14/03
28	acc. receive & testing ok	5d	08/12/03	08/18/03
29	Bulk fabric sourcing	25d	08/12/03	09/15/03
30	communication & follow up	3d	08/12/03	08/14/03
31	fabric make and dispatch	18d	08/15/03	09/09/03
32	fabric receive & testing ok	4d	09/10/03	09/15/03
33	P P meeting and ready to cut	1d	09/16/03	09/16/03
34	specification check	0.3d	09/16/03	09/16/03
35	production - feasibility check	0.3d	09/16/03	09/16/03
36	merchandiser - BOM check	0.4d	09/16/03	09/16/03
37	cutting	10d	09/17/03	09/30/03
38	sewing	10d	09/19/03	10/02/03
39	quality check	10d	09/23/03	10/06/03
40	finishing	10d	09/25/03	10/08/03
41	packing	6d	10/03/03	10/10/03
42	goods out of factory	1d	10/13/03	10/13/03

All Resource Histogram

Current Task
All Tasks
Available Units

Units in Days



Default Complete | Complete Milestone | Remaining | Remaining Milestone | Free Float | Total Float(+) | Total Float(-) | Required Date

Critical Remaining | Remaining Milestone

Parent Complete | Complete Milestone | Remaining | Remaining Milestone

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The above Gantt chart (figure 6.8) shows all the tasks (blue text) with subtasks (brown text), name of resources allocated against each task, and duration of each subtask. The total numbers of tasks increased from 19 to 42; however the total duration of manufacturing cycle remained 61 days. The histogram at the bottom of figure 6.8 depicts the workload distribution in different weeks.

While analysing the weekly workload of executives with and without sub-tasks, it became clear that sub-tasks helped in correct distribution of resources. For example, in the absence of sub-tasks merchandiser Suman was found to have workload of 100 percent and 20 percent in weeks commencing July 21 and July 28 respectively. Post sub-task distribution resulted in Suman getting workload in two weeks, commencing Aug 4 and Sept 15 respectively (figure 6.9).

Figure 6.9 Post Sub-task Distribution of Workload

Project Name: JDW-HE-060-Lilac

Res ID	Resource Name														
38A5ILQ	merchandiser - Suman		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	51h	16h	8h						3h				
		% Used	128%	40%	20%						8%				
		Available	-11.2h	24h	32h	40h	40h	40h	40h	40h	36.8h	40h	40h	40h	8h
38A5ILY	merchandiser - Rupa		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated		32h	40h	40h	8h								
		% Used		80%	100%	100%	20%								
		Available	40h	8h			32h	40h	40h	40h	40h	40h	40h	40h	8h
38A5ILR	Sample master - Zakir		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	10h	24h							2h				
		% Used	21%	48%							5%				
		Available	39.6h	26h	50h	50h	50h	50h	50h	50h	47.6h	50h	50h	50h	10h
38A5ILZ	sampling team (Anbu + 2 tailors)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	8h	16h	8h	24h									
		% Used	16%	32%	16%	48%									
		Available	42h	34h	42h	26h	50h	50h	50h	50h	50h	50h	50h	50h	10h
38A5ILS	fabric executive - Vineet		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	32h	16h		24h				24h	8h				
		% Used	80%	40%		60%				60%	20%				
		Available	8h	24h	40h	16h	40h	40h	40h	16h	32h	40h	40h	40h	8h
38A5ILT	production executive - Saugat		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	2h	16h		8h	16h				2h				
		% Used	6%	40%		20%	40%				6%				
		Available	37.6h	24h	40h	32h	24h	40h	40h	40h	37.6h	40h	40h	40h	8h
38A5ILU	spreading & cutting resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									24h	40h	16h		8h
		% Used									48%	80%	32%		80%
		Available	50h	50h	50h	50h	50h	50h	50h	50h	26h	10h	34h	50h	2h
38A5ILV	sewing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									8h	40h	32h		
		% Used									16%	80%	64%		
		Available	50h	50h	50h	50h	50h	50h	50h	50h	42h	10h	18h	50h	10h
38A5ILW	finishing & packing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated										16h	48h	64h	
		% Used										32%	96%	128%	
		Available	50h	50h	50h	50h	50h	50h	50h	50h	50h	34h	2h	-14h	10h
38A5ILX	Quality team (Rajesh + 2 QC)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated				16h	8h					32h	40h	8h	
		% Used				40%	20%					80%	100%	20%	
		Available	40h	40h	40h	24h	32h	40h	40h	40h	40h	8h		32h	8h

The PS8 software has a resource levelling feature which helped in even distribution of workload against any sharp variations. As per figure 6.9, merchandiser Suman was over-utilised 128 percent in the week commencing July 21 and the finishing and packing resource was over utilised 128 percent in the week commencing Oct 6. Merchandiser Rupa was utilised 100 percent in the weeks commencing Aug 4 and Aug 11, and the finishing and packing resource and quality team utilised 96 percent and 100 percent respectively in the week commencing Sept 29. Any workload close to or exceeding 100 percent meant overtime of that particular resource or potential delay in the manufacturing lead time, therefore the resource levelling feature had to be used to distribute the work. Figure 6.10 shows the weekly workload pattern after levelling of resources, where none of the executive workload exceeded 100 percent. However, levelling of resources in this particular order resulted in the delivery date of the order being extended by 4 days, to 17 October 2003.

Figure 6.10 Post Sub-task Distribution of Workload after Resource Levelling

Project Name: JDW-HE-060-Lilac

Res ID	Resource Name		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
38A5ILQ	merchandiser - Suman		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	27h	40h	8h						3h				
		% Used	68%	100%	20%						8%				
		Available	12.8h		32h	40h	40h	40h	40h	40h	36.8h	40h	40h	40h	40h
38A5ILY	merchandiser - Rupa		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated		8h	40h	40h	32h								
		% Used		20%	100%	100%	80%								
		Available	40h	32h			8h	40h	40h	40h	40h	40h	40h	40h	40h
38A5ILR	Sample master - Zakir		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	10h	24h							2h				
		% Used	21%	48%							5%				
		Available	39.6h	26h	50h	50h	50h	50h	50h	50h	47.6h	50h	50h	50h	50h
38A5ILZ	sampling team (Anbu + 2 tailors)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	8h	16h		16h	16h								
		% Used	16%	32%		32%	32%								
		Available	42h	34h	50h	34h	34h	50h	50h	50h	50h	50h	50h	50h	50h
38A5ILS	fabric executive - Vineet		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	32h	16h		24h				24h	8h				
		% Used	80%	40%		60%				60%	20%				
		Available	8h	24h	40h	16h	40h	40h	40h	16h	32h	40h	40h	40h	40h
38A5ILT	production executive - Saugat		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated	2h	16h			24h				2h				
		% Used	6%	40%			60%				6%				
		Available	37.6h	24h	40h	40h	16h	40h	40h	40h	37.6h	40h	40h	40h	40h
38A5ILU	spreading & cutting resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									24h	40h	16h		8h
		% Used									48%	80%	32%		16%
		Available	50h	50h	50h	50h	50h	50h	50h	50h	26h	10h	34h	50h	42h
38A5ILV	sewing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated									8h	40h	32h		
		% Used									16%	80%	64%		
		Available	50h	50h	50h	50h	50h	50h	50h	50h	42h	10h	18h	50h	50h
38A5ILW	finishing & packing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated										16h	40h	40h	32h
		% Used										32%	80%	80%	64%
		Available	50h	50h	50h	50h	50h	50h	50h	50h	50h	34h	10h	10h	18h
38A5ILX	Quality team (Rajesh + 2 QC)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13
		Allocated					24h					32h	40h	8h	
		% Used					60%					80%	100%	20%	
		Available	40h	40h	40h	40h	16h	40h	40h	40h	40h	8h		32h	40h

Stage 3: Multi Project Gantt chart

Along with JDW-HE-060-LILAC, two more orders, JDW-HE-060-WHITE and El Corte 104-1-SUIT were selected for preparing multi project Gantt chart. In Kirat, one merchandiser was responsible for two to three buyers, whereas the other executives in charge of fabric development and procurement, accessories sourcing, pattern maker, sample making were in a common pool. The three orders above were selected based on a list of 10 common resource persons (table 6.8). Three separate Gantt chart for JDW-

HE-060-LILAC, JDW-HE-060-WHITE and El Corte 104-1-SUIT were prepared with subtasks and are shown in figures 6.11, 6.12 and 6.13 respectively. The brief specifications of three multi-project orders loaded onto one Gantt chart are listed below.

Table 6.9 List of Orders for Multi-project Gantt Chart

Project Name	Duration in days	Start Date	Finish Date	Schedule Method
JDW-HE-060-LILAC	61	07/21/03	10/13/03	Critical Path
JDW-HE-160-WHITE	46	08/14/03	10/16/03	Critical Path
El Corte 104-1-SUIT	71	09/15/03	12/22/03	Critical Path

Three orders were selected using purposive sampling so that different lengths of the manufacturing cycle, staggered delivery and start dates were represented. Generally, every executive looked after 15 to 20 orders at any given point of time, at varied levels of progress. For the pilot study, only three projects were selected for integration so that the complete lifecycle of all projects could be covered. All 10 executives were also performing tasks for other orders. The longitudinal study tested the reliability and scope of prioritised task allocation in a multi-order environment and execution of tasks on time with minimum confusion, minimum intermittent work interruption and ease of execution.

Figure 6.11 JDW-HE-060-LILAC Gantt Chart With Sub-tasks and Resource Histograms

Project Name: JDW-HE-060-Lilac

Task #	Task Name	Duration	Schedule Start	Schedule Finish
1	order confirmation	1d	07/21/03	07/21/03
2	sample - feasibility check	0.3d	07/21/03	07/21/03
3	production - feasibility check	0.3d	07/21/03	07/21/03
4	merchandiser - BOM check	0.4d	07/21/03	07/21/03
5	fit sample make	7d	07/22/03	07/30/03
6	pattern mkg	1d	07/22/03	07/22/03
7	material conformity	2d	07/23/03	07/24/03
8	cut and sew	3d	07/25/03	07/29/03
9	fit check	1d	07/30/03	07/30/03
10	fit sample approval	5d	07/31/03	08/06/03
11	size set make	9d	08/07/03	08/19/03
12	pattern mkg	1d	08/07/03	08/07/03
13	material conformity	2d	08/08/03	08/11/03
14	cut and sew	3d	08/12/03	08/14/03
15	quality check	3d	08/14/03	08/18/03
16	reproducibility check	3d	08/15/03	08/19/03
17	size set approval	5d	08/20/03	08/26/03
18	fabric sourcing	10d	07/22/03	08/04/03
19	sourcing sample fabric options	6d	07/22/03	07/29/03
20	compatibility check -pattern	2d	07/30/03	07/31/03
21	compatibility check - reproducibility	2d	07/30/03	07/31/03
22	finalising fabric option	2d	08/01/03	08/04/03
23	fabric approval	5d	08/05/03	08/11/03
24	accessories approval	5d	07/22/03	07/28/03
25	Bulk accessories sourcing	15d	07/29/03	08/18/03
26	communication & follow up	8d	07/29/03	08/07/03
27	accessories make source	8d	08/05/03	08/14/03
28	acc. receive & testing ok	5d	08/12/03	08/18/03
29	Bulk fabric sourcing	25d	08/12/03	09/15/03
30	communication & follow up	3d	08/12/03	08/14/03
31	fabric make and dispatch	18d	08/15/03	09/09/03
32	fabric receive & testing ok	4d	09/10/03	09/15/03
33	PP meeting and ready to cut	1d	09/16/03	09/16/03
34	specification check	0.3d	09/16/03	09/16/03
35	production - feasibility check	0.3d	09/16/03	09/16/03
36	merchandiser - BOM check	0.4d	09/16/03	09/16/03
37	cutting	10d	09/17/03	09/30/03
38	sewing	10d	09/19/03	10/02/03
39	quality check	10d	09/23/03	10/06/03
40	finishing	10d	09/25/03	10/08/03
41	packing	6d	10/03/03	10/10/03
42	goods out of factory	1d	10/13/03	10/13/03

All Resource Histogram

Current Task
All Tasks
Available Units

Units in Days

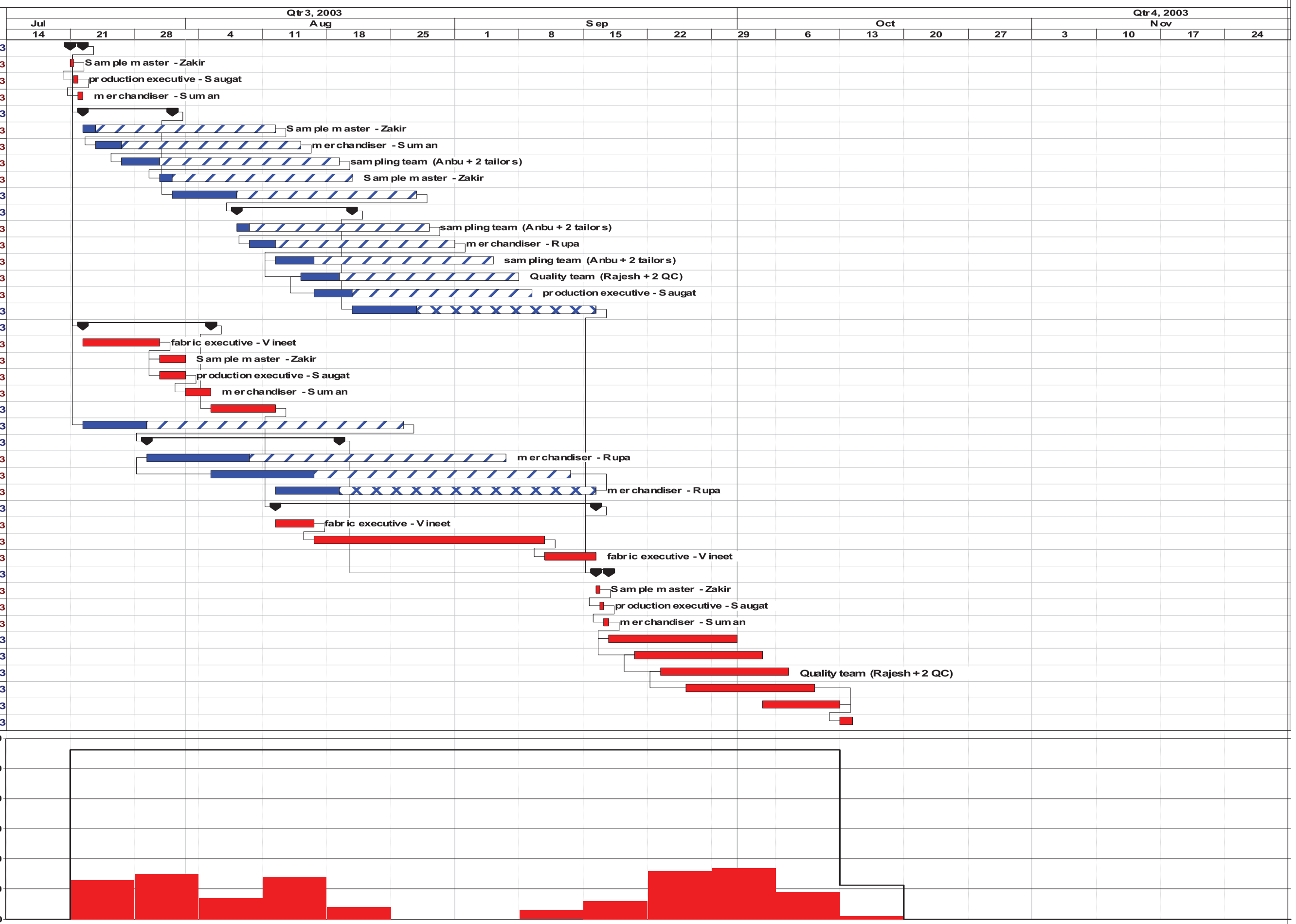
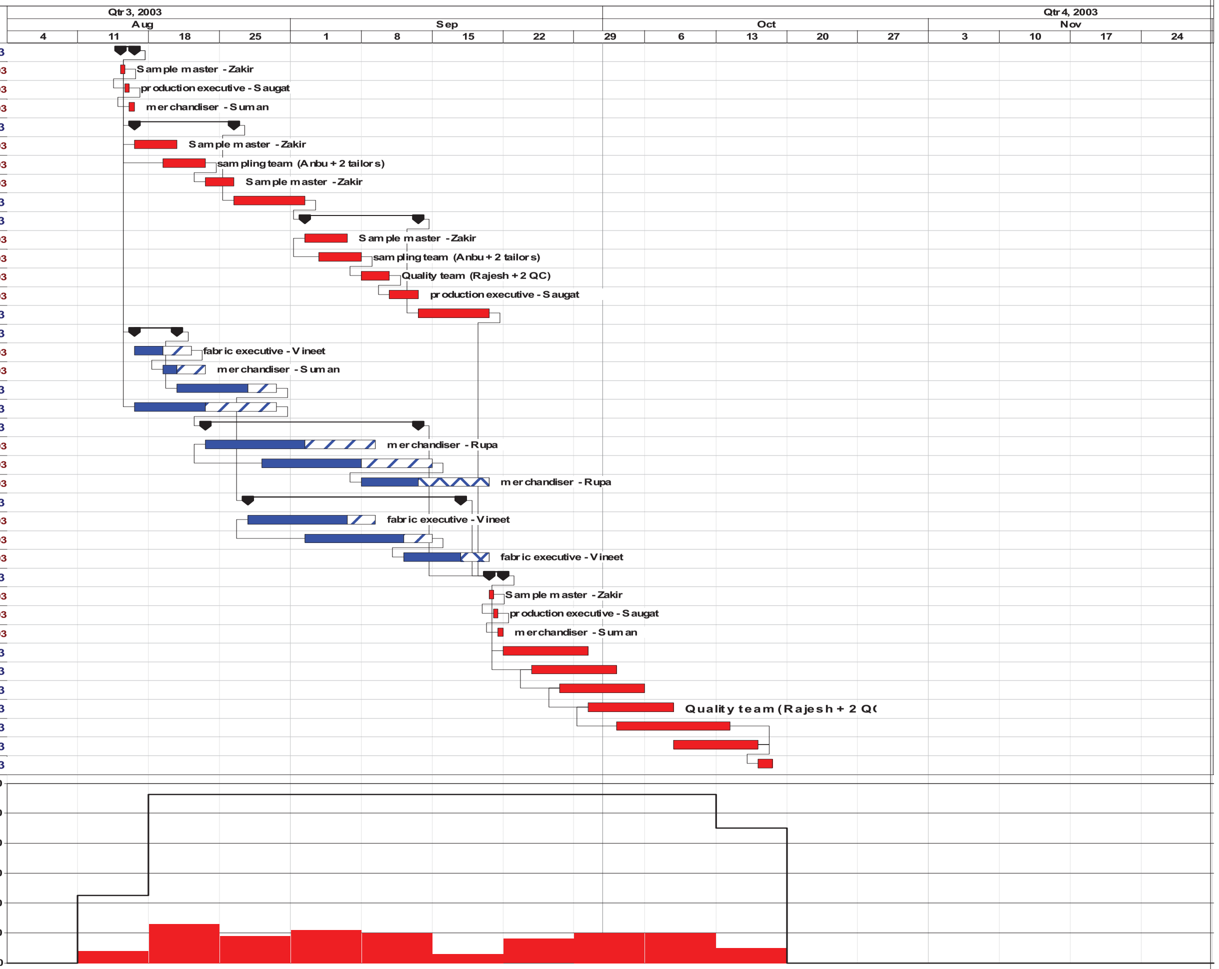


Figure 6.12 JDW-HE-060-WHITE Gantt Chart with Sub-tasks and Resource Histograms

Project Name: JDW-HE-060-White

Task #	Task Name	Duration	Schedule Start	Schedule Finish
1	order confirmation	1d	08/14/03	08/14/03
2	sample - feasibility check	0.3d	08/14/03	08/14/03
3	production - feasibility check	0.3d	08/14/03	08/14/03
4	merchandiser - BOM check	0.4d	08/14/03	08/14/03
5	fit sample make	7d	08/15/03	08/25/03
6	pattern mkg	3d	08/15/03	08/19/03
7	cut and sew	3d	08/19/03	08/21/03
8	fit check	2d	08/22/03	08/25/03
9	fit sample approval	5d	08/26/03	09/01/03
10	size set make	8d	09/02/03	09/11/03
11	pattern mkg	3d	09/02/03	09/04/03
12	cut and sew	3d	09/03/03	09/05/03
13	quality check	2d	09/08/03	09/09/03
14	reproducibility check	2d	09/10/03	09/11/03
15	size set approval	5d	09/12/03	09/18/03
16	fabric sourcing	3d	08/15/03	08/19/03
17	sourcing sample fabric options	2d	08/15/03	08/18/03
18	finalising fabric option	1d	08/19/03	08/19/03
19	fabric approval	5d	08/20/03	08/26/03
20	accessories approval	5d	08/15/03	08/21/03
21	Bulk accessories sourcing	15d	08/22/03	09/11/03
22	communication & follow up	7d	08/22/03	09/01/03
23	acc. make / source	7d	08/28/03	09/05/03
24	acc. receive & testing ok	4d	09/08/03	09/11/03
25	Bulk fabric sourcing	15d	08/27/03	09/16/03
26	communication & follow up	7d	08/27/03	09/04/03
27	fabric make and dispatch	7d	09/02/03	09/10/03
28	fabric receive & testing ok	4d	09/11/03	09/16/03
29	PP meeting and ready to cut	1d	09/19/03	09/19/03
30	specification check	0.3d	09/19/03	09/19/03
31	production - feasibility check	0.3d	09/19/03	09/19/03
32	merchandiser - BOM check	0.4d	09/19/03	09/19/03
33	cutting	6d	09/22/03	09/29/03
34	sewing	6d	09/24/03	10/01/03
35	Washing	6d	09/26/03	10/03/03
36	quality check	6d	09/30/03	10/07/03
37	finishing	8d	10/02/03	10/13/03
38	packing	6d	10/08/03	10/15/03
39	goods out of factory	1d	10/16/03	10/16/03



All Resource Histogram

- Current Task
- All Tasks
- Available Units

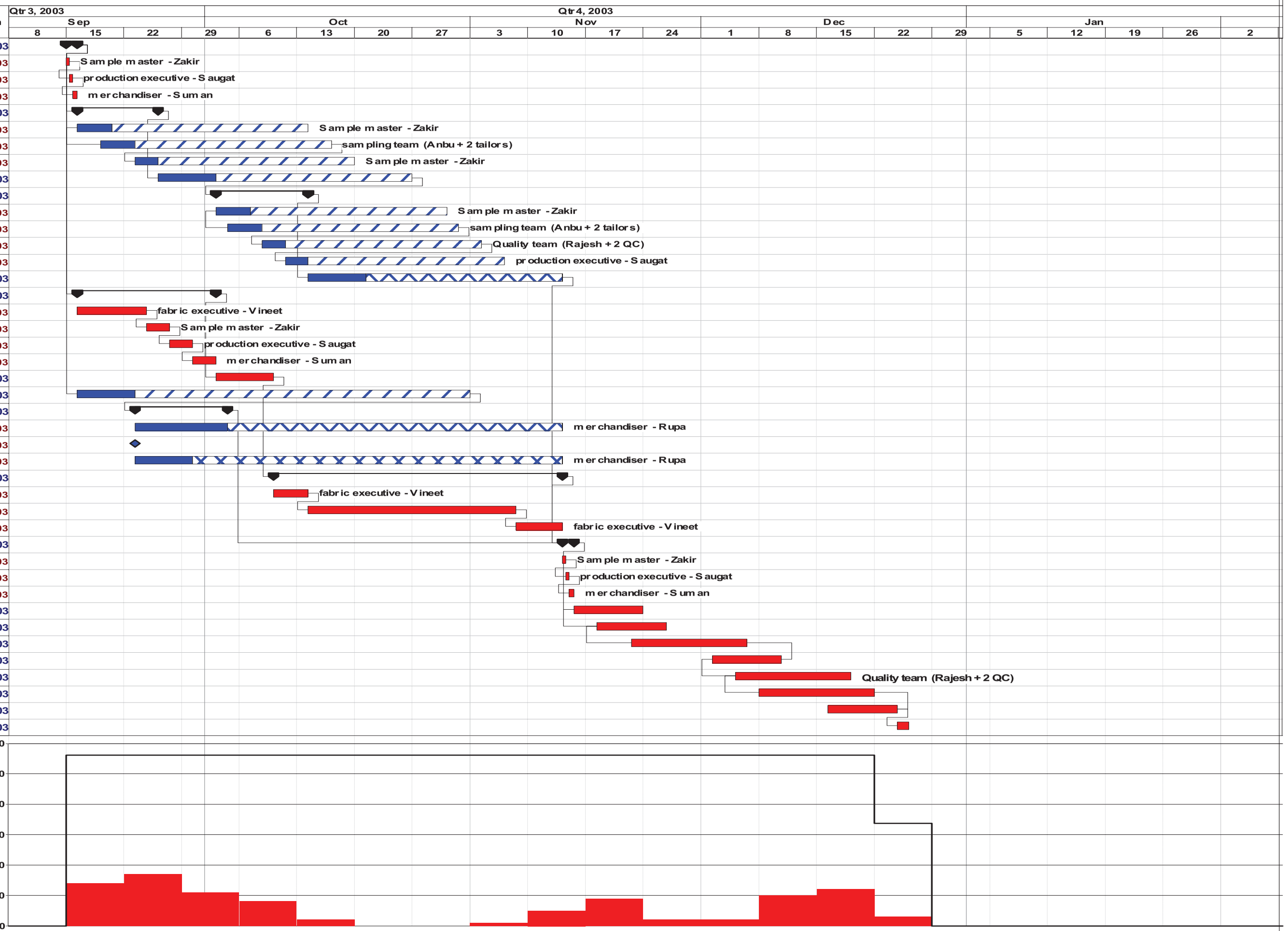
Units in Days

Page [1 , 1] of [1 , 1]

Figure 6.13 El Corte 104-1-SUIT Gantt Chart with Sub-tasks and Resource Histograms

Project Name: El Corte 104 -1-Suit

Task #	Task Name	Duration	Schedule Start	Schedule Finish
1	order confirmation	1d	09/15/03	09/15/03
2	sample - feasibility check	0.3d	09/15/03	09/15/03
3	production - feasibility check	0.3d	09/15/03	09/15/03
4	merchandiser - BOM check	0.4d	09/15/03	09/15/03
5	fit sample make	7d	09/16/03	09/24/03
6	pattern making	3d	09/16/03	09/18/03
7	cut and sew	3d	09/18/03	09/22/03
8	fit check	2d	09/23/03	09/24/03
9	fit sample approval	5d	09/25/03	10/01/03
10	size set make	8d	10/02/03	10/13/03
11	pattern making	3d	10/02/03	10/06/03
12	cut and sew	3d	10/03/03	10/07/03
13	quality check	2d	10/08/03	10/09/03
14	reproducibility check	2d	10/10/03	10/13/03
15	size set approval	5d	10/14/03	10/20/03
16	fabric sourcing	12d	09/16/03	10/01/03
17	sourcing sampleing fabric options	6d	09/16/03	09/23/03
18	compatibility check - pattern	2d	09/24/03	09/25/03
19	compatibility check - reproducibility	2d	09/26/03	09/29/03
20	finalising fabric option	2d	09/30/03	10/01/03
21	fabric approval	5d	10/02/03	10/08/03
22	accessories approval	5d	09/16/03	09/22/03
23	Bulk accessories sourcing	8d	09/22/03	10/02/03
24	communication & follow up	8d	09/23/03	10/02/03
25	accessories source & dispatch	0d	09/22/03	09/22/03
26	accessories receive and testing OK	5d	09/23/03	09/29/03
27	Bulk fabric sourcing	25d	10/09/03	11/12/03
28	communication & follow up	3d	10/09/03	10/13/03
29	fabric make & dispatch	18d	10/14/03	11/06/03
30	fabric receive and testing OK	4d	11/07/03	11/12/03
31	PP meeting and ready to cut	1d	11/13/03	11/13/03
32	specification check	0.3d	11/13/03	11/13/03
33	production feasibility check	0.3d	11/13/03	11/13/03
34	merchandiser - BOM check	0.4d	11/13/03	11/13/03
35	cutting	6d	11/14/03	11/21/03
36	sewing	6d	11/18/03	11/25/03
37	Embroidery after sewing	10d	11/21/03	12/04/03
38	Washing	6d	12/02/03	12/09/03
39	quality check	10d	12/04/03	12/17/03
40	finishing	10d	12/08/03	12/19/03
41	packing	6d	12/16/03	12/23/03
42	goods out of factory	1d	12/24/03	12/24/03



Development of the combined Gantt chart was achieved in the PS8 using a function called multi-project synchronisation feature. Before synchronisation, the following parameters were set.

- In the multi-project set up all three orders are allowed stagger.
- In the multi-project set up, order JDW-HE-160-WHITE was given top priority, followed by order JDW-HE-060-LILAC. El Corte 104-1-SUIT was given lowest priority.
- In the multi-project set up Rupa-merchandiser and Zakir master-sampling are taken as critical resources (constraints) that set the pace of the entire project.
- All individual orders are set as 'fixed type'.
- Schedule method was set as 'critical path' and schedule direction was set as 'forward'.

All executives were also given a list of guidelines to follow:

- Delay non-critical-path tasks within the available float.
- Give priority to critical tasks and extend non-critical-path task durations within the available float, if necessary.
- Follow relay race approach.
- Weekly meeting with all executive members to jointly discuss the progress of the three orders in combination.

In the multi-project Gantt chart, the project could be given any individual name. El Corte 104-1-SUIT was used to name Gantt charts while JDW-HE-160-WHITE was used for the reports generated.

Figure 6.14 **Multi Project Gantt chart**

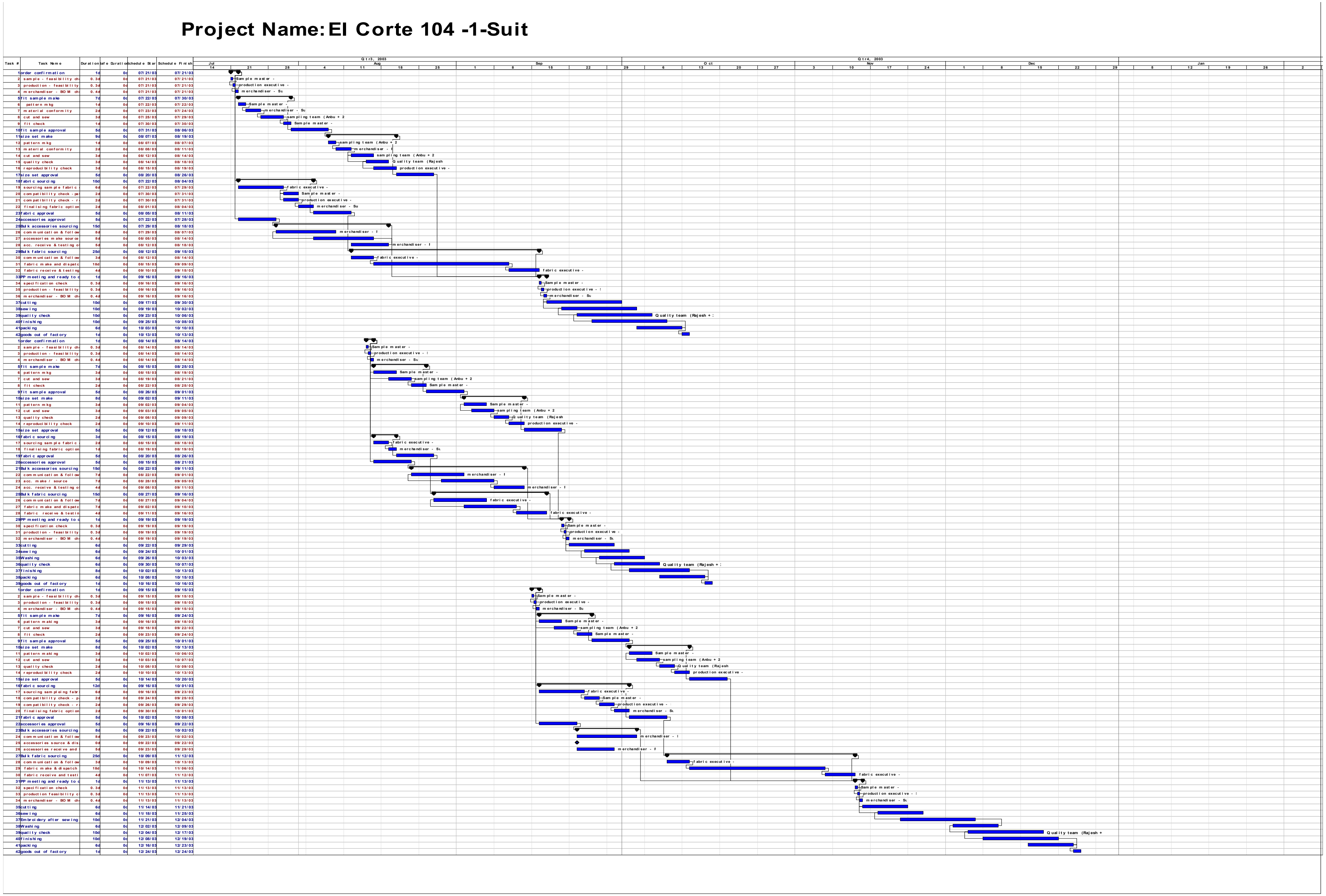


Figure 6.15 **Multi Project Weekly Resource Utilisation**

Project Name: JDW-HE-060-White

Res ID	Resource Name																								
38A5ILQ	merchandiser - Suman		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated	51h	16h	8h	11h	40h				42h	8h	16h						3h						
		% Used	128%	40%	20%	28%	100%				104%	20%	40%						8%						
		Available	-11.2h	24h	32h	28.8h		40h	40h	40h	-1.6h	32h	24h	40h	40h	40h	40h	40h	36.8h	40h	40h	40h	40h	40h	24h
38A5ILY	merchandiser - Rupa		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated		32h	40h	40h	16h	40h	8h	32h		64h	40h												
		% Used		80%	100%	100%	40%	100%	20%	80%		160%	100%												
		Available	40h	8h			24h		32h	8h	40h	-24h		40h	40h	40h	40h	40h	40h	40h	40h	40h	40h	40h	24h
38A5ILR	Sample master - Zakir		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated	10h	24h		10h	24h	8h	24h		31h	32h	16h	8h					2h						
		% Used	21%	48%		21%	48%	16%	48%		62%	64%	32%	16%					5%						
		Available	39.6h	26h	50h	39.6h	26h	42h	26h	50h	18.8h	18h	34h	42h	50h	50h	50h	50h	47.6h	50h	50h	50h	50h	50h	30h
38A5ILZ	sampling team (Anbu + 2 tailors)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated	8h	16h	8h	24h	24h		24h		16h	8h	8h	16h											
		% Used	16%	32%	16%	48%	48%		48%		32%	16%	16%	32%											
		Available	42h	34h	42h	26h	26h	50h	26h	50h	34h	42h	42h	34h	50h	50h	50h	50h	50h	50h	50h	50h	50h	50h	30h
38A5ILS	fabric executive - Vineet		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated	32h	16h		32h	8h	24h	32h	40h	56h	16h		16h	8h			8h	24h						
		% Used	80%	40%		80%	20%	60%	80%	100%	140%	40%		40%	20%			20%	60%						
		Available	8h	24h	40h	8h	32h	16h	8h		-16h	24h	40h	24h	32h	40h	40h	32h	16h	40h	40h	40h	40h	40h	24h
38A5ILT	production executive - Saugat		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated	2h	16h		10h	16h			16h	7h	8h	8h	8h	16h				2h						8h
		% Used	6%	40%		26%	40%			40%	18%	20%	20%	20%	40%				6%						33%
		Available	37.6h	24h	40h	29.6h	24h	40h	40h	24h	32.8h	32h	32h	32h	24h	40h	40h	40h	37.6h	40h	40h	40h	40h	40h	16h
38A5ILU	spreading & cutting resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated									24h	80h	24h		8h				8h	40h					
		% Used									48%	160%	48%		16%				16%	80%					
		Available	50h	50h	50h	50h	50h	50h	50h	50h	26h	-30h	26h	50h	42h	50h	50h	50h	42h	10h	50h	50h	50h	50h	30h
38A5ILV	sewing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated									8h	64h	56h							32h	16h				
		% Used									16%	128%	112%							64%	32%				
		Available	50h	50h	50h	50h	50h	50h	50h	50h	42h	-14h	-6h	50h	50h	50h	50h	50h	50h	18h	34h	50h	50h	50h	30h
38A5ILW	finishing & packing resource		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated										16h	64h	128h	32h								40h	72h	16h
		% Used										32%	128%	256%	64%								80%	144%	53%
		Available	50h	50h	50h	50h	50h	50h	50h	50h	50h	34h	-14h	-78h	18h	50h	50h	50h	50h	50h	50h	50h	10h	-22h	14h
38A5ILX	Quality team (Rajesh + 2 QC)		Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Dec 1	Dec 8	Dec 15	Dec 22
		Allocated				16h	8h			16h		32h	72h	40h								16h	40h	24h	
		% Used				40%	20%			40%		80%	180%	100%								40%	100%	60%	
		Available	40h	40h	40h	24h	32h	40h	40h	24h	40h	8h	-32h		40h	40h	40h	40h	40h	40h	40h	24h		16h	24h

A weekly resource utilisation chart was found to be very useful for a manager and/or planner. The total workload for every executive for every week was indicated for the duration of the manufacturing cycle. Out of the total duty hours for each executive how much time was allocated for tasks and how much was free is clearly indicated, thus helping monitoring and rationalising changes of plan, if any. Workload exceeding 100 percent indicated a shortage of resources and a solution was required, by either working overtime or re-scheduling target dates.

The software generated ***Resource Assignments Reports*** (figure 6.16) informs all executives of the tasks being allocated to them, the time allocated for each task, scheduled start and finish date and the name of the project (order) the task belonged to.

Figure 6.16 Resource Assignments Report

Project Name: JDW-HE-060-White

Res #	Res ID	Resource Name	Email Address	Current Availability
1	38A5ILQ	merchandiser - Suman		8h/d

Project ID	Project Name	Task #	Task Name	Base	Total	Actual	Remaining	Start	Finish
2IDVLC1	JDW-HE-060-Lilac	4	merchandiser - BOM check	0h	3.2h	0h	3.2h	07/21/03	07/21/03
2IDVLC1	JDW-HE-060-Lilac	7	material conformity	0h	16h	0h	16h	07/23/03	07/24/03
2IDVLC1	JDW-HE-060-Lilac	22	finalising fabric option	0h	16h	0h	16h	08/01/03	08/04/03
2IDVLC1	JDW-HE-060-Lilac	24	accessories approval	0h	40h	0h	40h	07/22/03	07/28/03
2IDVLC1	JDW-HE-060-Lilac	36	merchandiser - BOM check	0h	3.2h	0h	3.2h	09/16/03	09/16/03
2IDVLC1	JDW-HE-060-White	4	merchandiser - BOM check	0h	3.2h	0h	3.2h	08/14/03	08/14/03
2IDVLC1	JDW-HE-060-White	18	finalising fabric option	0h	8h	0h	8h	08/19/03	08/19/03
2IDVLC1	JDW-HE-060-White	20	accessories approval	0h	40h	0h	40h	08/15/03	08/21/03
2IDVLC1	JDW-HE-060-White	32	merchandiser - BOM check	0h	3.2h	0h	3.2h	09/19/03	09/19/03
2IDVLC1	El Corte 104 -1-Suit	4	merchandiser - BOM check	0h	3.2h	0h	3.2h	09/15/03	09/15/03
2IDVLC1	El Corte 104 -1-Suit	20	finalising fabric option	0h	16h	0h	16h	09/30/03	10/01/03
2IDVLC1	El Corte 104 -1-Suit	22	accessories approval	0h	40h	0h	40h	09/16/03	09/22/03
2IDVLC1	El Corte 104 -1-Suit	34	merchandiser - BOM check	0h	3.2h	0h	3.2h	11/13/03	11/13/03

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The software generated ***To Do List*** (also referred to as Upcoming task by resources in the software) for every executive could be made for any customised date range. The *To Do List* (figure 6.17) listed tasks for a given close ended time period or before/after any specific date. The *To Do List* also listed incomplete tasks, their project names, scheduled start dates, duration of task, and predecessor reference.

Figure 6.17 To Do List

Project Name: JDW-HE-060-White

To Do List

For Resource:	merchandiser - Suman	E-mail:		Manager:		
Project Name	**Task Name**	**Schedule Start**	**Duration**	**Safe Duration**	**On CC**	**Predecessor(s) #**
Uncompleted Task						
JDW-HE-060-Lilac	merchandiser - BOM check	07/21/03	0.4d	0d	No	3
JDW-HE-060-Lilac	material conformity	07/23/03	2d	0d	No	6
JDW-HE-060-Lilac	finalising fabric option	08/01/03	2d	0d	No	21
JDW-HE-060-Lilac	accessories approval	07/22/03	5d	0d	No	1
JDW-HE-060-Lilac	merchandiser - BOM check	09/16/03	0.4d	0d	No	35
JDW-HE-060-White	merchandiser - BOM check	08/14/03	0.4d	0d	No	3
JDW-HE-060-White	finalising fabric option	08/19/03	1d	0d	No	17
JDW-HE-060-White	accessories approval	08/15/03	5d	0d	No	1
JDW-HE-060-White	merchandiser - BOM check	09/19/03	0.4d	0d	No	31
El Corte 104 -1-Suit	merchandiser - BOM check	09/15/03	0.4d	0d	No	3
El Corte 104 -1-Suit	finalising fabric option	09/30/03	2d	0d	No	19
El Corte 104 -1-Suit	accessories approval	09/16/03	5d	0d	No	1
El Corte 104 -1-Suit	merchandiser - BOM check	11/13/03	0.4d	0d	No	33

For Resource:	merchandiser - Rupa	E-mail:		Manager:		
Project Name	**Task Name**	**Schedule Start**	**Duration**	**Safe Duration**	**On CC**	**Predecessor(s) #**
Uncompleted Task						
JDW-HE-060-Lilac	material conformity	08/08/03	2d	0d	No	12
JDW-HE-060-Lilac	communication & follow up	07/29/03	8d	0d	No	
JDW-HE-060-Lilac	acc. receive & testing ok	08/12/03	5d	0d	No	27 FF 2d
JDW-HE-060-White	communication & follow up	08/22/03	7d	0d	No	
JDW-HE-060-White	acc. receive & testing ok	09/08/03	4d	0d	No	23
El Corte 104 -1-Suit	communication & follow up	09/23/03	8d	0d	No	
El Corte 104 -1-Suit	accessories receive and testing OK	09/23/03	5d	0d	No	

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The software generated a task-wise multi-project workload report (Resource project task effort-weekly) (figure 6.18) for the resource executive on a weekly basis. The distribution of workload by project and then by task helped executives to assess their own workload by type of task.

Figure 6.18 Resource Project Task Effort-Weekly

Project Name: JDW-HE-060-White

Res #	Resource Name	Jul 21	Jul 28	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 6	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17
1	merchandiser - Suman																		
2IDVLC1	**JDW-HE-060-Lilac**	**51h**	**16h**	**8h**						**3h**									
1	order confirmation	3h																	
4	merchandiser - BOM check	3h																	
5	fit sample make	16h																	
7	material conformity	16h																	
18	fabric sourcing		8h	8h															
22	finalising fabric option		8h	8h															
24	accessories approval	32h	8h																
33	PP meeting and ready to cut									3h									
36	merchandiser - BOM check									3h									
2IDVLC1	**JDW-HE-060-White**				**11h**	**40h**				**3h**									
1	order confirmation				3h														
4	merchandiser - BOM check				3h														
16	fabric sourcing					8h													
18	finalising fabric option					8h													
20	accessories approval				8h	32h													
29	PP meeting and ready to cut									3h									
32	merchandiser - BOM check									3h									
2IDVLC1	**El Corte 104-1-Suit**									**35h**	**8h**	**16h**						**3h**	
1	order confirmation									3h									
4	merchandiser - BOM check									3h									
16	fabric sourcing											16h							
20	finalising fabric option											16h							
22	accessories approval									32h	8h								
31	PP meeting and ready to cut																	3h	
34	merchandiser - BOM check																	3h	
Resource Totals:		**51h**	**16h**	**8h**	**11h**	**40h**				**42h**	**8h**	**16h**						**3h**	

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During project execution, another feature of PS8 was found to be particularly helpful for apparel manufacturing operations. PS8's grouping feature extended the capabilities of the subproject and merged options. Grouping in apparel business helped to maintain separate order files for different orders of a group while still being able to define dependencies between the orders. Often different colours were ordered for one style; while tasks like fit sample approval and size set were common amongst them, lab dip, fabric source, cut, make and finish were separate for every colour. Separate subprojects could be created for different colours. The elements of the subproject present in the master project are its duration, percentage complete and an optional selection of resource assignment information. The subproject feature in PS8 satisfied this requirement. However this feature could not be analysed as the three orders selected were not set up with subproject features.

6.3.3 Data Analysis

The analysis of workload distribution pattern across the manufacturing cycle revealed an interesting fact. It was found that there was generally more workload at the beginning and tail end of the manufacturing cycle, whereas in the middle section there was less workload. JDW-HE-060-LILAC order had a 13 week cycle and during weeks 6 and 7 (starting 25 Aug and 1 Sept respectively) there was zero workload (histogram in figure 6.11). In JDW-HE-060-WHITE order also, week 6 (15 Sept) of a total of 10 weeks manufacturing cycle had least workload (histogram in figure 6.12). Similarly, in the El Corte 104-1-SUIT order, weeks 7 and 8 (Oct 20 and Oct 27 respectively) in a 15 week cycle had zero workload (histogram in figure 6.13). This lull of activities in the middle of the cycle could probably be attributed to the period during the last leg of pre-production activities, when tasks were completed by in-house executives and they were awaiting decision/execution from buyers and/or suppliers, though it was widely believed that orders with staggered delivery date would lead to evening out of workload across an organisation. Even in the multi-project combined Gantt chart, weeks 14 and 15 were found to have zero workload out of total cycle time of 23 weeks. The red colour pictorial representation of critical activities in Gantt chart helped executives to understand and appreciate individual responsibilities. As the names of resource persons could be written in the Gantt chart, it was very clear among organisation executives to pictorially understand what their predecessors achieved and why, the importance of their own task and what to leave for their successor.

All executives felt thoroughly guided using ***resource assignments reports*** as every sub-task level was listed. The executives used same as a checklist during the six month period.

The executive used the ***To Do List report*** to the maximum for their daily schedule. All ten executives expressed that this To Do List was very handy for two reasons: first, predecessor reference often helped them to fetch the task from the concerned executive, thus prompting a relay race like situation. Second, every task in the To Do List indicated whether that task was part of critical path/critical chain or not, helping them to prioritise their work. The 'to-do' list generated by the software for every individual resource gave them a clear priority of work to be done as per schedule. All executives felt that the multi-project To Do List made it easier for them to understand reports about the ongoing tasks for immediate follow up.

If any particular type of task was repeated for multiple orders, grouping by task type helped an executive to learn from mistakes as well as implement new lessons easily. Some of the executives felt that ***task wise multi project workload report*** helped them see their workload in future weeks, thus enabling them to plan better (specially for taking short breaks without disturbing the schedule).

The ***resource levelling option*** of the software enabled an executive to decide to either work overtime or reschedule the time line in advance. 8 out of 10 resource executives felt in favour of levelling of resources, even if it resulted in delay of an activity. The executives felt that working with 100 percent or more workload mean invariably working late hours (for desk job) or overtime (for skill-based tasks). In other words, it implied higher stress levels and/or inconsistent quality level. The executives felt levelled resources offered a de-stressed work environment resulting in high quality output. However, two sets of resources, the sampling team and finishing and packing executives felt otherwise. They felt peaks and troughs in workload were welcome as this helped them to work flexi-time and simultaneously earn extra money working overtime. Incidentally, both these resources were skill-based and entitled to overtime.

Every executive felt that the software enabled multi-project schedule nearly eliminated intermittent work interruption and planned their schedule better. However, during the actual execution of the three projects every executive's actual work load schedule could not be compared against that of the software generated schedule as they were also attending to tasks from orders other than the three in the multi-project Gantt chart, rendering segregation of the workload impossible.

Every executive felt the software enabled multi-project schedule nearly eliminated intermittent work interruption so that they could plan their schedule better. However, during the actual execution of the three projects every executives' actual work load schedule could not be compared against that of software generated schedule as they were also attending tasks from orders other than the three orders in the multi-project Gantt chart. It was therefore impossible to segregate the workload.

The three orders, JDW-HE-060-LILAC, JDW-HE-060-WHITE and El Corte 104-1-SUIT analysed in the multi-project Gantt chart had 61, 46 and 71 days or 13, 10 and 15 weeks lead time respectively. Assuming that 10 resource executives were available throughout, then total resource availability for JDW-HE-060-LILAC order was 130 man-weeks. However, some work was executed in only 41 man-weeks, i.e. 31 percent. Further work executed in a man-week varied from 5 percent to 128 percent utilisation with an average of 50.48 percent. This effectively meant that utilisation of workload for JDW-HE-060-LILAC order was 15.5 percent. By the same measure, utilisation of workload for JDW-HE-060-WHITE and El Corte 104-1-SUIT was 16 and 11.5 percent respectively. These measures could be used to denote effective executive utilisation. When the three projects were executed in the multi-project scenario, the effective executive utilisation increased to 23 percent.

6.3.4 Conclusion

The software generated multi-project weekly workload schedule for executives coupled with the relay race approach helped every executive to anticipate workload in advance and share resources between different orders better. It was realised that multi-order resource workload was more realistic than individual workload for separate orders. The multi-project Gantt chart implementation clearly addressed several human resource bottleneck issues in pre-production processes.

Seeking last minute extension of delivery date by apparel manufacturers was a common problem. The multi-order workload plan enables pre-emption of the overload permitting a decision to either work overtime or re-schedule activity dates. The ***resource levelling option*** helped in making a decision scientifically.

As already stated, workload at the start and end sections of any order cycle was considerably higher than mid-section. This called for careful selection of orders with predetermined lead time and calculated staggering of delivery dates in one team of executives for scientific and optimum use of available resources. Assuming that the 10-executive resource was an ideal mix of expertise to execute an order, then 13 orders could be handled by one team at 100 percent utilisation rate. Therefore, orders for a team of executives should be chosen with a uniformly staggered delivery date with the correct mix of lead time. Although ideal 100 percent utilisation of all resources might not be possible practically, software helped in analysing what the correct mix of orders for a group of resources should be, rationally and scientifically grouping multiple orders for optimum utilisation of resources without delaying the delivery date. It was also observed in Kirat that a typical team of ten executives generally handled 20-30 orders at a time. Thus, in an actual scenario, it was more than likely that smooth execution of some tasks on some days would be interrupted either due to non-availability of time from executives or misplaced priorities.

The executives reported the generic benefits of using software while executing talks using the multi-order Gantt chart:

- To Do List was a kind of mental assurance as it was a fool proof mechanism of order follow up.
- Holidays were incorporated in the calendar, so there were no last minute surprises.
- Being always up to date with order status and pre-empt capability gave them an edge over buyers. It boosted their self confidence.
- Even though task prioritisation within a day was not felt necessary, a common schedule in black and white helped all to work around a common goal.
- Rather than individually setting and following up daily targets, team work approach and milestone-based targets was found to work well with the multi-project Gantt chart.
- The software feature and reports also helped executives to understand their interdependent role in an order better and instilled a sense of teamwork.

6.4 Intermittent Work Interruption

During critical path / critical chain implementation in Silvershine Apparels, intermittent work interruption was found common among pattern making, sampling, quality checking, and specification sheet preparation activities (section 6.2.3). Account managers were accountable to their customers for successful completion of the orders. All customers, whether national or international, tend to think that their orders were of the highest priority and wanted to see frequent progress in their orders. Therefore, resources tended to migrate between one order and another in response to the latest/loudest customer's demand to keep as many customers satisfied as possible. This phenomenon is referred to as 'multitasking' by Goldratt (1997). It was decided to first carry out a pilot study with an identified activity where intermittent work interruption was extant, followed by a longitudinal study of a representative set of orders to measure the impact of intermittent work interruption in the manufacturing cycle time.

6.4.1 Pilot Study

A pilot study was carried out with an identified activity where intermittent work interruption prevails, to test the measurability of interruption time against work time, to measure the amount of time loss per interruption and to test the authenticity and reproducibility of measuring technique.

6.4.1.1 Methodology

This study was to provide an illustrative profile (of what is typical in industry) using a representative case (section 3.5.3). Hence, a typical case of purposive sampling was used to select Silvershine Apparels. The reason for selecting Silvershine Apparels was familiarity, while the previous two case studies were conducted with ample management support. Data was collected by a research associate for one month, supervised by the researcher. The method of data collection was structured format designed in MS Excel worksheet. Pre-production activities in Silvershine Apparels were observed for one week to locate where Intermittent Work Interruption was occurring and whether it was measurable. Pattern making activity in Silvershine Apparels was selected for observation. In this case, 'pattern making' work defined the manual process which included developing a pattern either from a measurement chart through drafting, and/or from a basic block, manual grading and making of final production pattern. Minute to minute activity of one pattern master was collected for one month excluding lunch breaks. The time scale was divided into 0.5 hours (half hour) durations and each column in ensuing graphs represents duration of 0.5 hours.

Each row represents a different style. A cell is marked black when the pattern master was working on the style and grey when no work was taking place on the style.

In order to measure the amount of time lost per interruption, a set of similar styles was selected and pattern making of those styles were compared with and without any interruption. 'Similar styles' implied that the pattern making time for the styles was similar. In actual working conditions, the same styles could not be observed for with and without interruption, therefore 'similar styles' were selected.

6.4.1.2 Data Collection

Data was collected observing one pattern master for one month, with timing initiated from the moment the pattern master started work on a style. Working pattern of the pattern master on a particular day is illustrated in table 6.10. Each box represents 0.5 hours duration. Excluding 0.5 hours lunch break, the pattern maker worked for 10.5 hours in that day and prepared patterns for 5 different styles. Out of five styles being worked, work was interrupted on 2 styles (W231 and 2PIE), interruption took place once for each style and the durations of interruption were 5.5 hours and 6 hours respectively. Pattern making for the other three styles was uninterrupted.

Table 6.10 Pattern Making in Intermittent Work Interruption Environment (Actual Scenario)

Style	Time Scale																					
W 231																						
2 PIE- M Size																						
S3g-58 T								Lunch Break														
Jumper																						
Elastic Skirt																						

Legend

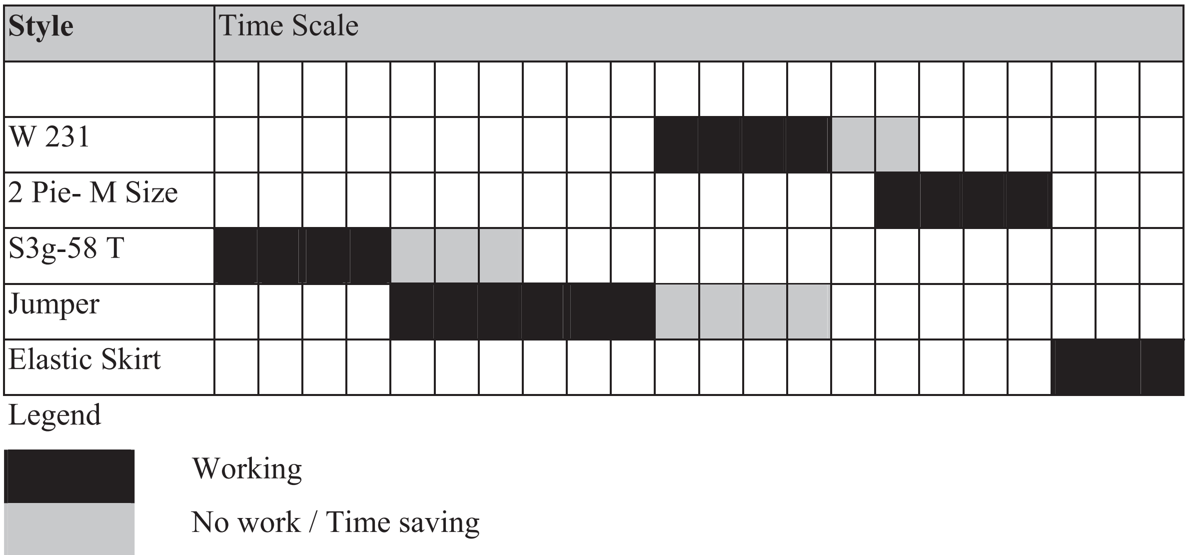
Working

No work / Time saving

6.4.1.3 Data Analysis

In case the pattern maker was given a fixed priority schedule and work was not interrupted, then all styles could have been worked upon at a stretch without interruption. Table 6.11 represents a hypothetical case scenario of the day represented in table 6.10. However it may be noted that style W231 and 2PIE took 2 hours each when work was interrupted. Therefore, it may be safely assumed that styles W231 and 2PIE would take less than 2 hours when worked on without interruption. It was therefore decided to measure the effect of interruption on activity duration. As in a real life scenario, it was not possible to have data for activity duration with and without interruption for the same style, so it was decided to take similar styles.

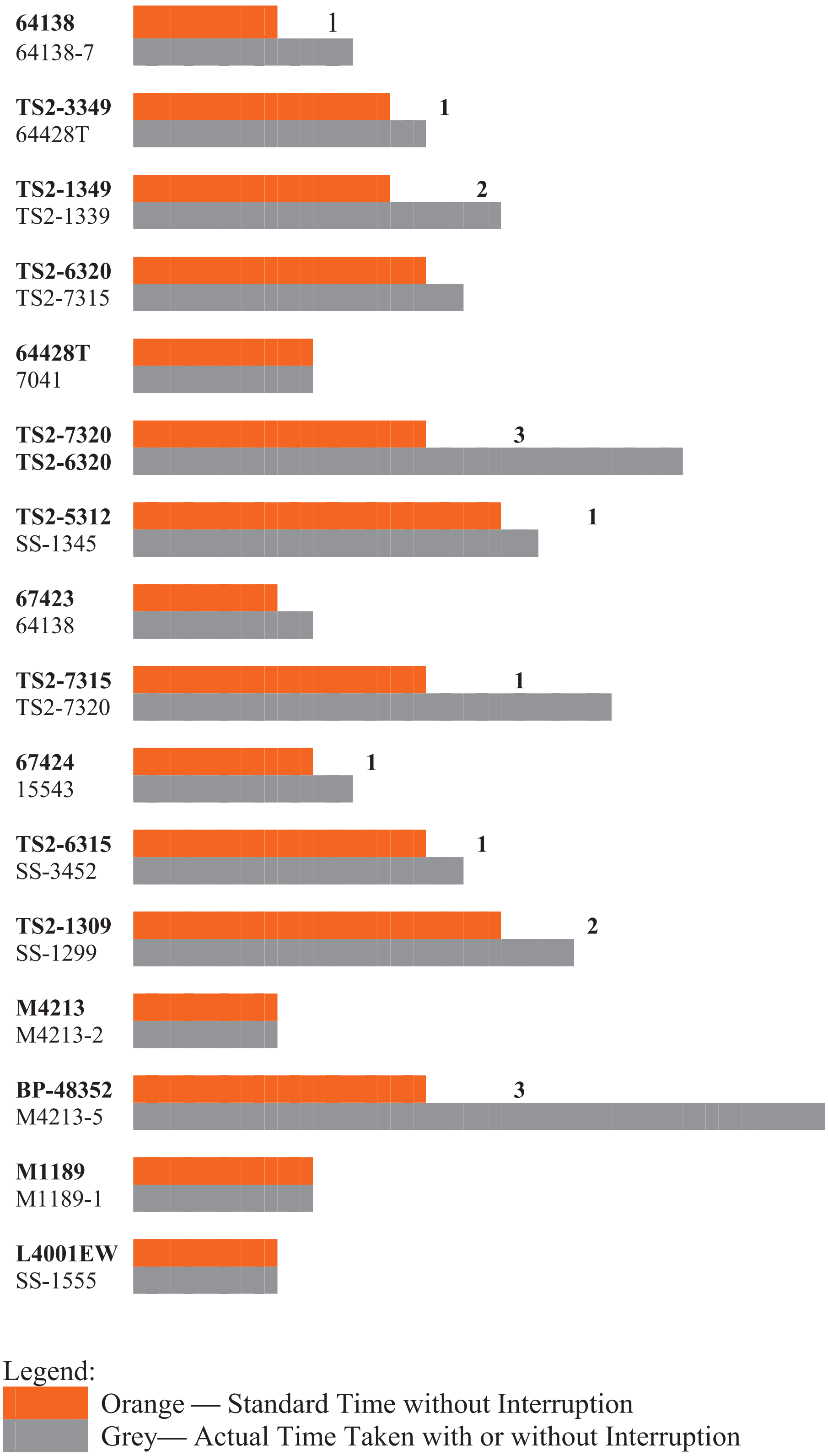
Table 6.11 Pattern Making Without Intermittent Work Interruption (Hypothetical Scenario)



The hypothetical scenario in table 6.11 could have many different sequences. Assuming work interruption caused a loss in concentration (and the pattern maker must have spent some additional time for styles W231 and 2PIE during the interruption), it could be safely concluded that in a no-interruption scenario, the pattern maker would probably complete the pattern for all 5 styles in less than 10.5 hours.

To measure the amount of time loss per interruption, 16 nearly similar styles were selected from those in production or sampling.

Table 6.12 Intermittent Work Interruption on Similar Styles



In the chart above, the number of interruptions was shown numerically against the bars. For example, style TS2-3349 had taken 3.5 hours, while a nearly similar style 64428T had taken four hours with one interruption. Similarly, times taken for the set of all 16 similar styles were noted and it was found that in four sets, there was no interruption and no difference in time, in another two orders there was no interruption but 0.5 hours difference was observed in time. In the remaining 10 sets of orders, there were interruptions and also differences in time. An analysis of these 10 sets of orders showed that interruption occurred 16 times and total time lost was 17 hours. On the average, 45 percent of time was lost due to interruptions. In four out of these 10 cases, a single interruption caused a delay of 0.5 hours and in one case, two interruptions caused a one- hour delay. An interview with the pattern master supported that fact that for every single interruption, on an average 0.5 hours additional time was required to acclimatise to the new task; this could be termed as 'focus loss' or 'start up loss'.

6.4.1.4 Conclusion

In certain technical tasks such as pattern grading, Intermittent Work Interruption induced start up loss due to time required to regain concentration and style familiarisation, thus increasing overall task duration. Due to frequent changes of task, the start up loss/set up time/focus loss could increase the overall task duration by an average of 45 percent. Apart from pattern making, CAD and sample making were other areas where Intermittent Work Interruption was a regular phenomenon. Intermittent Work Interruption was found even among merchandisers and quality controllers. It was observed that while one merchandiser was preparing size 'tech pack' of one style, she was made to abandon that work half way and asked to prepare a fax reply for another style. Quality controllers measuring size sets (for dispatch by courier to a buyer) were often interrupted by merchandisers and made to attend to other pressing issues. It was argued by the factory that Intermittent Work Interruption is necessary for addressing emergent requirements and switched priorities. After brainstorming with merchandisers, quality controllers, pattern masters and managers, it was realised that concentration loss would be substantial in case of skill-based activities, but for managerial level work it was negligible. It was thus agreed that Intermittent Work Interruption for managerial and executive level personnel may be allowed. However, skill-based activities must be given a prioritised schedule and Intermittent Work Interruption avoided as far as possible. It was then decided to conduct longitudinal studies on the effect of Intermittent Work Interruption on other skill-based activities.

6.4.2 Longitudinal Study on Intermittent Work Interruption

Since focus loss/start up loss in respect of skill-based activities was expected to be substantial and had not been fully analysed earlier, it was decided to conduct longitudinal studies on effect of Intermittent Work Interruption on other skill-based activities.

6.4.2.1 Methodology

The sample company selection for longitudinal study was again to provide an illustrative profile using a representative case (section 3.5.3), therefore typical case purposive sample selection method was followed and data was collected through structured format. The manufacturing organization selected for the longitudinal study was Kirat. Silvershine Apparels was avoided to eliminate the possible wrong practices or biasness that may have been followed in Silvershine. The Pre-production activities in Kirat were observed for one week to identify the most crucial areas of Intermittent Work Interruption in skill-based activities. Two activities, namely pattern making and sampling, were selected for structured observation. Minute to minute activity in both departments was collected for three months including lunch breaks. While pattern making involved only the pattern maker (trying to assess the Intermittent Work Interruption of one person), sampling involved one sampling master-cutter and three tailors working in make through system. In the second case, Intermittent Work Interruption of one department was measured as a whole. Pattern making activity was divided into two parts; pattern making-I and pattern making-II. Time taken for pattern making-I included manual drafting to prepare the first pattern from the specification sheet for the first fit, while pattern making-II included pattern alterations (as per fit comments, if any), grading (manual), and preparing production ready patterns. After pattern making-I, the fit sample was prepared and sent for buyers' approval, which could take a couple of weeks to sometimes more than a month. During fit sample approval process, the patterns were modified a number of times based on the number of customer assessment iterations, which was an intermittent process and time was not taken for that process. Once a fit sample was approved, the patterns were finally modified, graded and duplicated for production pattern (pattern making-II).

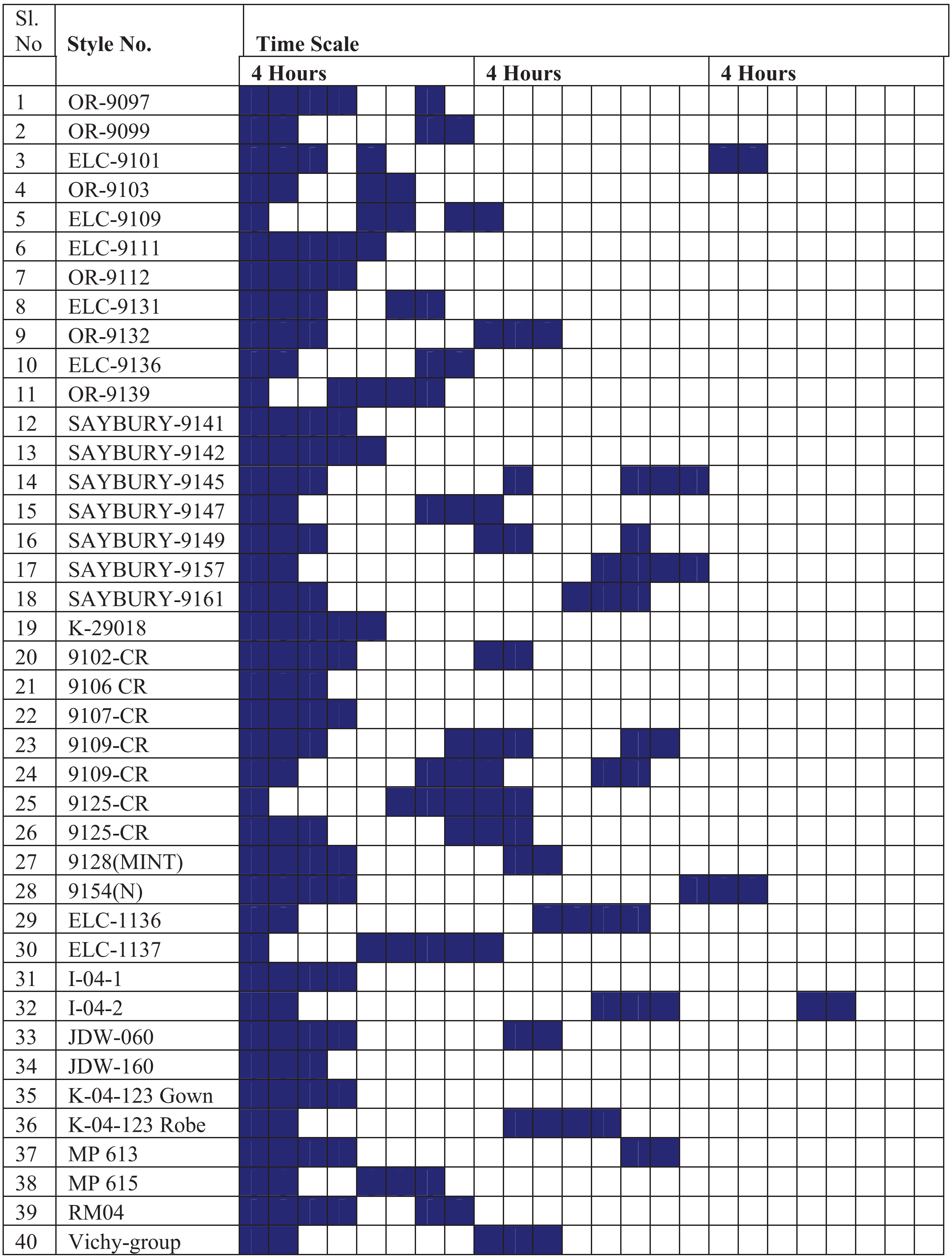
Sampling involved various activities like fabric spreading, which was generally done by the master cutter and sometimes with help from a tailor; pattern marking and fabric cutting, generally done by the master cutter. Re-cutting was generally done by the tailor himself. Selection of right accessories was generally done by the tailor in consultation with the master cutter and concerned merchandiser. For consulting with the merchandiser, the tailor had to go to the merchandising dept. and sewing was done by tailors. Generally, one style was worked upon by one tailor, but in exceptional cases one style could be worked upon by more than one tailor at a time. Based on the style, embroidery and other value additions are done either before, during or even after sewing. For embroidery and value addition, the sample had often to be sent to an outside contractor. A tailor also did the initial inspection for sewing defects and measurement variations. Sometimes the samples were inspected on a dummy for fit by the master cutter in the presence of the merchandiser. Once the sample was ready, the sample was measured according to specification by the merchandiser (while the master cutter looked on), recorded in the sample measurement sheet and declared ready for dispatch. While each pattern master was considered as one unit of pattern making resource, the sampling team consisting of the master cutter and three tailors was considered as one unit of sample making resource.

6.4.2.2 Data Collection

Forty styles were observed for pattern making-I and the same 40 styles were observed in sample making. Thirty-one styles were observed for pattern making-II. During the case study (chapter 6.4.1), it was observed that 0.5 hours was the minimum time span required to concentrate on any new work and accordingly time was taken in multiples of half hours. Fractions, if any, were rounded off to the next half hour. Data was collected style-wise for a period of 4 months and summarised in figures 6.19, 6.20, 6.21 respectively for pattern making-I, pattern making-II and sample making. Each row in the figure represents one style. One square box indicates duration of 0.5 hours. In the data collection format, pattern making was recorded for a maximum of twelve working hours and sample making was recorded for maximum 24 working hours (equivalent to three shift hours of 8 hours each). The shaded blocks indicated work in progress (either pattern making or sample making) on the style and empty blocks indicated no work in progress on the style. In the previous case study (section 5.5.1), data was collected for a given patternmaker for a given period of time, so the shaded blocks were non-overlapping. But in this longitudinal study, data was collected style-wise for a period of 4 months and the data collection sheets indicated a total of how many hours were actually worked on a style continuously, the total of breaks in continuity and total throughput time in hours taken for a style.

Data interpretation and calculations could be explained using an example. In figure 6.17, the pattern for style ELC-9109 was made in four and half hours (throughput time) with two interruptions of 1.5 and 0.5 hours in between. A total of 5 boxes were shaded; this meant effective time taken to complete the pattern was only two and half hours. From the case study it was found that, on an average, 0.5 hours time was lost for every interruption (section 5.5.1); accordingly, for style ELC-9109, there was a total of one hour (two interruptions of 0.5 hours each) of concentration loss for effective working time of 2.5 hours, which was 40 percent.

Figure 6.19 Intermittent Work Interruption in Pattern Making-I



Legend

(dark fill)	Working on the Style
(blank)	Not working on the Style

Table 6.13 Intermittent Work Interruption in Pattern Making I (Calculations)

Sl. No.	**Style No.**	Actual time (Hr.)	Time lost (Hr.)	% time lost	No. of interruptions	Duration of interruption (Hr.)	Avg. throughput (Hr.)
1	OR-9097	2.5	0.5	20.0	1	1	3.5
2	OR-9099	2	0.5	25.0	1	2	4
3	ELC-9101	3	1	33.3	2	6	9
4	OR-9103	4	0.5	12.5	1	1	3
5	ELC-9109	2.5	1	40.0	2	2	4.5
6	ELC-9111	2.5	0		0	0	2.5
7	OR-9112	2	0		0	0	2
8	ELC-9131	2.5	0.5	20.0	1	1	3.5
9	OR-9132	3	0.5	16.7	1	2.5	5.5
10	ELC-9136	4	0.5	12.5	1	2	4
11	OR-9139	2.5	0.5	20.0	1	1	3.5
12	SAYBURY-9141	2	0		0	0	2
13	SAYBURY-9142	2.5	0		0	0	2.5
14	SAYBURY-9145	3.5	1	28.6	2	4.5	8
15	SAYBURY-9147	2.5	0.5	20.0	1	2	4.5
16	SAYBURY-9149	3	1	33.3	2	4	7
17	SAYBURY-9157	3	0.5	16.7	1	5	8
18	SAYBURY-9161	3	0.5	16.7	1	4	7
19	K-29018	2.5	0		0	0	2.5
20	9102-CR	3	0.5	16.7	1	2	5
21	9106 CR	1.5	0		0	0	1.5
22	9107-CR	2	0		0	0	2
23	9109-CR	4	1	25.0	2	3.5	7.5
24	9109-CR	3.5	1	28.6	2	3.5	7
25	9125-CR	3	0.5	16.7	1	2	5
26	9125-CR	3	0.5	16.7	1	2	5
27	9128(MINT)	3	0.5	16.7	1	2.5	5.5
28	9154(N)	3.5	0.5	14.3	1	5.5	9
29	ELC-1136	3	0.5	16.7	1	4	7
30	ELC-1137	3	0.5	16.7	1	1.5	4.5
31	I-04-1	2	0		0	0	2
32	I-04-2	3.5	1	28.6	2	7	10.5
33	JDW-060	3	0.5	16.7	1	2.5	5.5

34	JDW-160	1.5	0		0	0	1.5
35	K-04-123 Gown	2	0		0	0	2
36	K-04-123 Robe	3	0.5	16.7	1	3.5	6
37	MP 613	3	0.5	16.7	1	4.5	7
38	MP 615	2.5	0.5	20.0	1	1	3.5
39	RM04	3	0.5	16.7	1	1	4
40	Vichy-group	2.5	0.5	20.0	1	3	5.5
41	Average	2.775		20.6	0.925	2.175	4.825

Data for pattern making-I was tabulated for 40 styles and for pattern making-II, 31 styles. Calculations for actual time, number of interruptions, time lost due to interruptions (leading to transient loss of concentration), percentage time lost due to loss of concentration, and actual throughput time were made. Calculations for pattern making-I is presented in table 6.13, similar calculations were done for pattern making-II and sample making and presented in table 6.14 and 6.15. The time lost due to interruptions was directly proportional to number of interruptions, not to duration of interruptions. For example style ELC 9101 has two interruptions and therefore loss of concentration is 1 hour, unaffected by the total duration of interruption, i.e. 6 hours. Two pattern masters were responsible for the task of pattern making-I and II collectively. Based on shifting priorities presented to them by the merchandisers, they would start, interrupt and complete the pattern making.

Out of 40 orders that were observed in patternmaking I, Intermittent Work Interruption was seen in 30 orders and resulted in an average of 20.6 percent loss of time. The maximum throughput time for making patterns for one particular style (I-04-2) was found to be 10.5 hours, out of which three and half hours were actual pattern making time. Average throughput time for pattern making-I was found to be 2.8 hours and for pattern making-II, 2.4 hours. Similarly, out of 31 orders that were observed in patternmaking-II, Intermittent Work Interruption was present in 22 orders and resulted in an average of 24.1 percent loss of time.

Figure 6.20 Intermittent Work Interruption in Pattern Making-II

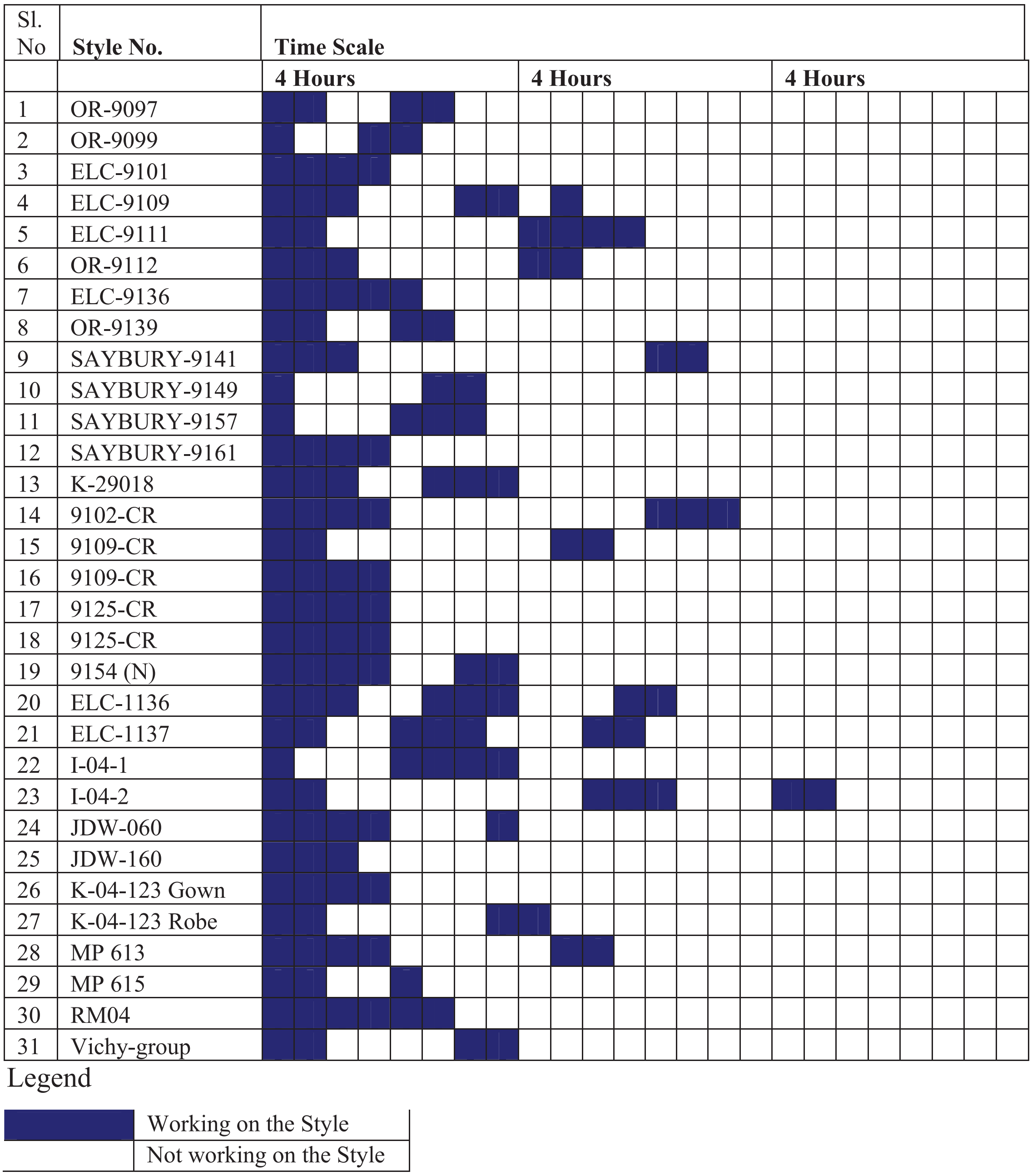
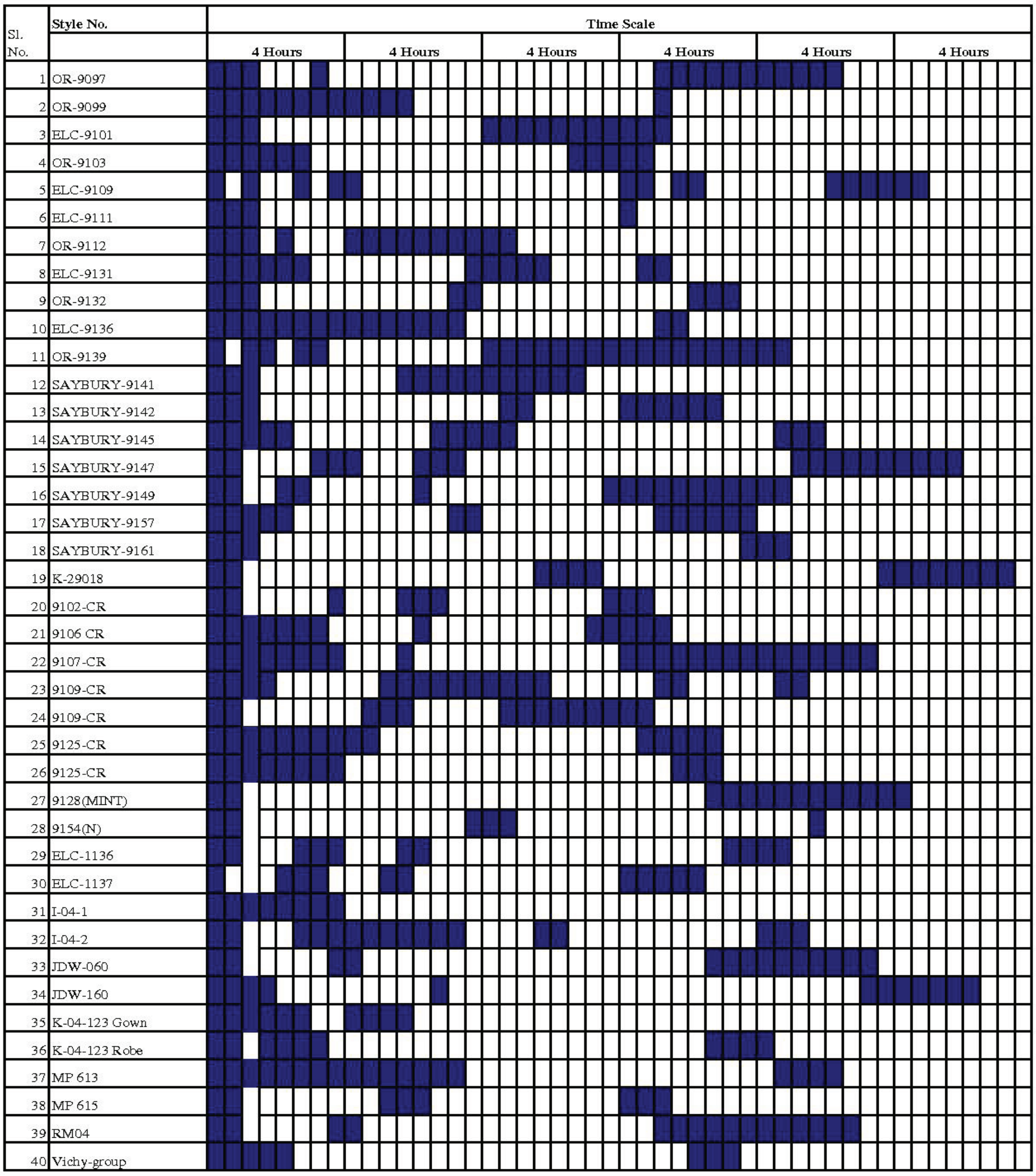


Table 6.14 Intermittent Work Interruption in Pattern Making II (Calculations)

Sl. No.	**Style No.**	Actual time (Hr.)	Time lost (Hr.)	% time lost	No. of interruptions	Duration of interruption (Hr.)	Avg. throughput (Hr.)
1	OR-9097	2	0.5	25.0	1	1	3
2	OR-9099	1.5	0.5	33.3	1	1	2.5
3	ELC-9101	2	0		0	0	2
4	ELC-9109	3	1	33.3	2	2	5
5	ELC-9111	3	0.5	16.7	1	3	6
6	OR-9112	2.5	0.5	20.0	1	2.5	5
7	ELC-9136	2.5	0		0	0	2.5
8	OR-9139	2	0.5	25.0	1	1	3
9	SAYBURY-9141	2.5	0.5	20.0	1	4.5	7
10	SAYBURY-9149	1.5	0.5	33.3	1	2	3.5
11	SAYBURY-9157	2	0.5	25.0	1	1.5	3.5
12	SAYBURY-9161	2	0		0	0	2
13	K-29018	3	0.5	16.7	1	1	4
14	9102-CR	3.5	0.5	14.3	1	4	7.5
15	9109-CR	2	0.5	25.0	1	3.5	5.5
16	9109-CR	2	0		0	0	2
17	9125-CR	2	0		0	0	2
18	9125-CR	2	0		0	0	2
19	9154 (N)	3	0.5	16.7	1	1	4
20	ELC-1136	3.5	1	28.6	2	2.5	6.5
21	ELC-1137	3.5	1	28.6	2	2.5	6
22	I-04-1	2.5	0.5	20.0	1	1.5	4
23	I-04-2	3.5	1	28.6	2	5.5	9
24	JDW-060	2.5	0.5	20.0	1	1.5	4
25	JDW-160	1.5	0		0	0	1.5
26	K-04-123 Gown	2	0		0	0	2
27	K-04-123 Robe	2	0.5	25.0	1	2.5	4.5
28	MP 613	3	0.5	16.7	1	2.5	5.5
29	MP 615	1.5	0.5	33.3	1	1	2.5
30	RM04	3	0		0	0	3
31	Vichy-group	2	0.5	25.0	1	2	4
32	Average	2.40		24.0	0.84	1.60	4.02

Figure 6.21 Intermittent Work Interruptions in Sampling



Legend

(dark fill)	Working on the Style
(blank)	Not working on the Style

Table 6.15 Intermittent Work Interruption in Sample Making (Calculations)

Sl. No.	Style No.	Actual time (Hr.)	Time lost (Hr.)	% time lost	No. of interruptions	Duration of interruption (Hr.)	Avg. throughput (Hr.)
1	OR-9097	7.5	1	13.33	2	11	18.5
2	OR-9099	6.5	0.5	7.69	1	7	13.5
3	ELC-9101	7	0.5	7.14	1	6.5	13.5
4	OR-9103	5.5	0.5	9.09	1	7.5	13
5	ELC-9109	7.5	3	40.00	6	13.5	21
6	ELC-9111	2	0.5	25.00	1	10.5	12.5
7	OR-9112	7	1	14.29	2	2	9
8	ELC-9131	6.5	1	15.38	2	6.5	13
9	OR-9132	4	1	25.00	2	11.5	15.5
10	ELC-9136	8.5	0.5	5.88	1	5	13.5
11	OR-9139	11.5	1.5	13.04	3	5.5	17
12	SAYBURY-9141	7	0.5	7.14	1	4	11
13	SAYBURY-9142	5.5	1	18.18	2	9.5	15
14	SAYBURY-9145	6.5	1	15.38	2	11.5	18
15	SAYBURY-9147	9	1.5	16.67	3	13	22
16	SAYBURY-9149	8	1.5	18.75	3	9	17
17	SAYBURY-9157	6.5	1	15.38	2	9.5	16
18	SAYBURY-9161	3	0.5	16.67	1	14	17
19	K-29018	7	1	14.29	2	16.5	23.5
20	9102-CR	9	1.5	16.67	3	4	13
21	9106 CR	6.5	1	15.38	2	7	13.5
22	9107-CR	12	1	8.33	2	7.5	19.5
23	9109-CR	9	1.5	16.67	3	8.5	17.5
24	9109-CR	7	1	14.29	2	6	13
25	9125-CR	7.5	0.5	6.67	1	7.5	15
26	9125-CR	5.5	0.5	9.09	1	9.5	15
27	9128(MINT)	7	0.5	7.14	1	13.5	20.5
28	9154(N)	3	1	33.33	2	15	18
29	ELC-1136	5.5	1.5	27.27	3	11.5	17
30	ELC-1137	5.5	1.5	27.27	3	9	14.5
31	I-04-1	4	0	0.00	0	0	4
32	I-04-2	8.5	1.5	17.65	3	9	17.5
33	JDW-060	7	1	14.29	2	12.5	19.5

34	JDW-160	6	1	16.67	2	16.5	22.5
35	K-04-123 Gown	5	0.5	10.00	1	1	6
36	K-04-123 Robe	5	1	20.00	2	11.5	16.5
37	MP 613	9.5	0.5	5.26	1	9	18.5
38	MP 615	4	1	25.00	2	9.5	13.5
39	RM04	8	1	12.50	2	11	19
40	Vichy-group	4	0.5	12.50	1	11.5	15.5
41	Average	6.61		15.36	1.93	9.10	15.71

For sample making, all activities done in-house were timed and recorded in the following table sample-wise (Figure 6.21). Anyone in the sampling team of master-tailor-merchandiser doing something (either cutting, sewing, inspecting or even selecting accessories, etc.) on the style is recorded as 'working'. Technically, it was possible to complete a sample once started, but due to some reason or another (often changed priorities and pending decisions), there were interruptions which were recorded as 'not working'. Out of 40 styles observed, only one style was completed uninterrupted. The average working time for sample making came out to be approximately 6.6 hours and time lost due to Intermittent Work Interruption in sample making found to be 15.35 percent. Average throughput time was 15.7 hours with duration of interruption 9.1 hours and number of interruptions two on an average.

6.4.2.3 Data Analysis

In pattern making-I, pattern making-II and sample making, duration of interruption was found to have a very strong positive correlation (0.98, 0.95 and 0.85 respectively) with actual throughput time. In pattern making-I and II, the number of times work was interrupted also found to have positive correlation (ranging between 0.79 to 0.76) with actual throughput time. This established the finding that pattern making throughput time was highly dependent on interruption time as well as number of interruptions. However, number of interruptions in sample making did not have a strong correlation (0.45) with actual throughput time. This indicated that loss of concentration was a serious problem in pattern making activity whereas sample making is not really affected by concentration loss.

Table 6.16 Comparison Between Pattern Making and Sample Making

	Avg. Actual time (Hrs.)	Avg. % time lost (on actual time)	Avg. No. of interruptions	Avg. Duration of interruption (Hrs.)	Avg. throughput (Hrs.)
Pattern Making I	2.78	20.61	0.93	2.18	4.83
Pattern Making II	2.40	24.05	0.84	1.60	4.02
Sample Making	6.61	15.36	1.93	9.10	15.71

The average elapsed time for pattern making-I (including interruption time) is 4.83 hours, however actual duration for same is only 2.78 hours. The potential to reduce the actual time by eliminating intermittent work interruptions is another 20.61 percent.

The reasons for interruptions in sample making were observed as:

- Merchandiser consulting with the buyer for selecting right accessories, so a decision was pending (on hold) for that style. The tailor had to perforce work on another style.
- During sewing, any confusion in specifications led to clearance pending from the merchandiser and master. The tailor had to perforce work on another style.
- Some construction method required a clarification from the master, who was busy cutting a pattern in another style, resulting in the tailor switching over to yet another style.
- Some special sewing was required to be done and that special machine (generally only one was kept in the sampling department) was being used by another tailor, resulting in the tailor switching over to another style.

6.4.2.4 Conclusion

Although the average time of actual work, number and duration of interruptions as well as average throughput time for pattern making-II were found to be higher by minimum 10 percent (number of interruptions) to maximum 30 percent (duration of interruptions) than pattern making-I, no substantial difference in pattern of work was found. Although the average throughput time for patternmaking I and II cannot be compared as the nature of work was different, the lower number and duration of interruptions may have contributed to the fact that initial pattern development from specification sheet required more/frequent clarifications due to incomplete information, lack of understanding and interpretation of specifications by the pattern master.

The reasons behind Intermittent Work Interruption in pattern making and sample making were simple changes in priorities and often, measurement clarifications. Prioritising of work was considered as the prime control parameter to minimise Intermittent Work Interruption and accordingly, a patternmaking and sampling activities priority chart was introduced in both. The list of styles for which either the first pattern was to be prepared (Pattern making- I) or the pattern was to be modified, graded or production pattern prepared (pattern making-II) was prepared in synchronicity with other activities. Daily target list was given to the individual pattern masters who were advised to adhere to the prioritised schedule.

The combined priority list of activities was to be generated after complete implementation of the multi-project Gantt chart. So the longitudinal effect of control parameters on Intermittent Work Interruption was not measured as part of the research; however, the important observations led to conclusions and recommendations to improve efficiency.

Priority charts were also introduced to the sampling section. Adherence to priority charts was possible to a great extent, but the targets were never met due to the difficulty in setting realistic targets caused by unforeseen activities. The researcher concludes that even though target setting was not possible, Intermittent Work Interruption was reduced to a great extent by adhering to the priority chart.

Chapter Seven

7.0 Conclusion

Indian clothing supply chains were studied to explore normal practice with respect to current supply chain management theory. The aim of this investigation is to identify the critical issues concerning production lead time for contract apparel manufacturing supply chain, analyse the reasons behind delay in lead time, evaluate different improvement options, and suggest easy to use rationale-driven practical solutions. The said solutions would be arrived at by analysing the reasons behind the delay in lead time, evaluating different improvement options and suggested for implementation as easy to use rationale-driven practical solutions. The solutions also include best practices backed by scientific logic and appropriate operation research principles.

7.1 Indian Apparel Supply Chain Issues

Objectives 1(*To develop a full understanding of the Indian apparel export manufacturing industry and its supply chain network)* **and 2** *(To analyse the variability of processes within the network and develop best practice methods*) were aimed at developing an understanding of the Indian supply chain networks and in particular analysing the variability of the product development and pre-production processes in the networks.

Product development, sample approval during fit and size set and management of the critical path are the most time consuming activities and need improvement. Cost of communication and late submission of samples are given negligible importance. However, concern about controlling costs was more evident than controlling time. There are three reasons behind over-emphasis on cost control: firstly, monetary conversion of time delay was not easy to calculate; secondly, traditional CMT manufacturing practice is over-dependent on cost control and thirdly, Indian apparel manufacturers are mainly involved from the post-merchandising stage onwards, where price is more important than time (section 2.7).

While it is acknowledged that more and more buyers are now looking for Indian manufacturers' ability to develop new products (section 2.3.2), a change is found necessary in the latter's mental outlook. The survey emphasised the communication problem during sourcing of material, the inordinately lengthy product development period and equally specific, the long sample approval procedure, all of which require immediate redress to be able to compete globally.

The unanimous view of industry was an in-depth evaluation of internal activities which they could influence and control. Moreover, the focus should be on identifying parameters that are controllable and on techniques that are universally applicable. Hence it was decided to investigate the product development and pre-production processes in greater depth.

Due to continuous change and unpredictable trends in fashion garments, the product development process sequence is of the non-exhaustive type, and continuously evolving. It was realised that it would be impractical to rationalise or standardise the product development process sequence. Instead, rationalisation of the number of sample approvals may be a feasible step towards rationalisation of the process, thus shortening the product development and pre-production lead time.

It was realised that the number of sample approval steps could be rationalised to three. The first is to check the look, silhouette, overall proportion of measurement and construction details, in tune with the second stage of Plumlee's six stage no-interval coherently phased product development (NICPPD) model (section 2.3.1). In the next step, the sample is checked for fit, measurement and balance (compatibility between fabric type, drape and measurements), which is in tune with the third stage of Plumlee's model. In the third step, the sample is checked for size grades, workmanship, all raw materials and accessories and proximity to the first sample, in tune with the fifth stage of Plumlee's model. While all three steps would be required for full-packaged (fully factored) manufacturing, it was found that the second and third step of sampling was generally sufficient for contract manufacturing. This outcome justified and set the scene for further research.

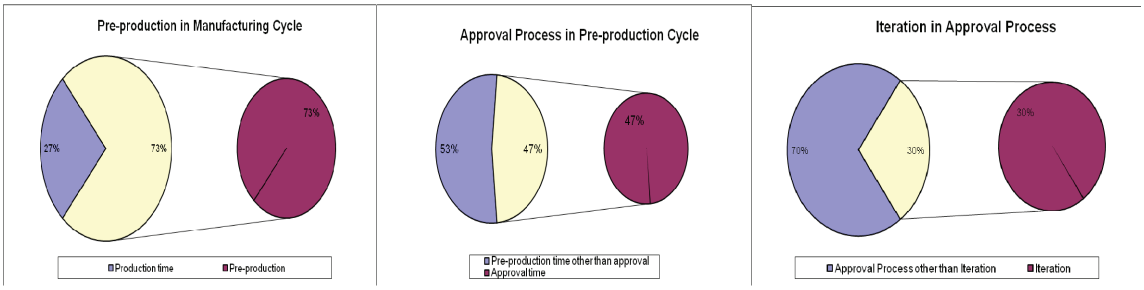
The outcome of the follow-on research can be broadly divided into two sections: firstly, improvement potential in lead time and secondly, bottleneck management of pre-production resources.

7.2 Improvement Potential in Lead Time

The third and fourth objectives were to analyse value added and non-value added delay contributing activities in the production cycle, with a view to identifying improvement opportunities.

Pre-production time took approximately three fourth of total lead time (order confirmation to delivery). Approval process takes nearly half of pre-production time and iteration, which is a subset of approval process and a non-value added activity, takes up nearly one third of approval time.

Figure 7.1 Pre-production, Approval and Iteration Process in Manufacturing Cycle



Although strong positive correlation was found between the overall process time with sub-processes, it was also obvious that different sub-processes had varying degrees of influence on the overall process time.

This analysis thus testified to the fact that 'sample making right first time' was the weakest link in the Indian apparel manufacturing supply chain and justifies (re-emphasises) the apprehension expressed on technical capability of product development (section 2.3.2).

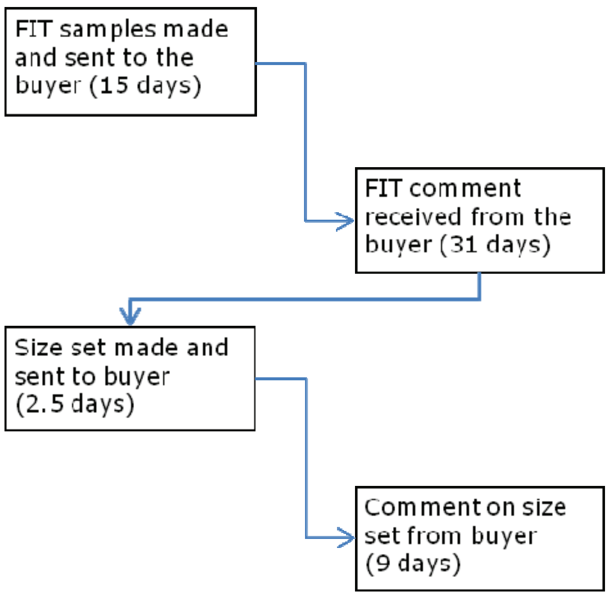
No significant correlation (0.37) between actual production time (fabric spreading till goods shipped out of factory) and total lead time suggested that change in production time had no effect on overall manufacturing lead time. However as the actual production time hardly overshoots the planned production time (section 2.7), it may be interpreted that irrespective of total lead time increase or decrease, the production time allotted remained unchanged. This phenomenon proves another apprehension correct that 'pre-production activities actually overshoot planned time, eating into planned production time' (section 2.7). The reduced production time effectively means hastened production process and leads to compromised product and process quality, a concern expressed by several experts in the literature (section 2.7).

The instances of iteration during fit sample were found more than double than the cases of iteration during size set. Fit sample making requires in-depth understanding of silhouette in context with the specification, while size set sample making merely uses the grade rule (often supplied by the buyer). This indicates either incapability of correct interpretation of the sketch and specification during patternmaking, an apprehension expressed by experts (section 2.3.2) or due to specification changes asked by buyer. Average iteration time during fit sample was also found to be significantly higher than iteration during size set sample approval. This indicates possibility of successive iteration due to repeated rejection. Secondly, this also indicates that the duration of fit sample making is probably higher than size set making. This may be attributed to the Indian pattern maker's habit of drafting patterns afresh with every changed measurement instead of manipulation of the basic block (section 2.3.2).

It was also found that approximately 40 percent of pre-production activities were externally dependent; this meant approximately 60 percent of pre-production time was dependent on internal resources that could be compressed by half through critical chain implementation. Iteration took up another 15 percent of pre-production time, which is externally dependent. As both sets of tasks were mutually exclusive, elimination of both could be beneficial. For example, elimination of iteration will reduce 15 percent of externally dependent time and critical chain implementation will result in a further 30 percent reduction (half of 60 percent) of internal activity. Therefore, overall reduction possibility in pre-production time due to elimination of iteration and implementation of critical chain totals 45 percent. It was also found that in a 100 day lead time period, pre-production consumed 73 days. 45 percent reduction of 73 percent means 33 percent reduction in overall lead time. So it could be conclusively stated that elimination of iteration and implementation of critical chain had inherent potential to reduce manufacturing lead time by one third. Frequent iteration in fit and size set sample approval corroborated the theory that *"Indian product development team is strong in fabric development, sourcing, pricing, etc….but they are very poor in knowledge of fit and pattern details"* (Malik, 2009) One third time reduction from total manufacturing cycle or 33 days reduction in absolute term would give tremendous competitive advantage to Indian manufacturer and would nearly compensate for the shipping time.

The value added and non-value added time analysis revealed an interesting aspect of a manufacturing supply chain. Every macro activity (value addition) was followed by a validation activity by the downstream player. Validation was primarily the approval process. Due to geographical distance and other logistic issues, validation activity took two to three times the original value addition.

Figure: 7.2 Sample Approval Process



For example, FIT sample making was followed by FIT sample approval by buyer. While the FIT sample making took the equivalent of 15 days[20], the approval of FIT sample took 31. Similarly size set sample making took the equivalent of 2.5 days, while the approval of the same took around nine. It is interesting to note that while the first two processes (fit sample approval) are seen in the third stage of Plumlee's model, the size set approval process is from Plumlee's fifth stage. It can thus be assumed that fit sample approval process actually spreads over into Plumlee's fourth stage and market feedback and style modification at the retail end was probably influencing delayed feedback on fit sample. Moreover, the limited weekly schedule of live model fitting at the customer's end (section 5.3.4) also increases the waiting time, attributing to the delay.

Significantly lower time for size set sample approval may be attributed to two reasons: firstly, while the fit sample was sent to a buyer in a different country, size set was approved by the buyer's representative office in India. Secondly, during fit sample approval, it is generally important for manufacturers to await the arrival of the physical sample with remarks, to be able to understand the fit comments correctly and modify accordingly. However, for size set, manufacturers may not actually await arrival of the physical sample and move into the next activity after incorporating changes based on remarks sent by fax/e-mail. It may be concluded that local or on-site expertise and authority is the key to faster response during sample approvals.

This finding also re-emphasizes the findings of the earlier study (4.3.2) where only half of the focus group felt that returning of physical sample is not necessary during size set approval. While it was already argued in the earlier study that there can be no standard practice (section 4.2.3), it can be justified that a fit sample requires market feedback at the retailer's end and therefore, need to be couriered. However the size set is actually a check of technical details like placement of accessories, grading of patterns, fitting, measurements, fabric shrinkage, etc. (section 4.3.3), therefore, the regional office of the buyer may be capable of evaluating (approving or rejecting) the same. The above finding reinforces the earlier findings that fit sample making is the bottleneck in sample approval, accounting for time lost as well as creating vulnerability to iteration.

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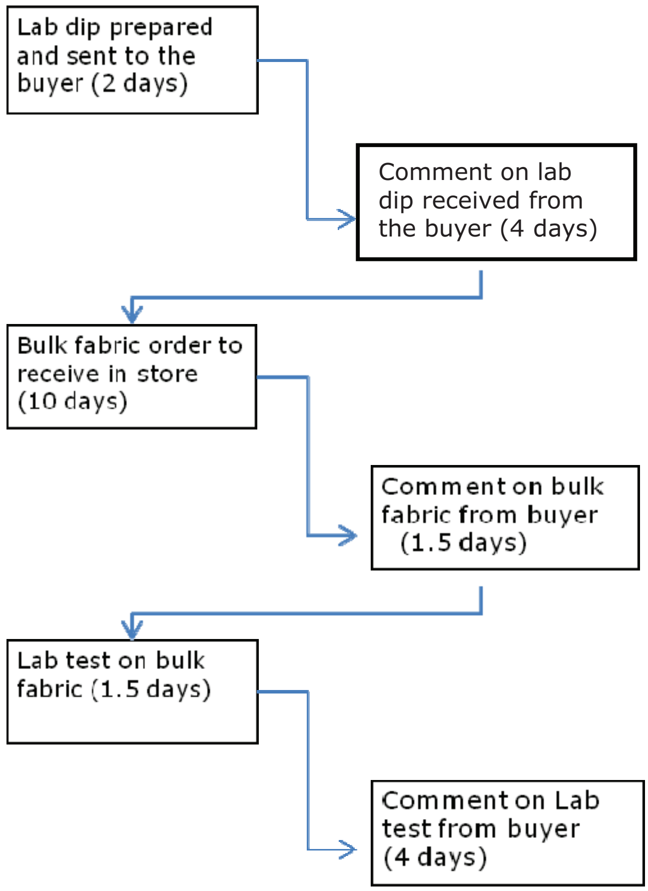
[20] The duration in minutes is by divided by 24 hours and 60 minutes to convert to 'days equivalent'

Lab dip preparation is followed by approval by buyer (or buyer's office). While the Lab dip preparation took two days equivalent[21], the approval of Lab dip took four. Similarly, the lab test on bulk fabric took 1.5 days equivalent, while the approval of lab test again took four. Only in the case of bulk fabric make and procure activity, actual value-addition time (ten days equivalence) was more than validation time (1.5 days).

Figure 7.3 Material Approval Process



It is interesting that the size set and fabric-related approvals are dealt with at the buyer's regional office in India, whereas only fit sample approval was couriered to the buyer's country. This also explains what approvals must be done by buyer abroad and which activities can be validated by the buyer's regional office. If we try to analyse all activities with relation to Plumlee's model, we see that the activities in the fourth stage of Plumlee's

[21] The duration in minutes is by divided by 8 hours (shift) and 60 minutes to convert to 'days equivalent'

development cannot be executed at the manufacturer's end. Thus the sample has to be couriered, lengthening the approval process and making it vulnerable to iteration. The remaining activities can be done at the buyer's representative office in the manufacturer's country.

Lastly, a very high positive correlation (86.35) between waiting time and actual elapsed time indicates that minimisation or elimination of waiting time would compress the manufacturing lead time. As explained in section 5.3.1, the reason behind waiting time is the traditional practice of working with a target schedule date rather following the relay race approach, where succeeding activity pulls the work from the preceding activity. As the longitudinal study revealed that transportation time was only 10 percent and approximately 51 percent of elapsed time was waiting time (which is pure non-value- added activity), it can be concluded that change of work practice to 'relay race' approach can safely minimise or even eliminate a bulk of the waiting time.

The post longitudinal study literature search on value added and non-value added time measurement in garment industry revealed some interesting insights of value stream mapping of production processes in the Indian garment industry (Agarwal 2007), (Nagar *et al.* 2008). While this research simultaneously tracked 85 pre-production activities and 18 production activities for a total of 35 orders, Agarwal's study mapped only one order for 220 activities in production processes (fabric spreading onwards) and Nagar's study covered one order for more than 243 activities, spanning from raw material store to shipment. Agarwal recorded a little over six percent as value added time while Nagar recorded a little over one percent as value added time. There was, however, a difference between both approaches in scope as well as in calculating value added and non-value added time.

7.3 Bottleneck Management of Pre-production Resources

The fifth objective of the study was *'To evaluate the applicability of different optimisation techniques to reduce lead time in the manufacturing supply chain.*

The first optimisation technique evaluated was concurrent and collaborative product development. While collaboration between partners aims to develop a product in less time (due to less iteration in the process), concurrency aims to reduce the cycle time by parallelism. It was found that concurrent and collaborative product development has the potential to reduce developmental lead time. However, concurrency and collaboration were practiced, not as a time reduction strategy, but to garner economic benefit, and time reduction was achieved as a secondary benefit. While the study concentrated on medium and small scale industries, substantial economic benefit is realised only through a large scale of operation. Therefore it was realised that the size of the order, popularity of the brand name and type of merchandise were some of the key drivers behind the concurrency and collaborative practice amongst small and medium enterprises.

The second optimisation technique evaluated was critical path/critical chain principle to reduce lead time in apparel manufacturing cycle in general and pre-production activities in particular. Even though these principles proved to be effective in lead time compression, it was found that manual implementation and execution of critical path/critical chain in manufacturing environment was difficult and non- sustainable.

While analysing the reasons it was found that making a Gantt and/or PERT chart manually or using spreadsheet was voluminous, cumbersome (time consuming), complex in nature and error-prone. A Gantt and/or PERT chart made manually or by using a spreadsheet was unable to synchronise workload distribution between a large pool of activities and common limited pools of resource executives. In the order follow up mode (while the order is actually being executed), while changes in one activity take place, the Gantt and/or PERT chart cannot incorporate concomitant changes in other activities dynamically.

The benefits that can be realised from software-based critical path/critical chain implementation was ease of preparation of Gantt chart, automatic generation of critical path thus prioritising activities, realistic workload calculation for a common pool of executives for a group of orders, and being guided in day to day order execution /order follow up by numerous alerts and reports automatically generated by the software. The resultant prioritised, planned work execution, in contrast to the fire-fighting mode will reduce uncertainties/buffers in the manufacturing cycle thus reducing lead time.

Apart from lead time reduction, the study also reflected resource allocation pattern in pre-production processes. In tune with phase three of Plumlee's model, the study revealed that manufacturing organisations generally start the product development process converting the sketches and specifications to actual samples. While the process initiation can be receipt of 'techpack' (packet containing technical specifications) and/or order confirmation, the process involved material (fabric and accessories) evaluation and sourcing to construct the prototype and fit sample development from sketches and specifications, pattern development and fit standard finalisation. The next stage of activities executed by manufacturers like preparing size set and approval of material are in tune with phase five of Plumlee's model. Phase four of Plumlee's model primarily involves marketing the line to retail channel and refinement of cost and modification of the line, which does not involve much activity at the manufacturer's end (except of salesman sample if applicable).

From the executive workload pattern (figures 6.11, 6.12 and 6.13) it was clear that during the total 10-15 week span of the manufacturing cycle, generally the workload during mid-cycle, i.e. during the sixth and seventh week, was the least. This significant gap of activities may be attributed to phase four of Plumlee's model. Activities in phase four were done by the buyer, and the manufacturer's resources were not used in this phase. This resulted in freeing up resources' workload at the manufacturer's end in a sequential chain. This relatively free period between phases three and five was reflected in all resource histograms, where workload to resources was found to be zero in the mid section of the manufacturing cycle (figures 6.8, 6.11, 6.12, 6.13). This polarisation of resources created bottlenecks, delays, overtime of resources during the beginning and end of the manufacturing cycle, whereas resources were comparatively free in the middle of the cycle.

It was also observed from the multi-project analysis that while executing a single order, the common resource team were 11 to 16 percent loaded and while executing three orders at a time, the common resource team was loaded just 23 percent. Although a simple extrapolation would mean that one team could handle 13 orders, the area of concern remained the distribution of workload along the manufacturing cycle (by staggering of delivery days). Although minimised to a certain extent in comparison to a single order scenario, the multi-project histogram also showed reduced concentration of workload during the middle weeks of the manufacturing cycle.

This workload analysis actually explains why executives are overloaded during the initial and end part of a manufacturing cycle while under-tasked during the mid-section of the manufacturing cycle. While planning multi-project Gantt chart using software tools, a careful staggering of delivery dates can be planned to ensure peak workload of one order is superimposed with lean workload of another order to balance the overall workload of executives.

The third analysis of critical chain implementation in pre-production revealed that skill-based activities in general were comparatively more prone to intermittent work interruption. While analysing the intermittent work interruption, it was found that the actual time loss in throughput was only due to loss of concentration and did not depend on the duration of interruption (as the resource was busy in another activity). However, the duration of interruption and the number of times an activity was interrupted were both found to have a very strong positive correlation with actual throughput time of pattern making activity. Average percentage loss of time due to intermittent work interruptions ranged from 15 percent for sample making to 24 percent for pattern making, which could easily be saved by prioritised workload distribution to resources.

In many instances it was found that people were habituated to multitasking even without any forced interruption. When one person did all operations except sewing, he/she generally did batch processing. For example, a Pattern Master would prepare a pattern for three styles, then cut fabric for all three styles and issue them to the sample tailor for sewing and so on. Generally, in any small to medium size company, there was more than one pattern maker, sample maker, etc. To allow flexibility in such organisations, the preferred solution could be allowing one operator to do multitasking, who would take care of pressing emergencies, while the other operators could strictly follow the prioritised schedule.

Seeking last minute extension of delivery date by Indian apparel manufacturers was a perennial problem (section 1.3). The reason behind the delay was either due to non-inclusion of holidays in the calendar (Jana & Gibson, 2005), or inability to calculate and allocate resources. The multi-order workload plan (developed using PS8 software) enabled distribution of workload on resources, pre-empted the overload on executive resources in advance and thus a decision could be taken to either work overtime or re-schedule activity dates. The resource levelling option further balanced out the peak and trough loads scientifically and automatically, thus reducing overtime of resources.

Last minute changes in product specifications (section 2.3.2) often led to a change of process, thus changing workload of resources. In a real life scenario using a manual planning method, although the bill of material was changed to meet the new specification, the resultant change of process and/or change in resource workload was never re-calculated and/or reallocated, resulting in a bottleneck of resources. The multi-order workload plan (developed using PS8 software) enabled automatic and quick re-distribution of workload on resources.

With more and more buyers looking towards India for full service supply, Indian pre-production execution needs to improve efficiency considerably while venturing into other activities like line planning and research, concept development, marketing to retail channel and line optimisation, which are currently done by retail organisation/brands themselves.

Indian small and medium apparel industry generally cater to selective seasons (section 1.3). This resulted in accepting more orders (than resources can handle) in peak season and less orders (resources remain idle) in trough season. This seasonal factor at the macro level had already been reflected during the SCM awareness study (section 4.1). At micro levels also, organisations could scientifically calculate and combine orders (using specialised software) of various lengths of manufacturing lead time and stagger delivery dates in such a way so that the distribution of workload to one common group of resources remained uniform during the entire duration of manufacturing lead time.

7.4 Reflections and Scope for Further Work

It was confirmed during primary research that the clothing supply chain was controlled by influencing retailers as previous authors have stated (Gereffi 1999 cited in Tyler et al. 2006, Drucker 1992). Different buyers had different approaches to business, different ways of doing things and also different levels of willingness to give up control and allow manufacturers to take responsibility of more functions in the value chain. (Lezama et al. 2005). In a condition where a manufacturer could be supplying to many such buyers, the role and responsibility of a contract manufacturer was limited and he was perhaps inhibited from taking new initiatives, doing something new, or adopting innovative practices. Even though the measures suggested are required to be taken at the operational level by contract manufacturers, if the mandate came from the dominant player in the supply chain, the adoption of such best practices would be faster and easier. Thus the research established that reduction of number of iterations for fit and size set (thus approval time) could be a key area for improvement or even outsourcing to third party expertise.

The improvement could be brought about by imparting training or use of innovative technology and could be a future scope of study. Innovative technology options like virtual fit, use of soft dress form and web-based fitting could be explored in future research as a means to reduce pre-production lead time in the manufacturing cycle.

The research established that there was a strong requirement of rationalisation of sample approval process to reduce it to the minimum, avoiding unnecessary repeats and waste of time and effort. The focus group discussion indicated three stages to check. First, the look, silhouette, overall proportion of measurement and construction details; in the second stage, fit and measurement; and, in the third stage, size grades and workmanship, all raw materials and accessories and proximity to the first sample. The fast fashion proponents had, interestingly, either already rationalised the sample approval process (Barnes and Gaynor Lea-Greenwood, 2006) or were aiming for it. However, future research is required towards establishing such goals conclusively.

This research demonstrated improvised techniques to measure the value added, non-value added and necessary non-value added time in detail for pre-production processes, which includes external activities. Although standardised formats are available for value stream mapping, which are suitable for measuring micro details of in-house manufacturing processes (internal activities), future study may be carried out to standardise the value stream mapping of a garment pre-production process that contains activities dependent on both internal and external resources.

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Appendices

Appendix I

Human Nature of Working in a Project Environment

In a traditional critical path concept tasks are scheduled as-soon-as-possible (ASAP) from the project start date. Every task has a published start and finish date. While this task scheduled start and finish dates seems logical, it does not promote speed-to-market driven performance. In fact, it ensures that early finishes are lost, and only late finishes accumulate in the schedule.

Goldratt doubted that while critical path may be effective in machine driven project environment, it needs subtle modification to suit human driven project scenario. In his book "Critical Chain" Goldratt (1997) exemplified and summarized human nature of working in a project environment and demonstrated a modified concept critical chain. These characteristics are:

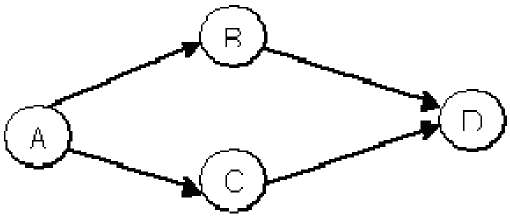
Firstly while estimating task duration, people worry about the effect of unplanned work interruptions and generally add hidden safety. A 10-day task duration may have 5 days of safety. This safety is hidden because the task is entered in the project as a 10-day task. While its perfectly reasonable to have safety factor (especially with third party activities in apparel manufacturing), but being hidden, often the purpose of safety is lost. General human nature is to put off starting of any task until the last minute, thus eating away the safety buffer in the beginning. Unfortunately, if the task then faces unplanned work interruptions then the task will overrun estimate no matter how hard one works, as there was simply not enough safety left to recover, this is referred as Student Syndrome. ***Realistic estimation of activity duration time (without any buffer) and transparent pooled buffer at important milestone and at the end of project is more realistic solution to the problem.***

Secondly work expands to fit the allotted time. If a task is estimated at 10 days, it usually doesn't take less, people will simply adjust the level of their effort to keep busy for the entire task schedule, and this phenomenon is called Parkinson's Law. **Critical path suggests all work should be scheduled as-late-as-possible.**

Thirdly while working in a multi-project environment, people tend to stop working on one task so that progress can be accomplished on another task in another project even though it comes with the penalties of reduced focus and loss of efficiency. Unwittingly resources tend to migrate between several projects in response to the latest, loudest customer demand in an attempt to keep as many customers satisfied as possible (Goldratt 1997), this phenomenon of showing progress on as many active projects as possible is called Multi-tasking. ***Critical chain suggests multitasking should be minimized and for that prioritizing of activity is pre-requisite.***

Fourthly as every task has a published start and finish date, and conventional wisdom rarely reward early finishes, people tend to meet the published dateline and never complete 'before time'. Thus crucial 'early finish' advantage of any activity is lost. Critical chain proposes ‘relay race ‘ approach, which de-emphasize the scheduled start and finish dates and rather concentrate, instead, on triggering their preparation and start on the preceding task’s progress.

Fifth, Critical Path is defined as the longest chain of tasks based upon only task dependencies and generally does not consider resource dependencies. In the enclosed four task example assignment both B and C can work concurrently as per dependencies are concerned. However if common resources are to be used for B and C, the dependency relation will change accordingly.



Picture One: Critical Path Concept

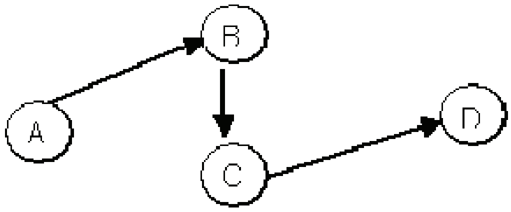


Diagram Two: Critical Chain Concept

Critical Chain is defined as the longest chain of tasks that consider both task dependencies and resource dependencies. Thus critical chain concept is bound to work more realistically in actual work environment where common resources are being used for a set of activities.

Appendix II
Indian Textile and Apparel Supply Chain

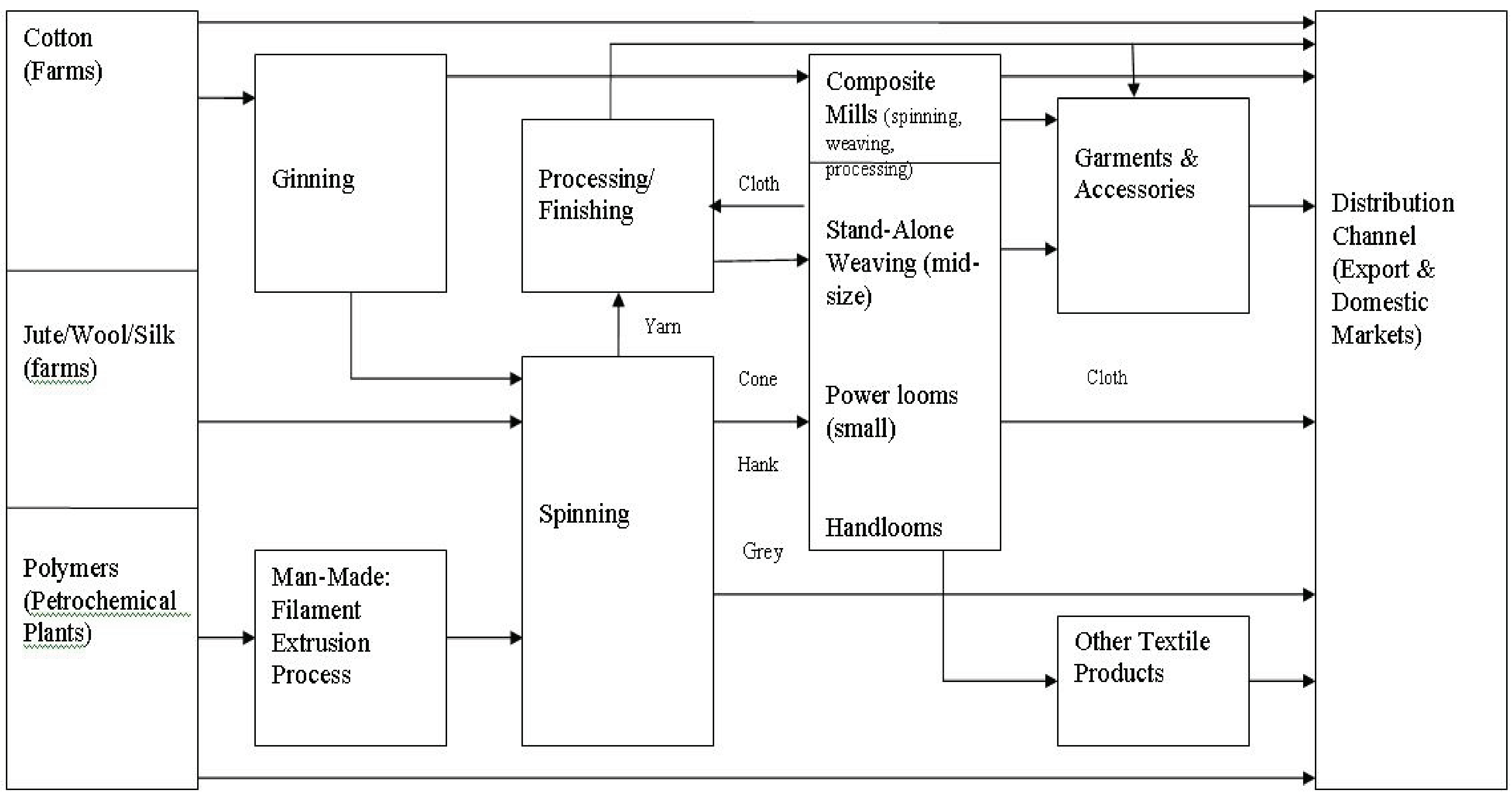


Figure 1: The Textile and Apparel Supply Chain

Appendix – III-A
Supply Chain Awareness Survey: Questionnaire

Supply Chain Management in Indian Clothing Industry: Pilot Survey (version 2000.07)

Good morning / afternoon, my name is Prabir Jana, Associate Professor at NIFT, New Delhi. This questionnaire is a part of the research work undertaken by me on “Supply Chain Management in Indian Clothing Industry”. This part of questionnaire (version 2000.07) aims to document the ***Indian Benchmark*** practices in the area of product development, pre-production planning and manufacturing functions. I would like the senior operation manager of the organisation to spare some of his valuable time answering the questionnaire, which will take approximately 45 minutes. By sharing the authentic information you will only contribute towards development of our industry.

Please do not write anything on the questionnaire, fill up the Feedback Format

ORGANISATIONAL CLASSIFICATION

In this section your organisation is being classified. Please choose the type that represents your organisation. If your organisation represents more than one type (question no. 1-3), e.g. if you are manufacturer as well as buyer, please complete separate **Feedback Format**

1. You are a
   (a) Manufacturer
   (b) Supplier
   (c) Buyer
   (d) Distributor
   (e) Retailer
   (f) Other, please specify

2. Which level of industry do you represent?
   (a) Fibre
   (b) Yarn
   (c) Fabric
   (d) Accessories
   (e) Garment
   (f) Home Textiles
   (g) Other, please specify

3. Which market segment do you serve?
   (a) Menswear
   (b) Women swear
   (c) Kids wear
   (d) Intimate apparel
   (e) Sportswear
   (f) Home textiles
   (g) Other, please specify

4. Write season wise percentage of total turnover.
   (a) Spring
   (b) Trans (season between spring and summer)
   (c) Summer
   (d) Autumn (Fall)
   (e) Trans (season between autumn and winter)
   (f) Winter
   (g) Holiday

5. What is the average no. of styles (production executed) per season?
   (a) Spring
   (b) Trans (season between spring and summer)
   (c) Summer
   (d) Autumn (Fall)
   (e) Trans (season between autumn and winter)
   (f) Winter
   (g) Holiday

6. How do you perceive the business? (tick appropriate)
   (a) Seasonal
   (b) Continuous.

7. Have you heard of Supply Chain Management (SCM)? Yes / No.
   If yes, what do you think about it? (You can tick multiple). If no, go to Q.no. 9
   (a) It is a management tool (or software solution) for reducing cost
   (b) It is a management tool (or software solution) for reducing time

(c) It is a management tool (or software solution) for improving quality
(d) It is something beyond Enterprise solutions.
(e) It is just another technical jargon

8. What do you believe sincerely? Please rank, strongly believe (5) to don't believe (0)
(a) India should be more concerned with productivity quality improvement rather SCM implementation
(b) India should understand ERP first then talk about SCM
(c) India should improve communication infrastructure first before talking about SCM
(d) In this knowledge economy software tools can't replace human being. As India has great human resource, we should not bother really.
(e) SCM is a concept, and can be implemented without computer support

9. Rank the areas where improvement (in terms of reducing time) is **required** in different categories of supply chain? Required max. improvement (5) and min. improvement (1)
[a] Product development (concept to style approval) time
[b] Approval of initial sample to approval of production sample
[c] Bulk fabric ordering to fabric received in house
[d] Cutting to packing
[e] Shipment leaving factory to buyer's warehouse

10. Rank the areas where **you think** improvement (in terms of reducing time) is **possible using modern technology** in different categories of supply chain? Max. improvement possible (5) and min. improvement possible (1)
[a] Product development (concept to style approval) time
[b] Approval of initial sample to approval of production sample
[c] Bulk fabric ordering to fabric received in house
[d] Cutting to packing
[e] Shipment leaving factory to buyer's warehouse

<u>INFORMATION FROM MANUFACTURING UNIT</u>
*In this section different statistical data of the manufacturing unit is asked**. Please write down the answer in correct units or tick the closest answer.***

11. What is the annual turnover (calculated based on factory cost of the product) of the factory?
(a) < 25 lakhs
(b) 26 - 125 lakhs
(c) 125 – 400 lakhs

(d) 400 – 800 lakhs
(e) > 800 lakhs (please specify)

12. What is the annual turnover of the factory in volume?
    (a) < 12500
    (b) 12500 – 62500
    (c) 62500 – 200000
    (d) 200000 – 400000
    (e) 400000

13. What is total Factory (Admn.+ Production floor) covered area ?

14. What is the production floor (only cutting+sewing+finishing) covered area ? (sq. mt)
    (a) Sprading & Cutting
    (b) Sewing
    (c) Finishing

15. What is actual average working hours per day (Average of best six month)?

16. What are the total numbers of operators (operators + helpers)?
    (a) < 8
    (b) 9 - 30
    (c) 31 - 80
    (d) 81 - 130
    (e) > 130 (please specify)

17. What is the annual operator (operators & helpers) turnover?
    (a) <10%
    (b) 11% - 25%
    (c) 26% - 40%
    (d) 41% - 55%
    (e) > 55%

18. What is the total number of sewing machines in your sewing floor?

19. What percentage of sewing machines are occupied (having work) during lean season (i.e. less than 80% work)

PRODUCT DEVELOPMENT AND PRE-PRODUCTION PLANNING:

20. Which are the months you work with full load (up to 80% capacity)? (tick the months)

    Jan ---Feb---Mar---Apr---May---Jun---Jul---Aug---Sep---Oct---Nov---Dec

21. What are the average no. of styles handled per month? (Calculate average of best six months)

22. What is your average throughput time? (Consider average of 20 orders in a year)

23. What is your product mix? Write top four products with % breakup and balance styles grouped into "others".

24. What is your fabric mix?
    (a) Solid dyed woven
    (b) Yard dyed woven
    (c) Printed woven
    (d) Solid dyed knits
    (e) Yard dyed knits
    (f) Printed knits

25. What is your product development (first spec to first fit sample) time? (Consider average of any 20 samples developed)

26. Average time (Consider average of any 20 samples developed) spent in each of the following stages of the product development process.
    (a) Concept received from buyer to sample fabric procured
    (b) Approval of fabric and sample order received from buyer
    (c) Exhibition sample made and shipped

27. Average time (Consider average of any 20 samples developed) spent in each of the following stages of the pre-production process.
    (a) Concept to style approval (initial sample) from buyer
    (b) Approval of initial sample to approval of technical and fit sample
    (c) Approval of technical and fit to approval of production sample
    (d) Approval of production sample to start of production.

28. What is your average sample adoption rate? No. of sampling styles get converted into production order upon total no. of sample developed, expressed in %. (Consider average of last two seasons)

29. How important are the following operational issues regarding product development? Rank most important as (5)
    (a) Communicate design electronically with the buyer
    (b) Rapid calculation of accurate costings and effects of design changes
    (c) Management of product development critical path
    (d) Ability to transfer development data to production systems
    (e) Others, please specify

30. How important are the following operational issues regarding planning? Most important as (5)
    (a) Compare actual to forecasted demand (of style) indicated by buyer
    (b) Compare actual to forecasted demand (of fabric type) indicated by buyer
    (c) Include third party capacity in calculations
    (d) Visualise future capacity requirements
    (e) Others, please specify

31. The reasons why all of the samples developed are not okayed for production. Rank maximum as (5) and minimum as (1)
    (a) Raw material in the developed sample was not as per specification
    (b) Measurement of the developed sample was not as per specification
    (c) Sample reached too late to buyer
    (d) Price point not accepted
    (e) Order quantity was too small to accept

32. From how many different accessory suppliers (total) you source your accessories?

33. Do you own the following facilities or subcontracting? Yes - No - N/A
    (a) Embroidery for bulk production
    (b) Garment washing/dying for bulk production
    (c) Textile testing facility
    (d) Garment care label making
    (e) Fabric washing (for shrinkage control)

34. Rank the pre-production activities in terms of most troublesome (5) and least (1).
    (a) Development and approval of embroidery from embroidery contractor
    (b) Development and approval of garment wash/dyed effect from outside process house

(c) Textile testing of fabrics till approved
(d) Development and approval of DTM (Dyed to Match) threads, buttons, etc.
(e) Development and approval of garment care label

35. What do you think average cost of product development (inclusive of mistakes and rework, try the break up in %)
(a) Raw material (fabric + accessories) development charges
(b) Labour charges for pattern development
(c) Communication charges (fax, e-mail, telephone etc.)
(d) Transportation & conveyance (courier, travel etc.)
(e) Other (specify)……………………………..

36. Write down details of preferred 10 accessories suppliers from India. (First column indicates no. of suppliers you have for any one type of accessory).

37. Write down details of preferred 10 accessories suppliers from abroad. (First column indicates no. of suppliers you have for any one type of accessory).

38. Why do you have multiple suppliers for same accessory?
(a) Availability of variety
(b) Not to put "all eggs in one basket"
(c) Price comparison
(d) Different quality requirement.
(e) Lead time comparison (some are quicker and some are slower)

39. Sourcing of which of these accessories you face problem? Rank them according to max.(9) and min.(1) problem.
(a) Thread
(b) Fastners (Buttons, zips, rivets etc.)
(c) Interlining
(d) Shoulder pad
(e) Cord, laces, etc.
(f) Labels
(g) Tags
(h) Polybag
(i) Carton
(j) Velcro

40. What type of problem you face while sourcing these accessories from India? Rank severest (5) to no problem (0)
   (a) Getting the right quality, i.e. specification
   (b) Getting the right quantity
   (c) Getting it DTM (Dye to Match)
   (d) Getting it in right price
   (e) Getting it in specified time

41. What type of problem you face while sourcing these accessories from abroad? Rank severest (5) to no problem (0)
   (f) Getting the right quality, i.e. specification
   (g) Getting the right quantity
   (h) Getting it DTM (Dye to Match)
   (i) Getting it in right price
   (j) Getting it in specified time

42. While sourcing accessories from India, which of the following was common? Rank as most instances (5) and least instances (1)
   (a) Communication gap between supplier's office and warehouse (as you are communicating with supplier's office whereas goods are actually delivered from supplier's warehouse)
   (b) Communication gap between you and your subordinate (store staff who actually receives the goods).
   (c) Delayed communication resulting delayed delivery of goods (as supplier's office and warehouse are at different places).
   (d) You need to communicate something visual, which was not possible through telephone (so, need to be sent through courier).
   (e) Other, specify…………

43. While sourcing accessories from abroad, which of the following was common? Rank as most occurrence (5) and least occurrence (1)
   (a) Communication gap between supplier's office and warehouse (as you are communicating with supplier's office whereas goods are actually delivered from supplier's warehouse)
   (b) Communication gap between you and your subordinate (store staff who actually receive the goods).
   (c) Delayed communication resulting delayed delivery of goods (as supplier's office and warehouse are at different places).
   (d) You need to communicate something visual, which was not possible through telephone (so, need to be sent through courier).
   (e) Others, specify…………

44. How many different fabric suppliers (total no.) do you source your fabric from?
   (a) Within India
   (b) From abroad

45. What is the annual average inventory (stock) of greige and finished fabric in terms of value and volume?

46. Write the break up (%) of different types of fabric being sourced from suppliers in India.

47. Write the break up (%) of different types of fabric being sourced from suppliers abroad.

48. Write down details of preferred 10 fabric suppliers (both India & abroad):

Thank you very much for your kind attention and patience in filling up the questionnaire. You may like to contact prabirjana@usa.net for further details.

Appendix IIIB
Supply Chain Management in Indian Clothing Industry: Pilot Survey (version 2000.07)

QUESTIONNAIRE FEEDBACK FORM

If your organisation more than one type (question number 1-3) e.g. if you are manufacturer as well as buyer, please complete separate questionnaire.

Organisation Name	
Organisation Address	
Organisation Code	
Contact Person/s	
Contact Person/s (alternate)	
Email Address (Important)	

ORGANISATIONAL CLASSIFICATION

QF-01	a		b		c		d		e		f			
QF-02	a		b		c		d		e		f		g	
QF-03	a		b		c		d		e		f		g	
QF-04	a		b		c		d		e		f		g	
QF-05	a		b		c		d		e		f		g	
QF-06	a		b											
QF-07	a		b		c		d		e					
QF-08	a		b		c		d		e					
QF-09	a		b		c		d		e					
QF-10	a		b		c		d		e					

INFORMATION FROM MANUFACTURING UNIT

QF-11	a		B		c		d		e		
QF-12	a		B		c		d		e		
QF-13	a										
QF-14	a		B		c						
QF-15	a										
QF-16	a		b		c		d		e		
QF-17	a		b		c		d		e		
QF-18	a										
QF-19	a										

INFORMATION ON PRODUCT DEVELOPMENT AND PRE-PRODUCTION PLANNING

QF-20	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

QF-21	a													
QF-22	a													
QF-23	a													
QF-24	a		b		c		d		e		f		g	
QF-25	a													
QF-26	a		b		c									
QF-27	a		b		c		d		e					
QF-28	a													
QF-29	a		b		c		d		e					
QF-30	a		b		c		d		e					
QF-31	a		b		c		d		e					
QF-32	a													
QF-33	a		b		c		d		e					
QF-34	a		b		c		d		e					
QF-35	a		b		c		d		e					

QF-36 Fill the table

No. of Supplier	Supply from (location)	Supply to (location)	Accessory type	Max. lead time (days)	Min. lead time (days)
3	Delhi	Gurgaon	Thread	21	7
			Thread		
			Button		
			Zips		
			Interlining		
			Shd. pad		
			Cord		
			Label		
			Tags		
			polybag		
			Carton		
			Others		

QF-37 Fill the table

No. of Supplier	Supply from (location)	Supply to (location)	Accessory type	Max. lead time (days)	Min. lead time (days)
			Thread		
			Button		
			Zips		
			Interlining		
			Shd. pad		
			Cord		
			Label		
			Tags		
			polybag		
			Carton		
			Others		

QF-38 a [ ] b [ ] c [ ] d [ ] e [ ]

QF-39 a [ ] b [ ] c [ ] d [ ] e [ ] f [ ] g [ ]

h [ ] i [ ] j [ ]

QF-40 a [ ] b [ ] c [ ] d [ ] e [ ]

QF-41 a [ ] b [ ] c [ ] d [ ] e [ ]

QF-42 a [ ] b [ ] c [ ] d [ ] e [ ]

QF-43 a [ ] b [ ] c [ ] d [ ] e [ ]

QF-44 a [ ] b [ ]

QF-45	Inventory	Greige Fabric	Finished Fabric
	Value		
	Meterage		

QF-46

Write the break up (%) of different types of fabric being sourced from suppliers in INDIA			
Sourcing of following fabrics	%	Max. lead time (days)	Min. lead time (days)
100% cotton greige fabric			
100% manmade (rayon, polyester etc.) greige			
Blended greige fabric			
Cotton yarn dyed stripes & plaids (plain / dobby)			
Manmade & blended yarn dyed stripes & checks			
Blended solid dyed and printed			
Cotton solid dyed and printed			
Manmade solid dyed and printed			
Cotton greige knits			
Cotton yarn dyed & jacquard knits			
Cotton printed knits			
Blended greige knits			
Blended yarn dyed & jacquard knits			
Blended printed knits			
Others			

QF-47

Write the break up (%) of different types of fabric being sourced from suppliers in ABROAD			
Sourcing of following fabrics	%	Max. lead time (days)	Min. lead time (days)
100% cotton greige fabric			
100% manmade (rayon, polyester etc.) greige fabric			
Blended greige fabric			
100% polyester finished woven fabric			
Denims			
100% polyester Knits			
100% polyester polar fleece			
Blended yarn dyed & jacquard knits			
Others			

QF-48

Write down details of preferred **Ten Fabric suppliers (both India and abroad)**					
Supplier	Supply from	Received at	Fabric type	Max. lead time (days)	Min. lead time (days)
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

Appendix IV

Brief of Organisations Participated in Pre-production Time Analysis

Kirat

Kirat is a 15 yrs old company, headquartered in Delhi, specialised in making nightwear for European and American market and having Rs. 160 million turnovers in 2003. The company has centralised merchandising division and two location of production. In the head office it has merchandising division and also has cutting and finishing facilities but subcontract the sewing capacity. The company also has an integrated manufacturing facility of 20,000 sq ft. in Haryana, around 30 km from the head office. In the integrated facility Kirat has cutting, sewing and finishing facility of 1500 garments per day. The head office has centralised merchandising department where 5 merchandisers control the total activity. The job responsibilities of merchandisers at Kirat are designated as handling different accounts. The company was strong in product development and 34% of the eventual order is from its own collection. The company participated in longitudinal study.

Uni Style Impex

Uni Style Impex (hereinafter referred as USI) is a owner driven company specialising in cut and sew knitwear catering to high value children's and ladies wear for European market. The export division has clocked Rs. 100 million turnovers in the first year of inception in 2003. The experienced staffs were having experience from erstwhile domestic enterprise with a new breed of young professionals with export manufacturing background. The company is very strong in product development and 87% of the eventual orders secured are from its own development collection. The company has 100% in house manufacturing capacity of 800 garments per day. The company participated in longitudinal study.

Gokaldas Images

Gokaldas Images (hereinafter referred as GI) is a owner driven but professionally run organization. India's one of the most respected and large manufacturing organization based in Bangalore. GI has more than 28 manufacturing facilities located around Bangalore and having turnover of $ 100 million. The dedicated manufacturing facilities make wide variety of products form shirts, trousers, ladies fashion, structured garments like suits, ski jackets and lingerie. The manufacturing location participated in the research was making ladies high fashion merchandise.

Essel Inc.

Essel is a buying agent based in Bangalore sourcing high fashion merchandise for retailers from UK and South East Asian countries. Essel is a partnership organization having turnover of $ 5 million in 2003. It was known to researcher that Essel has relatively netter system of record keeping of merchandising activities.

H&M

Liaison office for H&M Sweden sourcing high fashion merchandise. The turnover during 2003 was $ 80 million. The buying division participated in the study was sourcing from all over India. Thus collecting record will have representation from all over India. The company used to have custom built MIS software for record keeping and follow up.

V Overseas

Vishesh is a 15 yrs old company, headquartered in Delhi, makes high fashion garments and having approximately $ 8 million turnovers in 2003. The company has multiple location of production in NCR.

Misami Garments

Misami was a 10 yrs old company, headquartered in Chennai, makes high fashion garments for boys and childrens and having approximately $ 8 million turnovers in 2003. The company has multiple 4 location of production in Chennai and Bangladesh

ACC

Ambattur Clothing Company (hereinafter referred as ACC) is a owner driven but professionally run organization. India's one of the most respected and large manufacturing organization based in Chennai. ACC has more than 10 manufacturing facilities located around Chennai and having turnover of $ 100 million. The dedicated manufacturing facilities make wide variety of bottoms, trousers, men's shirts. The manufacturing location participated in the research was making men's shirt

Auric

Auric style was a 15 yrs old company, headquartered in Delhi, makes high fashion garments and having approximately $ 4 million turnovers in 2003. The company also sources garments for high fashion European buyer from several manufacturers in NCR. The company claimed to be using MS-Excel based time and action calendar

Vertex

Vertex Pvt. Limited is headquartered in NCR and have installed capacity of 48000 standard minutes per hour. Vertex Pvt. Limited has Rs. 900 million turnovers during year 2006, truly representing Indian exporter in medium to big category as explained in chapter 1.3. The company is working with multiple procurement channels; medium to big buying office, importers abroad as well as direct export. The company works with both woven and knitwear, having vertically backward integrated knitting facility while in woven category company works with domestic as well as imported fabrics. The company has 85% in-house own manufacturing and 15% out-house fabrication to balance the seasonal fluctuation. The company is headed by a dynamic and visionary leader, alumni from country's top business school. The company uses a web based ERP solution to manage its data. The young team of management are open to ideas and most importantly guided by a willing and co-operative top management. The company participated in Longitudinal study.

Appendix V Value Stream Mapping Format

Process	Date	Time	Time taken	Units	Man power/ Hands	Process symbol					NVA / VA	WASTE: Over Production	WASTE: Defects and Rework	WASTE: Motion	WASTE: Transportation	WASTE: Inventory	WASTE: Inappropriate Processing	WASTE: Waiting Time	Comments
STORES																			
Truck arrived and waiting for unloading	6-Feb	12:28:00	0:00:39			○	⇨	□	▽	**D**	NVA	○	○	○	○	○	○	●	Manpower unavailable for unloading due to Lunch Time
Unloading starts by loading into Blue Trolley	6-Feb	1:00:39	0:11:46		1	●	➡	□	▽	D	NVA	○	○	●	○	○	○	○	
Trolley full and rolls being counted by store employees	6-Feb	1:12:25	0:00:28			○	⇨	■	▽	D	NVA	○	○	○	○	○	○	●	
Trolley taken into the store	6-Feb	1:12:53	0:00:57			○	➡	□	▽	D	NVA	○	○	○	●	○	○	○	
Trolley waiting for fabric placement	6-Feb	1:13:50	0:01:31			○	⇨	□	▽	**D**	NVA	○	○	○	○	○	○	●	The rack to be used not decided beforehand hence, worker discussing with Staff
Loading of other style fabric into the rack	6-Feb	1:15:21	0:00:52			●	⇨	□	▽	D	NVA	○	○	○	○	●	○	○	
Trolley taken to another trolley with same styles filed in it.	6-Feb	1:16:13	0:00:39			○	➡	□	▽	D	NVA	○	○	○	●	○	○	○	
Unloading into the previous trolley	6-Feb	1:16:52	0:01:11			●	⇨	□	▽	D	NVA	○	○	●	○	○	○	○	
Troley taken to another rack for placing the remaining rolls	6-Feb	1:18:03	0:00:30		3	○	➡	□	▽	D	NVA	○	○	●	○	○	○	○	
Unloading to the rack starts	6-Feb	1:18:33	0:02:35			●	⇨	□	▽	D	NVA	○	○	●	○	○	○	○	Roll falls and breaks the woodden ply of a sponging troley kept below it.
Trolley moves back to the First rack	6-Feb	1:21:08	0:00:39			○	➡	□	▽	D	NVA	○	○	○	●	○	○	○	
Unloading into first rack	6-Feb	1:21:47	0:00:26			●	⇨	□	▽	D	NVA	○	○	●	○	○	○	○	
																			No trolley kept near truck for

Appendix –VI

Part-I

Activity	**style no**		**s4r 1147**		
	Buying agency		**AIE**		
	destination		**London**		
	value added time (in min)		**Actual time in days**	**Non-value added in min**	**Waiting Time in %**
	Conversion	**transportation**		**waiting**	
Buyer meeting					
Fit sample making					
a-requisition making	6				
finalised design making					
tracing design into butter paper	15				
tracing design into garment	7				
pattern making/cutting	57				
cutting of fabric	13				
Embellishments	86				
Embroidery					
Sewing	16				
Finishing	20				
Packing	2				
sending the sample to buying house		45			
TOTAL	**216**	**45**	**45**	**21339**	**99**
comments of the buyer					
sending the sample to buyer		2880			
Buyer analyse fit of the garment	15				
decision making					
sending back to the vendor		2880			
TOTAL	**15**	**5760**	**31**	**38865**	**87**
5) Size set sample making					
a-requisition making	28				
tracing design into butter paper	75				
tracing design into garment	37				
pattern grading n cutting (per piece include)	183				
cutting of fabric	67				
Embellishment/embroidery	428				

sewing of garments	80				
Finishing	94				
Packing	12				
TOTAL	**1005**	**0**	**7**	**2356**	**70**

Part - II

	value added (in min)		**Actual time in days**	**Non-value added time in min**	**Waiting Time in %**
	Conversion time	**Transportation time**		**waiting time**	
Comments of the buyer					
sending the sample to buyer		1440			
sending to buying agency					
Analysis of the fit of the garment	75				
decision making					
sending back to the vendor		1440			
TOTAL	**75**	**2880**	**9**	**10005**	**77**
Reqisition for lab dips from supplier					
Making swatch card	14				
sending to the supplier		480			
making of lab dip					
recipie making	120				
knitting samples	30				
Dyeing and finishing	300				
packing and sending to the exporter		480			
TOTAL	**464**	**960**	**5**	**976**	**41**
Comments of the buyer					
sending to buyer		1440			
Analysing the lab dips	15				
tests if required					
sending back to the vendor		1440			
TOTAL	**15**	**2880**	**12**	**2865**	**50**
Making purchase order for bulk fabric					
Costing of the fabric					
rate/lead time discussions with suppliers					
making purchase order	9				
sending to the supplier		480			

Bulk fabric manufacturing					
fabric development if required					
recipe making					
yarn dyeing (if required)					
Rewinding					
knitting	420				
dyeing (if applicable)	540				
finishing	2880				
checking	120				
packing					
sending to the exporter		480			
TOTAL	**3969**	**960**	**29**	**8991**	**65**

Part -III

	value added (in min)		**Actual time in Days**	**Non-value added time in min**	**Waiting time in %**
	Conversion time	**transportation time**		**waiting time**	
Sending bulk fabric for color approval					
making swatch card	16				
sending to the buyer/buying agency		45			
Comments of the buyer					
Analysis of colour					
tests if required					
sending back to the vendor		45			
TOTAL	**16**	**90**	**4**	**1814**	**94**
Lab test approval					
sending for lab test to testing centre		120			
Lab tests done					
sending reports back to exporter		120			
Sending the report to buyer/buying agency		45			
Analysis of the report	15				
comments send back to buyer		480			
TOTAL	**15**	**645**	**4**	**1260**	**66**
Sourcing of Trims					
making requisition for	15				

threads labels beadings					
sending to different suppliers	30				
getting back from suppliers	30			-30	
making swatch card	16				
sending the sample to buying house		45			
Approval for embroidery threads	10				
Approval for labels	5				
Approval for laces	10				
sending the sample to exporter		480			
TOTAL	**116**	**525**	**8**	**3199**	**83**

Part-IV

	value added (in min)		**Actual time in days**	**Non-value added time in min.**	**Waiting time in %**
	Conversion time	**transportation time**		**waiting time**	
Photo shoot sample making					
a-requisition making	6				
tracing design into butter paper	15				
tracing design into garment	7				
cutting of fabric	13				
Embellishment	86				
Embroidery	86				
Sewing	16				
Finishing	20				
Packing	2				
sending the sample to buying house		45			
TOTAL	**251**	**45**	**1**	**184**	**38**
cutting of fabric					
preperatory for spreading	9				
Spreading	57				
marker making (manual)	29				
Cutting	28				
Order qty	**2100**				
No of lays	18				
TOTAL	**2166**	**0**	**8**	**1674**	**44**
Embelishments					
streaching the fabric in the	1				

frame					
making design on the fabric	2				
beading work	78				
TOTAL	**170905**	**0**	**18**	**4415**	**3**
Embroidery					
hand embroidery (if applicable)					
TOTAL	**0**	**0**		**0**	
Sewing					
Sewing of garments	15				
TOTAL	**31500**	**0**	**17**	**6900**	**85**
Finishing					
thread cutting	3				
Measurement checking	4				
ironing	5				
packing n tagging	4				
TOTAL	**34335**	**0**	**16**	**813**	**11**
Packing					
Inspection					
packing into cartons	13				
TOTAL	**546**	**0**	**2**	**414**	**43**
	245609	**14790**	**216**	**39768**	**38**
None of the activities are considered in critical path	(total conversion time)	total transportation time	Actual no of days (**not in critical path**)	waiting time	% waiting time