OPTIMIZING INFORMATION FLOW TO ENHANCE DEMAND PLANNING IN SRI LANKAN APPAREL SUPPLY CHAINS: A STATISTICAL APPROACH

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Degree of Master of Science in Business Mathematics

Department of Mathematics

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Abstract

Sri Lankan apparel industry is country's main contributor to its export-led manufacturing industry while serving as an outsourcing firm to major international apparel brands all over the globe. Apparel industry earns its profits by properly allocating resources they spent on the apparel supply chain to provide their customers with quality products at the right time with the lowest cost possible. Thus, it is very important for the industry to have an accurate demand information flow at the right time to plan and allocate their recourses within their supply chain to earn profit. Therefore, the study has been carried out to develop a methodology to optimize the information flow with respect to the "time variable" to enhance the apparel demand planning. Required information has been collected through a pilot survey with industry experts and a secondary survey with 100 participants from the managerial level employees in the apparel information flow operations. Descriptive analysis, hypothesis testing, analytical hierarchy process analysis and critical path method are used to conduct the relevant inferences. Study results indicated that in order to increase the performance of the information flow to enhance demand planning, highest priority is given to the time spent on the information flow operations, second is the accuracy of the information, third and fourth are cost of the operation and reliability of the information respectively. Information flow of the selected case study is modelled using ISAP analysis and critical path method and it is analyzed using the free float and total float techniques where the developed methodology can act as a guideline to the apparel industry to enhance it demand planning process. Also, a conceptual methodology is developed using the cost slope concept to optimally use time and cost spent on the operation to find an optimal balance between the two resources

Key words: *Supply Chain, Network Analysis, Apparel Industry, AHP Analysis, Critical Path Method*

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List of Abbreviations

AHP	Analytic Hierarchy Process
CC	Crashed Cost
CD	Crash Duration
CI	Consistency Index
CPM	Critical Path Method
CR	Consistency Ratio
CS	Cost Slope
DS	Duration saved
ES	Earliest Occurrence Time
FF	Free Float
ICT	Information and Communication Technologies
LF	Latest Occurrence Time
ND	Normal Duration
PERT	Program Evaluation and Review Technique
RI	Random Index
RMG	Ready-Made Garment
SC	Supply Chain
SCM	Supply Chain Management
TF	Total Float

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CHAPTER 01

1. INTRODUCTION

Apparel Industry

The rise of globalization trend in last few decades redefined the production strategy where outsourcing prevalent among many top brands. In order to remain competitive, many corporations feel they must send some of their jobs offshore because their competitors have already done so (Shelton & Wacher, 2005). This competitive environment has led these brands to constantly look for strategies to reduce cost of operation, to have a supply chain (SC) with a shorter lead time and a high response level. It has led these brands for offshore production and on the on the other hand, product variety and quick replenishment complicates the manufacturing and distribution, because fashion industry is predominantly dealing with the products which are characterized by short product life cycles, volatile and unpredictable demand, tremendous product variety, long and inflexible supply processes, and a complex SC (Şen, 2008).

Global export of textiles and ready-made garment (RMG) exceeds US $ 300 billion per year, well over one-third of which is accounted for by developing countries. In 1980, only China, Hong Kong, South Korea, Taiwan, and USA were major global garment exporters. In the 1990s, India and Pakistan from South Asia and Malaysia, Thailand, and Indonesia from East Asia were added to this list. By the late 1990s, Bangladesh and Sri Lanka from South Asia and Philippines and Vietnam from East Asia too came into the list (Kelegama, 2004).

Apparel SC can be categorized as a buyer-driven SC. Buyer-driven chains are those in which large retailers, marketers and branded manufacturers play the pivotal roles in setting up decentralized production networks in a variety of exporting countries, typically located in developing countries (Ahsan & Azeem, 2010). In these buyers driven SCs, buyers become suppliers for retailers, and they become customers for the apparel manufacturers as well.

A brief buyer-driven apparel SC diagram is shown in Figure 1.1.

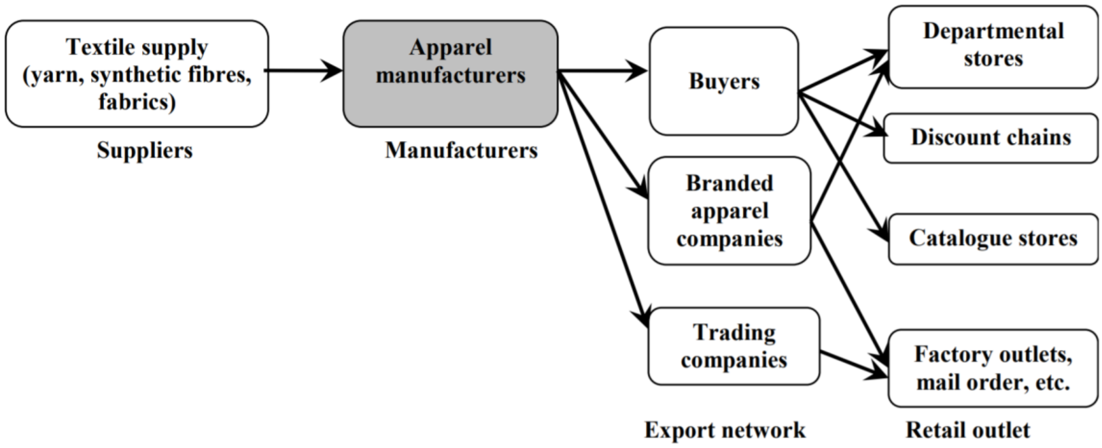


Figure 1.1 : Apparel Supply Chain

Source : (Appelbaum & Gereffi,1994)

Sri Lankan Apparel Industry

With 1977 economic reform- liberalization, Sri Lankan private sector enterprises were given the opportunity to expand their horizons into the international level. Government's newly initiated trade policy focus was to develop the Sri Lankan economy through an export-led economy rather than an economy based on import substitution.

Forty years later, Sri Lankan export industry has become a greatest strength in country's economy contributing 15.4% to the GDP in 2017. According to statistics issued by Census department, Sri Lanka's economy has grown 4.8 percent in 2015 against the 4.9 percent growth recorded in the previous year.

Sri Lanka's apparel manufacturing industry is the most significant player, representing 45.03% of country's export industry. The industry has grown over the last four decades and has become the number one foreign exchange earner and the largest single employer in the manufacturing industry (SLEDB, 2017).

Sri Lankan apparel industry consists of manufacturers and exporters of apparel under the large-scale category, as well as small & medium scale category. apparel categories like sportswear, lingerie, lounge wear, bridal wear, work wear, swimwear and children's wear, etc. are manufactured in Sri Lanka (Perera, 2016). When looking at the customer base, Sri Lankan apparel industry has built up strong relationships with internationally renowned labels like Victoria's Secret, Gap, Calvin Kleine, Liz Claiborne, Nike, Marks & Spencer and Intimissi and it is clearly visible that Sri Lanka's textiles and garment exports are concentrated in a few export markets. Catering to the quality conscious requirements, these brands are soured and manufactured in Sri Lanka. According to the Sri Lanka Export Development Board (SLEDB) website, 52% of the apparel exports are from USA, 41% of exports are from EU and the rest is exported to countries like Canada, India and Australia (SLEDB, Apparel Export Performances, 2019).

Website further states that in 2011, industry was generating more than 283,000 direct employments and 600,000 indirectly. Staring its journey as a sewing operator (contracted Manufacturer) and dependent on textile quota offered by USA and EU, currently it has transformed into a full apparel solution provider.

Major players in the Sri Lankan industry includes MAS Holdings Pvt Ltd, Brandix Lanka Ltd, Hirdaramani International Exports Pvt Ltd, Bodyline Pvt Ltd, Hela Clothing Pvt Ltd etc. Majority of these apparel manufacturing plants are situated in Western province Sri Lanka, indicating the fact that enough employment is available for those organizations. Sri Lankan apparel industry has developed reputation among its buyers (international labels mentioned in the previous section), for quality, on-time deliveries and customer service and Most important of all, reading the ethical practices practiced by the Sri Lankan industry.

With the favorable government policies attracting foreign investment and relevant facilities with special incentives for the Sri Lankan apparel sector, industry is continuously looking for strategies to enhance its performances.

Importance of Optimizing Information Flow in Sri Lankan Apparel Supply Chains

Supply Chain Management in Apparel Industry

Supply Chain (SC) can be defined as "all organizations and activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information and finance flows" (Lee, J. , 2001). All the entities of the SC are connected to each other and those entities are inter-dependent on each other to provide material, finance and information to each other to perform well as a network.

when investigating strategies to improve apparel industry performances, industry is not only aiming to deliver the product at lowest possible cost but most importantly to deliver in a shorter time which can be achieved by ensuring proper coordination among different activities This approach includes quick and on time deliveries, reducing the delay elements which are normally nonvalue-added elements and making the entire SC more efficient and agile. Thus, managing the entire pre-production, production and postproduction activities has become a crucial part in apparel SCs (K. Singh, 2015).

When looking into the apparel SC, as illustrated in Figure 1.1 as well, all the SC entities play a massive role in delivering the customer requirements equally. Special feature of the global apparel industry is that, all these entities are scattered all around the world. As mentioned earlier, Sri Lanka plays a huge part in this network being one of the world-renowned apparel manufacturers.

Along with the rapid development of technology and telecommunication, both global and Sri Lankan apparel business environments have become highly competitive. All most every stakeholder of this environment is constantly finding new strategies to gain the competitive advantage over their competitors in order to achieve the ultimate goal of increasing the overall profit. Focusing on their respective SCs and developing strategies to improve their respective Supply Chain Management (SCM) has become a popular choice among many organizations in the recent times, globally and locally (Lotfi Z., Sahran S., Mukhtar M., 2013).

The journey to enhance SC performances has become a primary focus which comprises the management of money, material gain and information throughout the SC.

Role of Information Flow in the Apparel Supply Chain

In order to increase the effectiveness and efficiency of the SC, many researches are being carried out to understand whether having a closer relationship between customer, supplier and other relevant parties can be used to achieve the above goal or not (Suhaiza Z,Premkumar R,Yudi F, 2008). Information flow of the apparel SC plays a huge role in achieving this goal, making efficient and unrestricted information flow a key player in a properly functioning apparel SC. Information flow is thus an essential element of SCM that needs to be managed properly (Badenhorst, Maurer, & Brevis-Landsberg, 2013).

Information is the major element of the decision-making process of the organization. Therefore, proper management of the information flow has a direct impact on the accurate timely decisions taken by the SC entities of the organization. Another fact to consider is that, since the apparel industry stakeholders are scattered all around the globe, researchers have identified that optimizing the information flow in the apparel SC is one of the most effective strategies which can be implemented by the industry. This fact further emphasize on how important information flow is to decision making process for apparel industry specifically for Sri Lankan apparel industry. Sri Lankan apparel industry act as an outsourcing entity for their customers overseas. Overall decisions they are taking depends on the information communicated between them and the overseas stakeholders of the organization. Information delays, discrepancies and delays in the information flow thus directly influence the decision making of the Sri Lankan apparel SC.

As mentioned by (Dimitriadis & Koh, 2005), information itself has limited value. In order to have any positive impact, it must be captured, sorted, and assimilated appropriately into the primary and support activities of the extended enterprise value chain.

Through the control of the information flow, characterize SCs appears in all suggested models of SCM and integration. It is pivotal to all other flows, as it must be effectively managed before any business activity (i.e. sales) takes place (J. Singh, 2007). With the rapid developments in the information communication technologies in the world (ICT), information sharing & co-ordination, increasing the quality and speed of responses throughout the SC can now be easily achieved.

Measuring the Performance of the Information Flow with Respect to Demand Planning

All these methodologies, frameworks and techniques which are proposed through the literature, primarily aims at increasing the performance of the overall SC. After the implementation of the selected techniques or methodologies with respect to the apparel industry, it is very important to monitor the performances in order to test whether there is a significant impact on the process after these implementations.

This study is focused on enhancing the performance of demand planning information flow. Therefore, it is important to investigate factors which affect to the efficiency of the demand planning process making it possible to develop indicators or investigate techniques to optimize the information flow. Many studies have been carried out under this study field and out of those, frequently mentioned indicators which can be applied to measure performance of demand planning information flow network are "Time, Cost and Accuracy of the information" (Badenhorst et al., 2013; Stair et al., 2012) .

This study will focus its investigations under these indicators, to further explore the performance of the network. Out of those also, "time" has been selected as the primary focus of the study as mentioned under "research objectives" section.

Impact of Optimized Information Flow on the Demand Planning

When looking into Sri Lankan apparel SCs, most of the organizations are customers of international brands. Therefore, demand planning plays a crucial part of their process because the very reason that these brands have outsourced their production to Sri Lanka is to reduce cost and to optimize their own SCs. Another interesting feature is that, although the raw material and initial production process (such as weaving and stitching) may remain the same for multiple products from the same retailers, still the manufacturer or the supplier has to start the raw material procurement and production process way before the order is received from these customers. Mismanagement of the demand information can cause huge loses to the organization. One such phenomenon is the "Bullwhip effect" (Metters, 1997).

Thus, demand planning details which are usually received from the international brands should be accurately processed through the respective SC in order to derive the expected outcome of the process. These characteristics of the apparel SC, emphasize on proper demand planning with a close collaboration throughout the chain since operations and manufacturing steps are interdependent (Mahmood & Kess, 2017).

Hence optimized information flow within the Sri Lankan apparel SC, ensures that right information is available at the right place on right time. Availability of accurate information will not only increase the performance of the decision-making process including the demand planning process, but also will reduce the cost, time and other resources allocated to operate the process as well.

Research Gap

Although many studies have been carried out with respect to enhancing Sri Lankan apparel SC performances, there are very few studies based on enhancing demand planning in the SC through an optimized information flow. There also, whatever the less amount of studies is mostly focused on proposing the most effective and accurate methods of demand forecasting.

According to Figure 1.1 as well, although there are initial suppliers and the ultimate customer for apparel manufacturers, their customers are "buyers, branded apparel companies and trading companies". Demand for the manufacturers is generated by those entities. Thus, proper communication between the Sri Lankan manufacturing plant and these overseas stakeholders, is the backbone of the apparel Sc's decision-making process. Proper demand planning in these manufacturing plants along with resource allocation and there by planning the demand they are receiving; all depends on this information flow.

There are rarely any studies, investigating the factors that affect the effective demand planning information flow in the Sri Lankan apparel industry and how this information flow can be properly maintained by ensuring an efficient, effective flow of demand information.

Since Sri Lankan apparel manufactures are outsourcing entities for the international buyers, managing the time of the overall operation is a crucial factor maintain the high-performance level of the apparel SC. Thus "proper allocation of time as a resource and managing time through the SC with respect to demand planning", can save lot of resources of the Sri Lankan apparel SC. But there are very few, almost no researches have been conducted to explore the importance of time as resource in demand planning process to improve the information flow.

There is a gap in the research area of exploring how important it is to save the time spent on the demand planning process or in the area of studying how allocate time optimally in the information flow to enhance the demand planning process.

Such a study would be in great assistance to improve the decision-making process of Sri Lankan apparel SCs and through that to enhance the apparel demand planning process. Scientific approach on enhancing the demand planning through the identification of study on how allocate "time" as a resource in the demand planning process can lead the overall SC to save a lot of time and by doing so, to save resources in the overall SC.

Considering all the above factors, study will focus on identifying the narrows down scope and research problem in this area and will attempt to find solutions for the problem in a systematic manner.

Research Problem

Sri Lankan apparel industry is a world-renowned manufacturing industry famous for its good practices, low cost labor but quality goods and services provided. As an outsourcing entity, this industry earns its profits by properly allocating resources they spent on the apparel SC to provide their customers with quality products at the right time with the lowest cost possible. Thus, it is very important for the industry to have an accurate demand information flow at the right time to plan the demand and allocate their recourses within their SC to earn profit for the industry.

As identified in the research gap section, managing time a resource with the apparel SC operations is a must for the industry to minimize the overall time taken for the decision-making process. Decision making process is dependent on the demand planning information flow. Thus, it is very important to evaluate the performance of the demand planning process in order to investigate methods to increase its performances.

Although there are many factors to assess the performance, the study will focus on “time spent on the process” and how the process can be improved by allocating time optimally. As an outsourcing industry whose focus is to provide the customer with their products as soon as possible, time plays a pivotal role in the operations of Sri Lankan apparel industry. Every second wasted is a non-value-added activity and extra cost to the overall apparel SC. Therefore, managing the time allocated to each activity of the apparel SC, is a sensitive and extremely important aspect of the apparel job roles.

While there are research studies focused on studying the market demand planning process from buyers’ perspective, there are not enough studies focused on demand panning process from the outsourcing firms’ perspective.

Considering all above-mentioned facts, research problem for the study has been identified as investigating “**how to optimize the information flow with respect to the time variable to enhance the demand planning process in apparel outsourcing manufacturers**” in Sri Lankan context.

Research Objectives

The main purpose of the study is “to investigate how time (as a resource) can be allocated optimally in the information flow of demand planning process to enhance its performances”. Although there can be many other factors which can influence the performance of the demand planning process of the apparel SC, study has limited its focus to investigate further with respect to the time variable.

Following objectives are derived in order to achieve the main purpose of this study.

- To understand the relationship between "time, cost and accuracy" as parameters to evaluate the performance of the information flow network of apparel demand planning process
- To identify methodologies to identify and model the demand planning information network
- To identify the critical activities in the demand planning process and optimizing the demand planning information flow to reduce the time of the identified critical path using CPM (Critical Path Method) technique
- To propose a conceptual model to reduce the cost of the identified demand planning information network

Significance of the Study

Sri Lankan apparel industry is the major contributor to the country's export-led manufacturing industry and development of the industry has a major impact on Sri Lankan economy.

Being a developing country, most of its organizations or companies do not have the ability to invest in big numbers to initiate various strategies to enhance the SC performances. Therefore, whatever the strategy they chose to initiate, should not be so expensive and most importantly, should give maximum impact to increase the performance of the whole SC. That is, in another words, the investment should provide the maximum output for the given input.

Findings of the study can be used as guidelines for the executives, management level employees to understand the nature of their current demand planning process better and to understand the cost/time they are spending on each transaction of the information flow network with respect to demand planning.

Not only these findings will be able to assist them in understanding the mishaps in the systems, but also will help them to understand the critical impacting factors, to have smooth information flow network which will eventually produce maximum output for the inputs they are providing.

Limitations of the Study

Studying all the aspects of the Sri Lankan apparel industry and demand planning process attached to each step of the SC network would be time consuming and financially difficult for the researcher. Also, organizations are reluctant to share in depth details about their operations due to confidential reasons. Therefore, only the major players of the apparel industry have been selected for the study and a case study has been selected to implement the developed methodology from the study.

Outline of the Study

Chapter 01 in this report is describing the background of the study, research problem identification, objectives of the study and how important is the finding of this study to the Sri Lankan Apparel industry.

Chapter 02 is presenting the results of the literature survey that has been carried out to investigate the nature of the Sri Lankan apparel industry, how the demand planning is happening in this industry and how information flow optimization strategies can be applied to enhance the demand planning process of Sri Lankan apparel manufacturers. The chapter will also provide the necessary details regarding the similar studies that has been carried out in the selected study area developing the base for the study in this report.

Chapter 03 is discussing the Research methodology that has been followed up in the study to achieve the intended research objectives. There details regarding study population, sample size, surveys that has been carried out to collect data, type of data and analyzing methods have been presented.

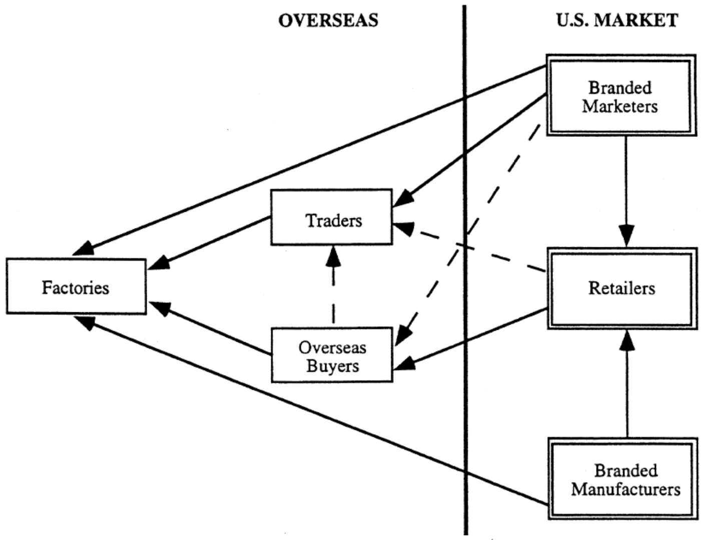
In **Chapter 04**, analysis of the collected data would be discussed in detail with the interpretation of the gathered data and the findings of the survey as well. In **Chapter 05**, based on the results in chapter 04, conclusions of the study are given with recommendations to the Sri Lankan apparel industry and about the research opportunities available in the field for future researchers.

CHAPTER 02

2. LITERATURE REVIEW

Characteristics of the Apparel Industry

The global apparel industry is identified as a buyer-driven value chain that contains three types of lead firms: retailers, marketers and branded manufacturers as illustrated in Figure 2.1. With the globalization of apparel production, competition between the leading firms in the industry has intensified as each type of lead firm has developed extensive global sourcing capabilities (G. Gereffi & Memedovic, 2003).



Notes: Solid arrows are primary relationships; dashed arrows are secondary relationships.

Figure 2.1 : Buyer-driven supply chain

Source : (G. Gereffi & Memedovic ,2013)

The apparel value chain which describe the network in detail (Figure 0.2), is organized around five main parts: raw material supply, including: natural and synthetic fibers, provision of components, such as the yarns and fabrics manufactured by textile companies, 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 (Gary Gereffi, 1999).

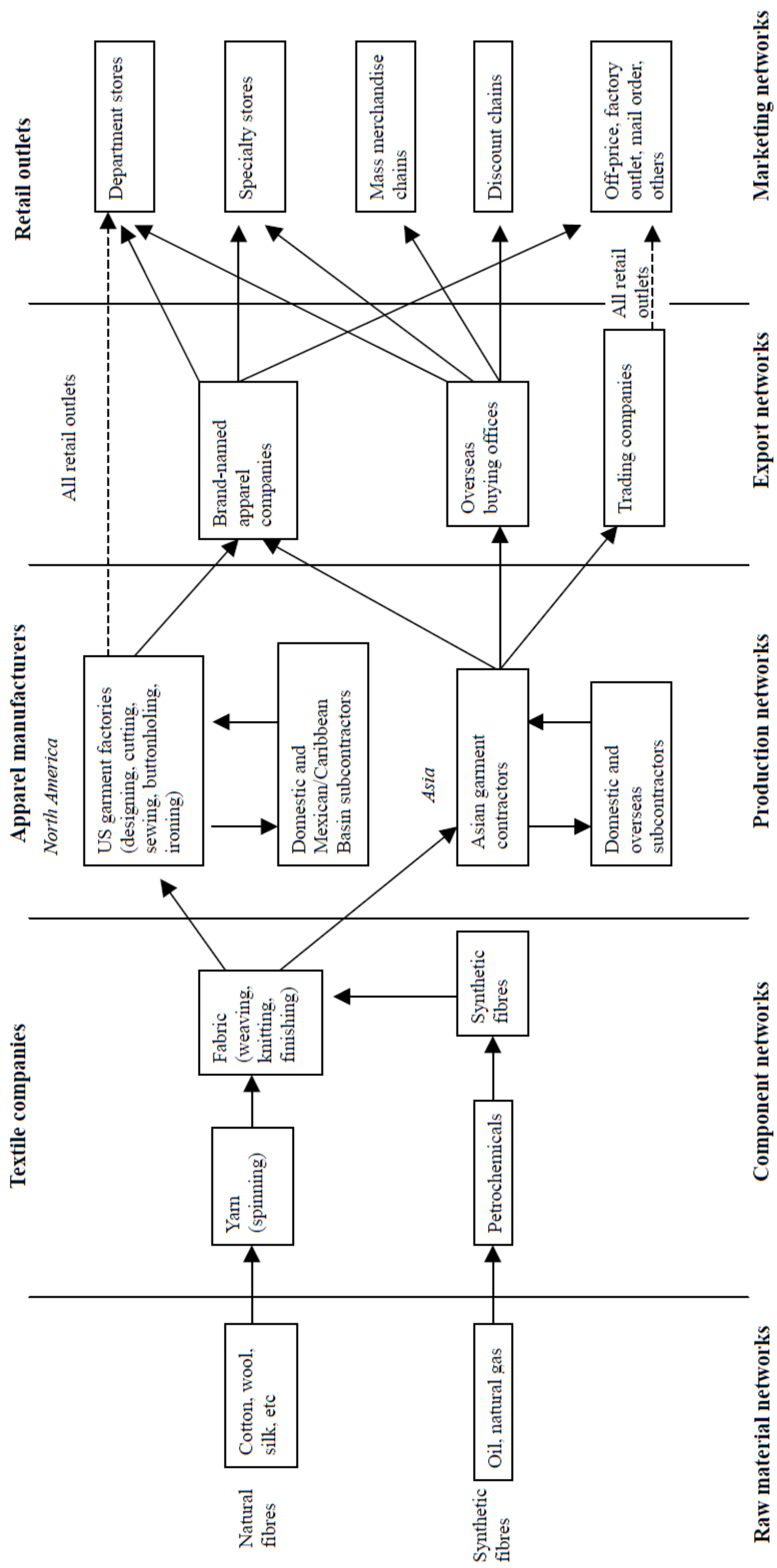


Figure 2.2 : The apparel value chain

Source : (Gary Gereffi ,1999)

As illustrated in above Figure 0.2,apparel industry is operating with a complex structure with many SC entities attached to the network and also due to the stochastic nature of demand, product diversity, and the high manpower required for production.

Because of the stochastic nature of the demand and diversity of the products within the SC network, members of the SC often experience overstock or lost sales. All these issues have led the global apparel manufactures to refer purchasing semi-finished products or finished products from low-cost countries (particularly countries with low labor costs). The already complex task of SC management in this sector becomes even more complicated when the chain stretches across the globe (Johnson, 2006).

Main reason behind this transformation, from in house production to outsourcing, is the rise of globalization trend in last few decades which has redefined production strategies where outsourcing prevalent among many top brands. Aa explained by (Şen, 2008) , price combat among the brands urges for offshore production, on the other hand product variety and quick replenishment complicates the manufacturing and distribution. This is mainly because fashion industry is predominantly dealing with the products which are characterized by short product life cycles, volatile and unpredictable demand, tremendous product variety, long & inflexible supply processes and a complex SC.

The industry specially apparel processing, consists of several activities prior to stitching task which is usually more focused when parley about the apparel product. The process of an apparel product production is quite long, and the process continues like in a pipeline. The traditional pipeline system starts with an idea about a product, often generated from a forecasted fabric or color, pushes that idea through a lengthy product development period as well as through extensive business-to-business market and production processes, and concludes with a push type sale to a final consumer (Kincade, Regan, & Gibson, 2007).

Overview of Apparel Manufacturing Operations

Since the study is focused on Sri Lankan context which expertise in the apparel manufacturing, this section will provide a brief understanding on the apparel manufacturing operation.

Apparel processing is mainly a manual type operation, and which consumes a lot of physical and time resource. From the SC point of view, apparel manufacturing is the continuation of the extensive textile processing which consists of a series of operations, including pattern, assortment, fabric handling, cutting, stitching, dry and wet processing, garment dyeing, finishing. There are many supporting operations like chemical and dyestuffs suppliers, accessories suppliers, embellishment service providers, quality testing services play a very important role in apparel manufacturing. Apparel manufacturers play an important role as they are considered as first tier supplier. Buyers often have direct communication with this tier and apparel producers' deal with the rest, e.g. second and third tier (Figure 0.2). It is not uncommon that an apparel producer sources the raw materials, components and others on behalf of buyers and as per their requirements (Mahmood & Kess, 2017).

1.2. <u>Sri Lankan Apparel industry</u>

As mentioned in earlier sections, Sri Lanka is a major apparel manufacturer for many internationally renowned brands and because of its lower labor cost, quality of the service and strong commitment to the welfare of its workers. Guided by the visionary slogan: "Garments without Guilt", ethical practices are at the root of the industry's success. With all these characteristics, "Made in Sri Lanka" label is now synonymous with quality, reliability, social & environmental accountability. Sri Lanka is the first amongst seven apparel manufacturing facilities in the world to be awarded the LEED platinum rating, setting a global benchmark for Green Apparel factories (Perera, 2016).

Sri Lankan apparel industry has shown significant steady growth over the past four decades (Figure 0.3) and it is Sri Lanka's primary foreign exchange earner accounting to 40% of the total exports and 52% of industrial products exports. This industry entirely privately owned has successfully exploited the opportunities in the international market (SLEDB, Apparel Export Performances, 2019).

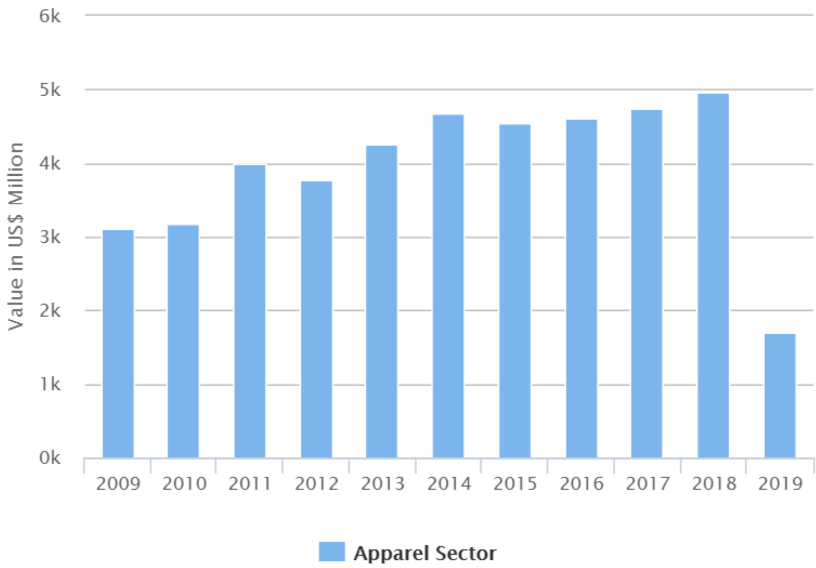


Figure 2.3 : Export performances of Sri Lankan apparel sector

Source: (SLEDB, Apparel Export Performances, 2019)

SLEDB website further emphasize on the fact Sri Lanka's top three apparel companies are already amongst the world's 50 most important suppliers, and the industry has sustained over US $3 billion in export revenue for five consecutive years. Mentioned below are the few highlights of Sri Lankan Apparel industry to indicate the crucial role played by the sector not only in developing Sri Lankan economy but also shining Sri Lanka’s name brighter in the international market as well.

- Several Indian retail brands count on sourcing from Sri Lankan factories attracting global brands to invest in Sri Lanka as an Indian Sub-Continent Hub.
- A large UK retailer watches their cost and lead-time savings grow exponentially - and it all began when they set up their regional Supply Chain Logistic Hub in Sri Lanka.
- Several European and Asian fabric suppliers, store their fabric in Sri Lanka to support fast fashion, taking advantage of fast regional shipping times and clearing in less than 24 hours.

- The USA and the United Kingdom have historically been the highest buyers of Sri Lankan apparel throughout the decades and they continue to reap the rewards of their long-time partnerships. Exports to the USA continue to soar over US$ 1 billion, and the EU contracts are worth over US$ 1.5 billion and have experienced powerful growth year on year (SLEDB, Apparel Export Performances, 2019)

Operations Within an Apparel Manufacturing Organization

As illustrated in Figure 0.2, apparel value chain is a complex network with many entities working together to fulfill the requirements of the end customer. As mentioned in the first section, Sri Lanka fit into this network of operations as an apparel manufacturer who acts as an outsourcing partner for the international brands. The study focuses on the improvements which can be implemented with these organizations. Therefore, this section will provide a brief insight about the operational procedures within these organizations to get a better understanding on the stakeholders and operational entities.

Within an apparel manufacturing organization, there are various departments which oversee sourcing, raw materials, manufacturing and finally exporting the manufactured goods to the respective customer. Figure 2.4 gives a general overview of these departments flow in a typical apparel manufacturing organization.

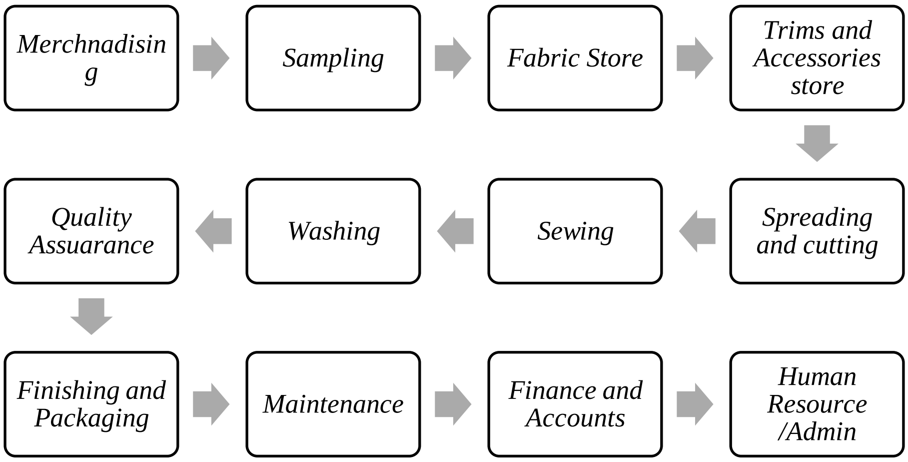


Figure 2.4 : Department flow of an apparel manufacturing organization

Source: (Clothing Industry, 2019)

According to (Clothing Industry, 2019), every department of the organization including the supporting departments like Finance and HR is responsible for the final outcome of the manufacturing organization.

Functions of the Different Departments in Apparel Industry

Mentioned below are the brief descriptions of each department in the organization (Nayak & Padhye, 2015; Rathinamoorthy & Surjit, 2015).

- ***Merchandising Department:*** Involves planning, developing, executing and dispatching the order (product) to the buyer.
  - Marketing merchandising - development of product, costing and ordering, and it has direct contact with the buyer
  - Product merchandising - carried out in the respective apparel unit and involves all the responsibilities starting from sourcing to finishing
- ***Sampling Department:*** Coordinates with the merchandising and production department. It is carried out to foresee finished product appearance and fit when produced in bulk and to confirm whether there are any inconsistencies in the pattern according to the buyer's specification.
- ***Fabric Sourcing Department:*** Engaged in deciding where and how the fabrics have to be procured. It works in conjunction with the merchandising department and looks after the delivery of the required garments within the scheduled time and cost.
- ***Fabric Inspection Department:*** Identifies and analyses fabric defects using various standard methods.
- ***Accessory Stores Department:*** Receipt of the raw materials or the accessories is normally completed in terms of documents that are received from the merchants.
- ***Production Planning Department:*** Upon receipt of the orders from the merchants, preproduction meetings with the departments must be done. After that, the production department will assign the style to the specific line that has the capacity to complete it on time. The planning section then carries out the estimation and planning of order quantity, plan cut date (PCD), breakup of order, operation breakdown, etc. Based on the respective unit.

- ***Laboratory Department:*** Testing of fabric and accessories. If the facility for specific tests mentioned by the buyer is not available in the industry, it should be sent to external laboratories that are authorized by the buyers.
- ***Machine Maintenance:*** Breakdown and preventive maintenance is mainly aimed toward reducing the downtime and increasing lifetime, respectively.
- ***Designing Department:*** Normally, large-scale garment industries have their own designing department for various garment styles which usually in charge of determining cutting average for costing**,** making the most efficient cutting marker**,** development and alteration of patterns**,** and development of size set pattern by grading
- ***Cutting Section:*** Receives the order from the production manager who has approved the cutting order to cut a given quantity of garment styles.
- ***Production Department:*** Sends a request from the cutting section for the cut parts. After assembling of the components, a line check has to be done where the shade matching, and the measurements are checked.
- ***Fabric Washing Section:*** After the completion of assembling and inspection process, the garments are sent to the washing department for the washing or finishing that is required for the respective style according to the specification sheet.
- ***Quality Assurance Department:*** To maintain and control the quality, the quality assurance department divides the work into different stages of manufacturing, which are categorized into three major groups such as preproduction unit, cutting audit and sewing unit.
- ***Finishing Department:*** Last section in the garment production prior to packing and dispatch and it plays a significant role in the final garment appearance. It involves trimming (removes the extra threads from the garment at the stitched areas), inspection**,** pressing, tagging section and Packing.

Improving the Performance of Sri Lankan Apparel Supply Chain

Along with the rapid development of technology and telecommunication, both global and Sri Lankan apparel business environment has become highly competitive and all most every stakeholder of this environment is constantly finding new strategies to gain the competitive advantage over their competitors in order to achieve the ultimate goal of increasing the overall profit.

Focusing on their respective SCs and developing strategies to improve SC management has become a popular choice among many organizations globally and locally in the recent times (Lotfi Z., Sahran S., Mukhtar M., 2013). Supply chain can be defined as all organizations and activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flows (Lee, J. , 2001). This journey to enhancing SC performances has become a primary focus which reflected the management of flows of money, material gain and information throughout the SC.

According to (Indraratna, 2017), in the report “State of the Economy” he mentions that,” although there has been declining earnings from exports as a percentage of GDP, partly due to weak external demand, the internal factors that have contributed to the continuation of such a trend cannot be ignored. Sri Lanka needs to identify products and services or their components in the value chain for which Sri Lanka has a competitive edge, resurrect the manufacturing sector, attract Foreign Direct Investments and explore new trade channels”.

In his report (Indraratna, 2017) emphasize that “there is a crucial need for Sri Lanka to develop and expand the manufacturing sector as the sector has underperformed for a prolonged period of time in both local and global markets. The manufacturing sector can contribute greatly to expedite inclusive growth. An appropriate manufacturing sector development policy will be helpful to coordinate and implement necessary strategies to develop this sector”.

With the rapidly developing technology and telecommunication, many apparel organizations in the world and in Sri Lanka (Ding, Chen, & Lyu, 2011; Lee & Oh, 2012; Yu, 2012) have identified Supply Chain Management (SCM) as a critical approach in enhancing overall performances and improving the capabilities its SC. Unlike earlier times, firms do not seek to compete with its industry in isolation of their suppliers and other entities of the SC. Seeing the benefit of building up developing a collaboration relationship between the entities of its SC and beyond their organization, the concept of SCM has been gradually developing since 1980s (Rhonda R L, Robert J V, 1999) .

According to (ISU, 2010), major challenge exists in any SC which is a network of nodes or locations, is to keep the coordination between these nodes focused into one common objective or in other words to develop this network into a system which is working towards a common set of objectives.

In order to be effective, firms must recognize that SCM issues are cross functional in nature. In addition, SCM requires information sharing and coordination. Therefore, information systems and metrics that focus on performance across the entire SC are needed. As evidenced by Figure 2.4, coordination and properly functioning information flow is critical for an apparel SC to optimize its performances in order to fulfill its customer requirements.

Hence flow of information, is one of the flows that characterize SCs and appears in all suggested models of SCM and integration. It is the most important one because it precedes all other flows, as it must be effectively managed before any business activity takes place (Singh, 1996). Hence, when comparing with other available flows in the SC, information is adding a significance importance to managing other flows in the chain especially with the emergence of the new information and communication technologies (ICT). ICT can enhance information sharing and co-ordination, and increase the quality and speed of responses throughout the manufacturing SC(Dimitriadis N I, Koh S C L , 2005).

The study focuses on using information flow optimization strategies in order to enhance Sri Lankan apparel SCs because improvements in the industry can be resulted in positive impact on Sri Lankan economy improving the quality of exports and increasing the foreign exchange to the country as well.

Importance of Information Flow in Apparel Supply Chains

In any SC, proper functioning of SCM strategies requires continuous decision making in five major areas. Those are production, inventory, location, transportation and information by each of the supply chain members individually and collectively (Hugos, 2018). Collective decisions made under these areas will decide the capabilities and effectiveness of the entire apparel SC.

There also as mentioned above, information is critical to apparel SC as it is a main requirement for the SC to coordinate daily activities, relating to the functioning and planning of the other four key areas. All the information collected within each entity of the has to flow efficiently between the functions of an organization and between the member firms of the supply chain (Hugos, 2018). However according to (Tyrinopoulos, 2004), efficient information flow, accuracy, reliability and comprehensiveness are directly associated with effective interoperability between various supply chain partners handling and using this information. Achieving interoperability means faster information flow, and an effective decision-making process. The inability of transferring information correctly, to where and when it is required, will have an impact on the decision making in the four key areas and therefore on the performance of the entire supply chain (Badenhorst et al., 2013).

For an industry like apparel where the SC entities are scattered all around the globe, properly functioning information flow is a must because it affects productivity and innovation of the organization as information flow determines the speed by which individuals can act and plan future activities (Wu, Huberman, Adamic, & Tyler, 2004).

Best approach to emphasize on the importance of properly functioning information flow is the concept of "Bullwhip Effect". It refers to the phenomenon where order variability increases as the orders move upstream in the supply chain. Limited information sharing increases the difficulty of reducing the bullwhip effect and leads to inefficient supply chain management (Li, 2013). The bullwhip-effect is a direct consequence of a lack of real-time information sharing and efficient information flow through the entire supply chain (Badenhorst et al., 2013).

Information Flow Optimization Strategies in Sri Lankan Apparel Supply Chains

There are many studies that are focused on (Mason-Jones & Towill, 2002; Tibin, Yingjin, Yong, & Xianglan, 2012; Vanpoucke, Boyer, & Vereecke, 2009) increasing the efficiency and effectiveness of the SC which requires a lot of time and large capital investments. These studies include implementation of new Enterprise Resource Planning (ERP) software, trainings for its work force etc.

Sri Lanka being a developing country with limited resources available, its export industry does not possess the ability to invest in various strategies to improve the performance of their respective SC. Thus, whatever the limited number of strategies executed by the organizations, must have the ability to make an impact on the whole SC. In other words, whatever the methodology they follow up, that should give the maximum output for all most every member of the SC. Thus, it can be expressed that information flow optimizing strategies are more suitable to enhance the SC performances of the export led manufacturing.

This study is focused on optimizing the information flow to enhance performances of the functions within the apparel SC, by making suitable changes to the direction of the information flow and understanding the parameters which measure the performances of the information flow network. In other words, rather than investing a huge amount of capital, study is trying to propose a methodology to enhance SC performances by adjusting the flow of information through the most suitable nodes in the network.

Demand Planning Process and Sri Lankan Apparel Supply Chains

From the literature review which has been conducted regarding the Sri Lankan apparel SC, it is evident that this buyer-driven SC network's planning, resource allocation and organizational goals are established in order to achieve the demand values set by their customer – international apparel brands. Although the ultimate customer of the overall SC is the end customer who buys the apparel products, for Sri Lankan apparel manufactures, their customer are these branded apparel companies (Figure 0.2).

Therefore, author has selected to explore the area of "enhancing demand planning in these SCs using information flow optimization techniques", through a suitable statistical approach in this study.

Demand planning in Sri Lankan Apparel Industry

With the objective of satisfying the ever-changing customer requirements, apparel companies have moved away from mass production. These companies which used to produce standardized styles that did not change frequently due to restrictions set by factories they now started to find ways to constantly provide unique and refreshing products. This strategic decision has resulted in the increase of seasons, indicating the time which fashion products are sold and increased competition between the companies (Bhardwaj & Fairhurst, 2010) .

As a result, apparel industry products now possess extremely short life cycles, highly unpredictable demand and long lead times due to which both sell-outs as well as overstock of merchandise caused by supply-demand mismatches are common and at the same time extremely costly (Nenni, Giustiniano, & Pirolo, 2013).

Therefore, proper flow of accurate demand information is vital to maintain an effective and efficient apparel SC.

Although there are many studies focused on finding the most effective an accurate methods of demand forecasting(Fonseka et al., 2003; Kamath & Jadhwani, 2009), there has not been much studies conducted on the importance of maintaining a proper flow of demand planning information. As mentioned in Chapter 01, this study is focused on enhancing the demand planning in the apparel SC by investigating statistical approaches that can be taken to optimize the information flow.

Demand Planning

The terms demand planning and demand forecasting which are often used as substitutes although a clear distinction can be made between the two terms. Planning seeks an answer what the future should look like while forecasting focuses on what the future situation will actually look like. Planners can use different forecasting methods to predict the outcome of their plans and if the outcome is not satisfactory, they can revise their plans (Armstrong, 2001). According to (Stock & Lambert, 2007), "Proper control of materials management requires forward planning whereas forward planning, in turn requires good forecasts" indicating the close correlation between the two concepts.

Another study which has been conducted with respect to the demand management in apparel industry states that the retailer or brand owner, as the buying entity, is powerful and influences the structure, relationships and operational practices across the network. Since most apparel brands rely on other partners for an important part of their value system, shortening the SC requires increased fine-tuning with these partners (Jacobs, 2006).

(Hilletofth, Ericsson, & Christopher, 2009) shows that SC demand planning process is about developing synergies between the demand creation and the demand fulfilment processes which comprise all the activities necessary for creating demand and is closely linked to the marketing discipline, whilst the demand fulfilment processes comprise all the activities necessary for fulfilling demand and is closely linked to SCM.

Figure 2.5 (Mahmood & Kess, 2017), illustrates the SC network with respect to the demand information flow. With respect to the study, "supply side" is the apparel manufacturing company which ensures the product flow within the SC according to the demand information given by the brand- "Demand side". De Treville et al. (2004) mention that demand integration is another approach to ensure the properly coordinated information flow, which includes increased access to demand information throughout the SC to permit rapid and efficient delivery, coordinated planning, and improved logistics communication.

In order to improve the reliability of the process, it is a must that demand information flow network should be looking at reducing the unreliability of both information acquisition and information processing. All these entities should work together to deliver the final outcome and it is very important that the demand planning information is processing through the chain accurately, with right information is at the right time with the right person to deliver the right product.

Thus, it is evident that, in order to develop a properly functioning demand planning process within the SC, all the entities in the SC should buildup the trust and proper coordination with respect to information sharing, between each entity.

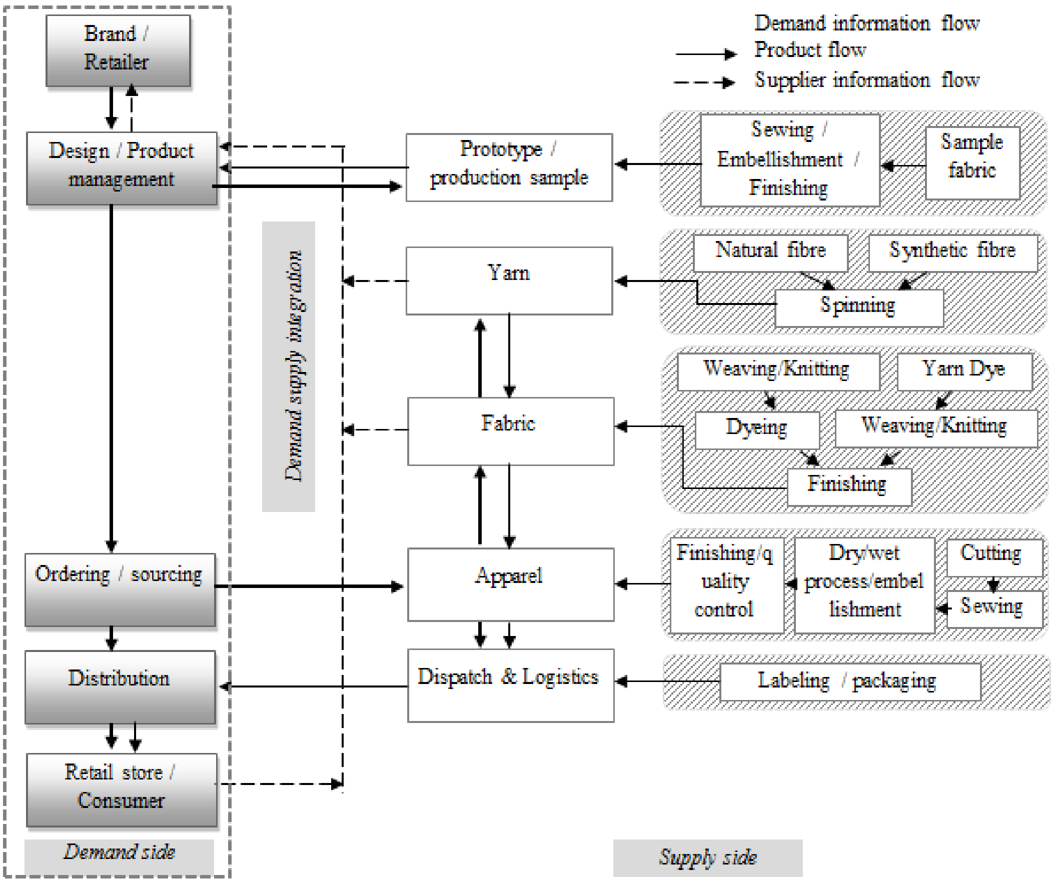


Figure 2.5: Apparel demand information network

Source : (Mahmood & Kess, 2017)

Measuring the Performance of the Demand Planning Information Network

All these literatures have proven how pivotal it is to have a properly functioning information flow and including the selected focus of the study which is demand planning information flow. Along with implementation of these strategies to enhance performances, it is essential to monitor these strategies, process and their outcomes in order to continue with an efficient SC. Many definitions can be given regarding the term "Efficiency" but under this study efficiency is described as "performing an activity correctly, referring to the economic utilization of resources" (Mahidhar, 2005).

In other words it is very important to measure the performances of the demand planning apparel information flow, to have an accurate understanding about the overall demand planning process performances, not only for the top management of these apparel organizations but for all the stakeholders of these organizations as well.

Information that is transferred between two humans is subject to certain conditions. Based on these conditions the efficiency of information transfer does not only depend on the speed of the transfer itself, but also on other factors as well (Badenhorst et al., 2013).

There are many studies which has been carried out to identify the indicators and measurements for information flow efficiency and (Stair et al., 2012) is one such study which describes characteristics that are applicable to information systems and information quality. Following mentioned are the characteristics from the study which is suitable to the scope of this study: to measure the information flow.

- Timely information is delivered when it is needed
- Information accuracy, provides error-free information
- Complete information, contains all important facts
- Flexible information can be used for a variety of purposes
- Reliable information can be depended on
- Relevant information is important to decision making
- Information is verifiable
- Information is accessible

After a through literature survey (Badenhorst et al., 2013) suggest flowing mentioned characteristics are most suitable to measure the performance of the information flow.

- Timeliness
- Accuracy
- Relevance
- Repeatability
- Responsiveness
- Interpretability
- Acceptability
- Comprehensiveness
- Usefulness
- Believability
- Consistency
- Accessibility
- Security

Since the focus of the study is measuring the demand planning information flow, appropriate indicators for demand information flow measurements can be selected out of the factors mentioned above, using relevant tools and techniques like “one to one interview with the apparel industry express”.

Statistical Approaches to Optimize the Information Flow in Demand Planning

Many researchers have attempted to find methods, strategies to optimize the information flow in order to minimize the cost of transaction or to maximize the overall output.

Important finding of one of these studies is that "better the design of the supply chain operations, the better the service level the customers will experience" since most any discrepancy in the supply chain network framework may result in extra cost or non-value adding activity to the overall SC (Bhardwaj & Fairhurst, 2010). This strategy has the potential to be applied to the problem discussed by the study because information network can also be resigned in order to deliver the expected outcome which is delivering the accurate demand data in order to enhance the apparel demand

Another approach is modeling the information flow of the system. This has become organize and coordinate processes, eliminate redundant processes, minimize the duplication of information and manage the sharing of intra- and inter organizational information (Durugbo, Tiwari, & Alcock, 2013). The study also claims that modelling is also required to understand organizational processes. This is mainly because it assists analysts to effectively communicate complex design issues (Hansen et al., 1978) and a better understanding of organizational processes is vital to assessing the performance of an organization.

One such method of modelling is LINQ which defines flows of information as information transformations done with support from actions and in support to actions. That is, Actions create Information which supports Actions which create Information and so on, which supports a flow of information from source to business outcome. This flow of information is enabled by People performing Actions; by Systems being used by People to perform Actions; by Systems automating Actions; and by Systems providing Information. Together, information, actions, people, and systems are the basic building blocks defining the LINQ information flows (Thuan, Swann, Chiu, & Antunes, 2017).

This study presents the methodology of LINQ which provides an analysis to examine contexts and identify the main building blocks according the basic model. It starts with all available documentation describing the context. It then analyses the texts for identifying the main building blocks of LINQ. The analysis is best performed by coloring appropriate texts in the documents. The colors include green for Information; orange for Actions, blue for Systems, and violet for People. This analysis is named IASP (Hoang Thuan, Anh Tri, Swann, & Hoa, 2019; Thuan et al., 2017).

Matinrad, Roghanian, & Rasi, (2013) have surveyed many studies that has been carried out in this field and according to them, if various stages of different chains cooperate with each other, "supply chain network" (SCN) can be developed and in order to achieve the highest level of performance in SCN optimization techniques are needed. Another example for this phenomena is presented by Yu, (2012) where he has presented this by a model which allows for the determination of the optimal multiproduct fashion flows associated with the supply chain network activities. This model discusses about enhancing the fashion/apparel SCM through cost and time minimization from a network perspective.

One other important aspect of optimizing the demand planning information flow is that investigating the most critical factors which are considered by the decision makers of the apparel SC when they are transferring or receiving the demand planning data to the respective stakeholders of their SC network. In most of the cases, industries like apparel have implemented complex supply chain information systems with their network. Evaluating the effectiveness has become difficult because of the same complexity level and the dynamic nature of the industry (Yin & Zhu, 2010).

According to (T. L. Saaty, 2002) , among many tools and techniques suggested by the scholars on the field, Analytic Hierarchy Process, (AHP) can be used as a strong technique to solve the evaluation problem considering the perspectives, experiences of the survey participants. Since apparel industry is majorly functioning with the experiences of its employees (who are involved with demand planning information flow) AHP can be used to determine what are the critical factors considered when it comes to measuring the performance of the demand planning information flow and to make decisions regarding the network by calculating the level of importance given to each criteria by the stakeholders of the network.

Another statistical technique which can be applied in the field is, Critical Path Method (CPM) technique to find the critical path of operations with respect to the apparel information flow. . One such successful example is the study proposing a methodology to analyze merchandising activities in Sri Lankan apparel supply chain with the application of Critical Path Method (CPM) and find out the critical path of merchandising processes, which influences the production startup time significantly; subsequently, crushing the merchandising activities to minimize the lead-time taken from order confirmation to planned start date (T Gnanavinthan, S A D Senanayake, T Mathiventhan & Anusooya, n.d.) .

Another technique which can be used to analyze the information flow network is Program Evaluation and Review Technique (PERT). PERT is designed to analyze and represent the tasks involved in completing a given project. It was developed to simplify the planning and scheduling of large and complex projects. PERT is concerned with the time needed to complete each task, and the minimum time needed to complete the total project and it incorporates uncertainty to schedule a project while not knowing precisely the details and durations of all the activities. PERT is a sophisticated method of project planning and control and developed based on a network portrayal of the activities that make up the project (Howard, 2009a).

Considering all above-mentioned strategies and methodologies, study is intended to propose a statistical methodology to be followed by the Sri Lankan apparel industry in order to enhance their demand planning process.

CHAPTER 03

3. METHODOLOGY

Introduction

The study has been designed to investigate the nature of demand planning process of the Sri Lankan apparel industry and its information flow network, to identify the issues and critical factors which are affecting to the proper flow of information in the demand planning process and finally to apply the developed statistical procedure to the selected case study to identify the most efficient path of information flow

Research Design

Figure 0.1 below, illustrates the step by step procedure followed up through the study to achieve the above-mentioned objectives. Once the study has been finalized for the research, thorough background study has been carried out with respect to the Sri Lankan apparel industry and selected study area referring to the industry reports and the academic literature as well. Then following up with the steps mentioned in the Figure 0.1, research design has been developed to achieve the developed research objectives through the appropriate statistical methods.

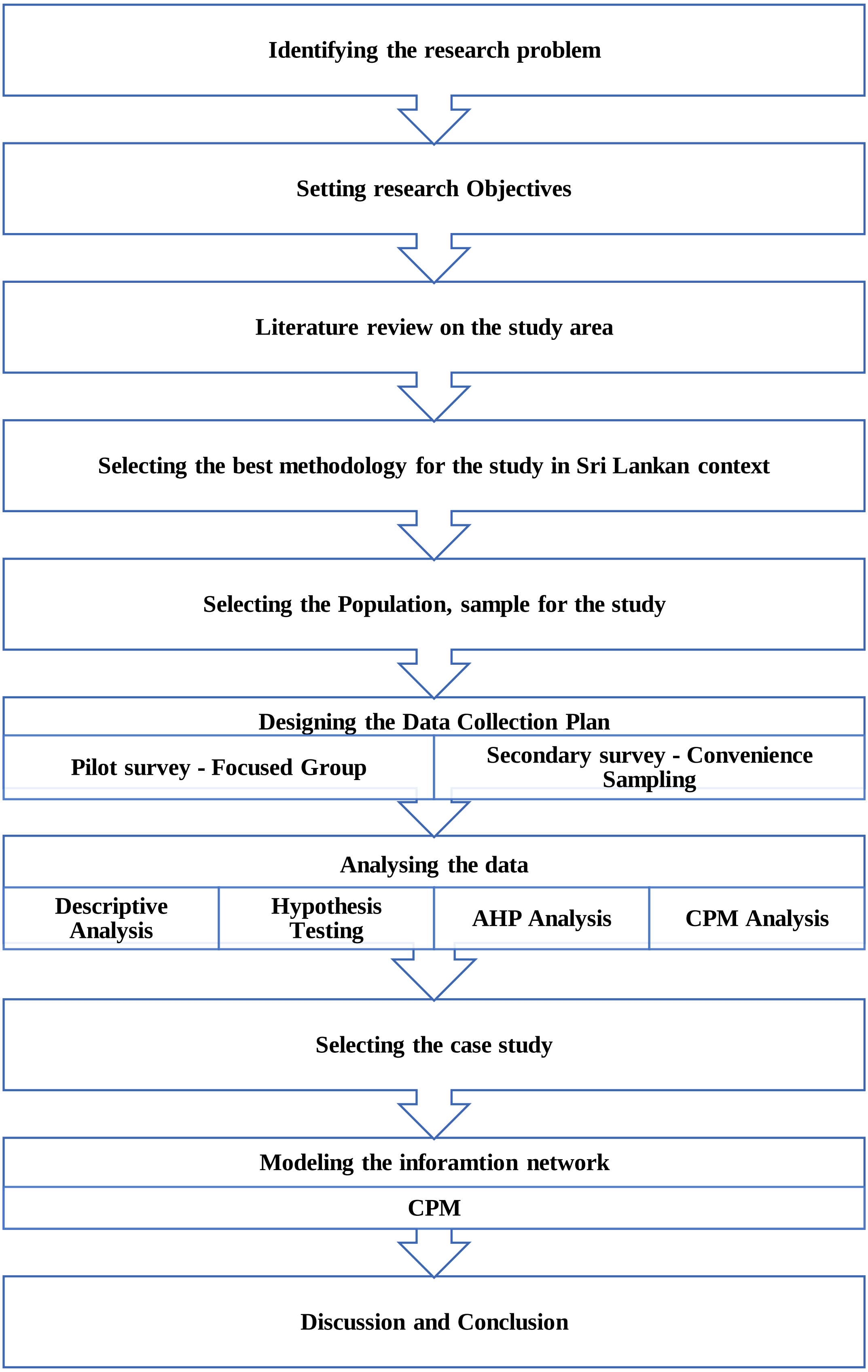


Figure 3.1 : Research design

Population and Sample Design for the Study

Two surveys have been planned under the study, pilot survey and the secondary survey. Thus, two populations have been defined for these surveys.

- Pilot Survey:
  - Objectives of the survey is to get a proper understanding on the nature of Sri Lankan apparel industry, its demand planning process, the overall nature of the apparel SC and how crucial it is to optimize the information flow to enhance demand planning in Sri Lankan apparel supply chains
  - Sample was selected from the top management employees of Sri Lankan apparel industry including the responsible personnel of the apparel manufacturing process and the apparel supply side as well to conduct the survey using snowball sampling technique. focused group interviews were conducted to collect the respective data.
- Secondary Survey
  - With the inputs taken from the pilot survey and the literature survey, AHP method was selected as the best technique to get the perspective of employees who are directly involved with the demand planning information flow.
  - Population has been selected as the "***Employees at managerial positions in major apparel organizations in Sri Lanka who are dealing with the operations of demand planning information flow"***.
  - Considering the objectives of the survey, ***convenience sampling*** has been selected as the sampling technique. Main reason behind the selection is that, study focus most on the employees who are dealing with demand planning information on a regular basis and those employees are working with the headquarters of these apparel organizations generally. Other than that, major players in the field have been selected because those organizations are well connected to all the stakeholders of the apparel SC from international level customers to both local and international suppliers & distributors.

Determining the Sample Size

Sample size for the secondary survey in which the perception of the managerial level employees in the apparel industry is collected, has been calculated using Cochran's Sample Size Formula.

The formula (mentioned below) allows the researcher to calculate the most appropriate sample size for the study at a desired level of precision, desired confidence level, and the estimated proportion of the attribute present in the population.

$$\text{Sample size } (n) = \frac{Z^2 \times \sigma \times (1-\sigma)}{e^2}$$

$Z =$ Desired confidence level
$e =$ Desired level of precision
$\sigma =$Estimated proportion of the attribute present in the population

Estimating, 95% confidence level, .5 proportion, and a margin of error (confidence interval) of +/- 5% sample size has been calculated as mentioned below.

$$\text{Sample size } (n) = \frac{0.95^2 \times 0.5 \times (1-0.5)}{0.05^2} = 385$$

Given the time & financial constraints for the study and confidential nature of the industry, it is difficult for the researcher to include 385 participants to the survey.

AHP is a multi-criteria decision-making tool and studies have suggested that minimum sample size include from 3 to 20 times the number of variables and absolute ranges from 100 to over 1,000 (Daniel J M, Dale G S, Tian L K, 2009).

(Mandeville & Roscoe, 1971) suggest that in multivariate research (including regression analyses) the sample size should be several times (preferable 10 times or more) as large as the number of variables in the study. In this study only 04 criteria and 03 sub criteria are to be tested under AHP analysis and according to (Mandeville & Roscoe, 1971) minimum sample size for the study would be 70.

Furthermore, sample is selected from the employees who are working in the head office or design headquarters of major Sri Lankan apparel organizations making it the best group of people to give the overall idea about the industry.

Therefore, considering the literature inputs and the financial, time and regulatory constraints from the selected company, sample size has been decided as 100 to conduct the survey based on AHP analysis.

Developing the Questionnaire

Questionnaire (Appendix A) for the study has been developed to capture the operational details about apparel information flow supply chain with respect to the demand planning also to capture the employees' point of view about evaluating the performance of the information flow network to transport demand planning data.

First part of the questionnaire focuses on investigating about the nature of the operations employees perform with respect to demand planning information flow in their respective SC. Second part of the questionnaire is based on the AHP based questions which focuses on the critical factors affecting the performance of the demand planning information flow of the apparel supply chain. It also focuses on how these critical factors impact on receiving, processing and issuing demand planning information to their respective stakeholders.

Data Analysis Methods

As mentioned in the , data for the study is being collected under 03 (three) surveys. With the Pilot survey, industry experts are being interviewed to get an overall idea about the demand planning process and the nature of the industry with respect to demand planning information flow and enhancing its performances through. The results of these interviews will serve as the basis for the secondary survey and for the case study as well.

Data which is to be collected from the secondary survey (Appendix A) will be analyzed under following mentioned methods.

Descriptive Data Analysis

All the data that has been collected under each question will be analyzed here to get a brief introductory knowledge on how the industry is behaving , what are the activities in the apparel supply chain which is affected by effective information sharing to improve demand planning, what are the widely used tools that are being use for information etc..

Hypothesis Testing

As the second step, using hypothesis testing it will be tested whether effective information flow will have a significant impact on the demand planning process and also is there any significant relationship between the critical factors which can be used to measure the demand information flow and the different entities/ departments of the apparel SC.

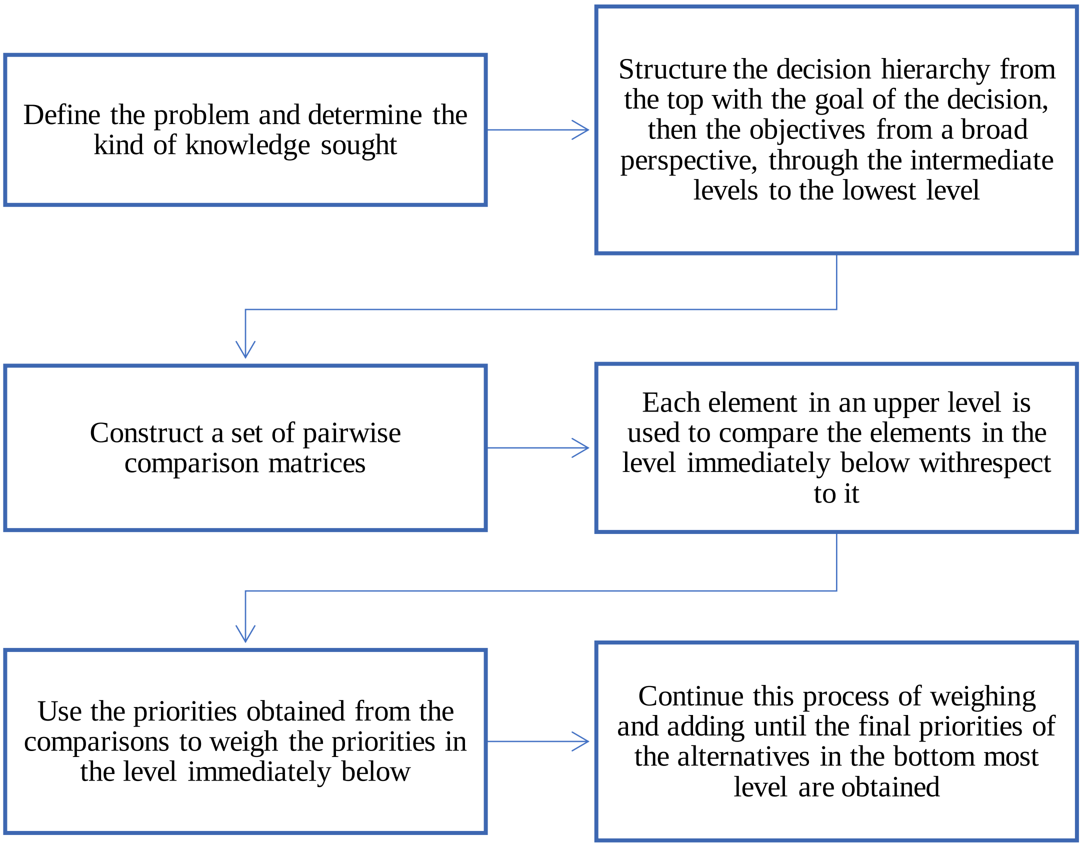
Analytical Hierarchy Process (AHP)

Main intention of this analysis is to investigate the relationship between the parameters/ indicators which can be used to evaluate the performance of the demand information flow of the apparel SC. Using AHP analysis relationship between 04 factors to be tested. out of those 04, 03 factors are derived from literature (time, accuracy and cost) and pilot survey results three parameters the other factor "reliability" is derived through pilot survey conducted with top management and industry experts.

Apart from investigating the relationship between these indicators, importance of each factor with respect to receiving, processing and issuing demand planning information is also examined using the same AHP hierarchy structure.

Analytical Hierarchy Process (AHP) analysis method, originate from the marketing sector, invented by Thomas Saaty in the late 1970s. it is one of the most widely used multi-criteria decision-making method which aims at mathematically modeling the decision-making processes and then used to solve complex problems using the collected data under this model (T.L. Saaty, 1980) .

According to (T. L. Saaty, 2002), in order to derive the organized decision making process under AHP, following steps (Figure 0.2) has to be followed up in order to decompose the major problem that the study has identified.



In the introduction chapter (Chapter 01) in the report, research problem and the

Figure 3.2 : AHP process

Source: (T. L. Saaty, 2002)

objectives are mentioned thus completing the step 01 which is "***Defining the problem***".

Building the Structure of The Hierarchy

Second step of the AHP process is to "***develop the AHP Hierarchy***" where it decomposes the decision problem at different levels of hierarchy. The first level describes the aim of the decision making and explained in further detail at a lower level using sub-criteria. If there is a need to evaluate alternative options with respect to the main criteria and sub-criteria, last level contains possible alternatives with their characteristics (Schmidt, Babac, Pauer, Damm, & von der Schulenburg, 2016).

Below Figure 0.3,illustrates a sample AHP hierarchy process with the objective of finding the best job based on main and sub criteria out

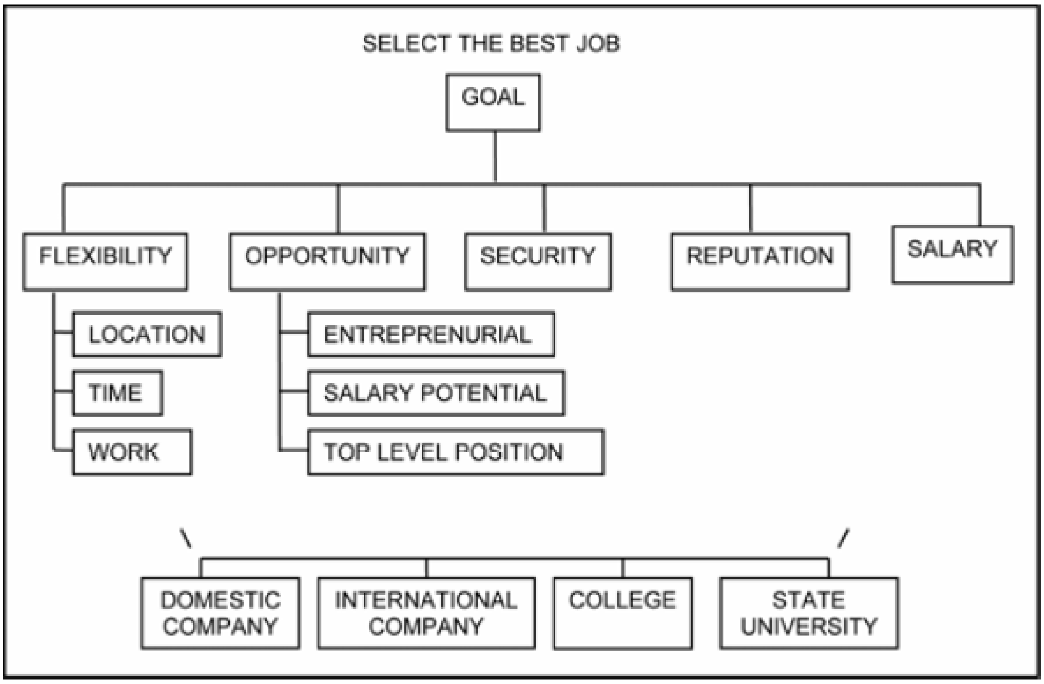


Figure 3.3 : Sample AHP hierarchy

Developing the Pairwise Comparison Matrices

As mentioned in the Figure 0.2, second step of the AHP analysis is to build the respective pairwise comparison matrices. As instructed in the AHP Survey form (Appendix A) participant the survey is asked to compare all the criteria pairwise at given levels.

And to make comparison (T. L. Saaty, 2002) suggests, a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property in regard to which they are compared as mentioned below in Table 3.1.

Table 3.1 : Comparison scale

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another
6	Strong plus	
7	Very strong	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Source: (T. L. Saaty, 2002)

<u>*Deriving the Criteria Weights*</u>

The next step is to derive the priority vector from the details give in pair-wise comparison matrix, by normalizing the column entries by dividing each entry by the sum of the column and then priority vector is built taking the overall row averages of the normalized column matrix.

Estimating Consistency Ratio (CR)

In addition to the weight calculations, in order to verify the results derived above concept of Consistency Ratio (CR) can be applied to the AHP calculation process. Consistency Ratio (CR) can be computed from the matrices to examine whether the participants' answers are random. Following (T. L. Saaty, 2002), the CR value has to be ≤ 0.1 while there are other authors suggested a CR ≤ 0.2 level acceptable as well (Schmidt et al., 2016).

- **Calculating the Consistency Ratio (CR)**
  - Step 01: Compute the **Consistency Index (CI),** Where n is the number of items being compared

$$CI = \frac{\lambda_{max} - n}{n - 1}$$ *Equation 1 : Consistency Index*

  - Step 02: Compute the **Consistency Ratio (CR)**

$$CR = \frac{CI}{RI}$$ *Equation 2 : Consistency Ratio*

  - Step 03: Here **Random Index (RI)** values means Consistency index of a randomly generated pairwise comparison matrix. RI depends on the number of elements being compared (i.e., Size of pairwise comparison matrix) and takes on the following values in Table 3.2.

Table 3.2 : Random index values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: (T. L. Saaty, 2002)

IASP Analysis

After investigating the perception of the selected sample with respect to the performance evaluating indicators/ factors of the demand planning information network, methodology is suggested to model the demand planning information flow using IASP analysis (Hoang Thuan et al., 2019; Thuan et al., 2017).

After identifying the activity flow of the demand information flow, CPM or PERT analysis methodologies can be applied according the available data and objectives of the study. these techniques, explain how to model the information network with proper sequencing and visualizing the demand information network of the respective SC.

Critical Path Method (CPM) Analysis

The two techniques CPM and PERT were developed by two different set groups in 1956-58. Walker from E.I. du Ponde de Nemours company developed the CPM to solve project scheduling problem. PERT was developed by a team of engineers working on the Polaris Missile programs of the U.S. Navy. Both these techniques are network-oriented techniques using the same principles. Bothe these methods have been used in numerus industries globally over the time (Jun-Jie & Jian-Xun, 2010).

The significant difference between two approaches is that the time estimates for the different activities in CPM were assumed to be deterministic while in PERT these are described probabilistically Both CPM and PERT Methods, consist of four main steps. Those are Planning, Scheduling, Allocation of resources and Controlling (R. Malhotra & D. K. Jain, 2019).

Following section states the methodology and the terms is followed under CPM and PERT technique with reference many literatures which have been published under the area (Kelley & Walker, 1959, Wiest and Levy, 1977, Agarwal, Dhall & Tayal, n.d.)

CPM/PERT Methodology

- **Planning:** Process is initiate started by splitting the total project into small projects. The smaller projects are further divided into different activities and are analyzed by a department or section. The relationship of each activity with respect to other activities are defined and established.
- **Scheduling:** The objective of scheduling is to give the earliest and the latest allowable start and finish time of each activity as well as its relationship with other activities in the project. The schedule must pinpoint the critical path i.e. time activities which require special attention if the project is to be completed in time
- **Allocation of resources:** Allocation of resources is performed to achieve the desired objective. Resource is a physical variable such as labor, finance, space, equipment etc. which will impose a limitation for completion of a project. This study is focused on allocating the "Time" resource to optimize the complete network.
- **Controlling:** The final phase in the project management is controlling. After making the network plan and identification of the Critical path, the project is controlled by checking progress against the schedule, assigning and scheduling manpower and equipment and analyzing the effects of delays. This is done by progress report from time to time and updating the network continuously. Arrow diagram and time charts are used for making periodic progress reports

Basic Terminology used in Network Analysis

A fundamental method in both PERT and CPM is the use of network systems as a means of graphically depicting the current problems or proposed projects in network diagram. A network diagram is the first thing to sketch an arrow diagram which shows inter-dependencies and the precedence relationship among activities of the project. Following are the terms used in the network analysis when developing the respective network.

- **Activity**
  - Any individual operation, which utilizes resources and has a beginning and an end is called an activity. An arrow is used to depict an activity with its head indicating the direction of progress in the project. It is of four types.
    - ***Predecessor Activity:*** activity that must be completed immediately prior to the start of another activity.
    - ***Successor Activity:*** activity which cannot be started until one or more of other activities are completed but immediately succeed them are called successor activity.
    - ***Concurrent Activity:*** Activity which can be accomplished concurrently is known as concurrent activity. An activity can be predecessor or successor to an event, or it may be concurrent with the one or more of the other activities
    - ***Dummy Activity:*** An activity which does not consume any kind of resources but merely depicts the technological dependence is called a dummy activity. Dummy activity is inserted in a network to classify the activity pattern to make activities with common starting and finishing points distinguishable or to identify and maintain the proper precedence relationship between activities those are not connected by events.
- **Event**
  - The beginning and end points of an activity are called events or nodes or connector. This is usually represented by circle in a network.

- **<u>Difference between event and activity</u>**
  - An event is that instant of time at which some specific part of project is to be achieved while an activity is the actual performance of a task
  - An activity requires time and resources for its completion. Events are generally described by such words as complete, start, issue, approves, taste etc. while the word like design, process, test, develop, prepare etc. shows that a work is being accomplished and thus represent activity.
  - While drawing networks, it is assumed that the movement is from left to right and Head event has a number higher than the tail event.
  - Thus, the activity (i-j) always means that job which begins at event (i) is completed at event (j)

CPM is designed to assist the project managers/ system mangers in planning, time scheduling, and control of projects. Two basic results provided by CPM are the project's duration (the total time needed to complete the project) and the critical path. One of the procedures for finding a critical path is to (1) determine the earliest occurrence times via a forward pass, (2) find the latest occurrence times via a backward pass of each activity, and then (3) identify critical activities. ***An activity is defined as critical if its Earliest Occurrence Time (ES) and its Latest Occurrence Time (LF) are equal***.

These critical activities constitute a **critical path** that is a ***single uninterrupted path spanning the entire project network from start to finish***, and consequently the total duration time of this project network can be obtained by summing these critical activity times. A project network can have more than one critical path (Goryachev, Goryachev, Monakhov, & Novakova, 2016).

<u>Activity Network</u>

According to (Zhu & Heady, 1994), activity network is an acyclic digraph, where the vertices represent events, and the direct edges represent the activities, to be performed in a project. As explained by (Goryachev et al., 2016) an activity network is represented by $G(V, E)$. Let V $\{v_1, v_2\ldots, v_n\}$ be a set of vertices, where v_1 and v_n are the start and final events of the project, and each vi belongs to some path from v_1 to v_n.

Let A⊂V×V be the set of a directed edge a_{ij} *vi; v j*, that represents the activities to be performed in the project. Activity *aij* is then represented by one, and only one, arrow with a tail event *vi*, and a head event *vj*. For each activity *aij*, a magnitude *tij T* is defined, where *tij* is the time required for the completion of *aij*. A critical path is a longest path from *v*1 to *vn*, and an activity *aij* on a critical path is called a critical activity. Let ES*i* and LF*i* be the **earliest event time**, and the **latest event time** for event *i*, respectively. Let ES *j* and LF*j* be the earliest event time, and the latest event time for event *j*, respectively.

$$ES_j = \max \{ES_i + D_{ij}\} \text{ and } LF_i = \min \{LF_j - D_{ij}\}$$

Equation 3 : Earliest Event Time and Latest Event Time

Total Float and Free Float

Another important analysis which can be derived through CPM are the concepts of "Total Fleet" and "Free float". "Float" which is defined as "slack" in some literature, is the " *amount of time an activity can be delayed from the early start without changing the completion date of the project*" According to (Nagata, Manginelli, Lowe, & Trauner, 2018) ***Total Float*** (TF) with respect to each activity is the *difference between the early and late start dates or the early and late finish dates of each activity*. ***Free Float (FF)***, per definition, is the *amount of time that the activity can be delayed before any successors will be delayed.*

Concept of ***Free Float*** implies that, if activities that are not on the critical path have a difference between their early start date and their late start date, those activities can be delayed without affecting the project completion date.

In simpler terms ***Total Floats*** is the amount of time that the completion time of an activity can be delayed without affecting the project completion time. Free Floats is the amount of time that the activity completion time can be delayed without affecting the earliest start time of immediate successor activities in the network.

A project can also have negative float, which means the calculated completion date of the last activity is later than the targeted completion date established at the beginning of the project.

PERT Analysis

PERT or Program Evaluation and Review Technique is a tool majorly used in the project management field schedule, organize, and coordinate tasks within a project. It is basically a method to analyze the tasks involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project (Howard, 2009b).

There can be instances whet in project planning where time values are subjected to variation. The main objective of the analysis through PERT is to find out the completion for an event within specified date. What are the chances of completing the job? This approach considers uncertainties. In this approach three-time values are estimated with each activity: Optimistic time, most likely time and Pessimistic time. The three-time values provide a measure of uncertainty associated with that activity (Agarwal, Dhall & Tayal, n.d). using these time values, **estimated time** (average time an activity will take if it is to be repeated large number of times and is based on the assumption that the activity time follows Beta distribution) and **variance of each activity** can be derived.

Using all the above mentioned data, PERT is carried under following steps (Graham, 2004; P. Lewis, 2001).

- Identify the specific activities and milestones of the project/process
- Determine the proper sequence of the activities
- Construct a network diagram
- Estimate the time required for each activity
- Determine the critical path

Case Study Approach

Although there are 04 indicators to evaluate the information flow, study focuses on how “time” as an indicator can optimize the information network. In other words, how to enhance the demand planning process by optimizing the time spent on the process.

In order to apply the proposed methodology case study approach has been applied in this study. Using CPM analysis critical path of the network is to be derived and then using PERT analysis, minimum time needed to complete the process will be identified.

After the selecting the case study, first step is to develop the information network with the use of IASP analysis (Hoang Thuan et al., 2019; Thuan et al., 2017). After that using CPM / PERT analysis, critical path to complete the demand planning task is identified.

CHAPTER 04

4. DATA ANALYSIS AND DISCUSSION

Introduction

In this chapter, analysis outputs are discussed which are derived using statistical analysis software applications like MS Excel and Minitab. Under the first section, descriptive analysis of the collected data is discussed which is providing an insight to the nature of the operations with respect to the demand planning information flow.

Then under hypothesis testing, developed scenarios are statistically checked to test whether those statements are significant or not using Minitab software application.

Next step is to conduct the AHP analysis using MS Excel according to the guideline provided by the various literature sources(Lima-Junior & Carpinetti, 2017; T. L. Saaty, 2002; Schmidt et al., 2016)

Thirdly demand information flow modeling techniques are discussed and using CPM analysis, critical path analysis is carried out with respect to the selected case study. Finally, conceptual framework is presented to optimally allocate time and cost within the information flow to enhance the demand planning process of the apparel SC.

Data Collection

Piot survey results have been used to lay the foundation knowledge base for the study and the information collected through the survey has been the foundation to build the secondary survey and in selecting the most appropriate case study as well.

Although 100 questionnaires have been sent to the selected sample to collect data for the secondary survey only 93 responses are received and from that also 2 entries have been removed due to errors in their responses. Since the response rate for study is 93% and it surpasses the minimum limit for the sample which is 70 according to (Mundfrom, Shaw, & Ke, 2005) researcher can move forward with the study.

Descriptive Analysis

Characteristics of the Employees Who Are Involved with Demand Planning Information Network

As illustrated in Figure 0.1, majority of the selected sample are Executives (39%), 33% are Senior Executives, Assistant Mangers are 22% and only 6% are Managers from the 93 responses received.

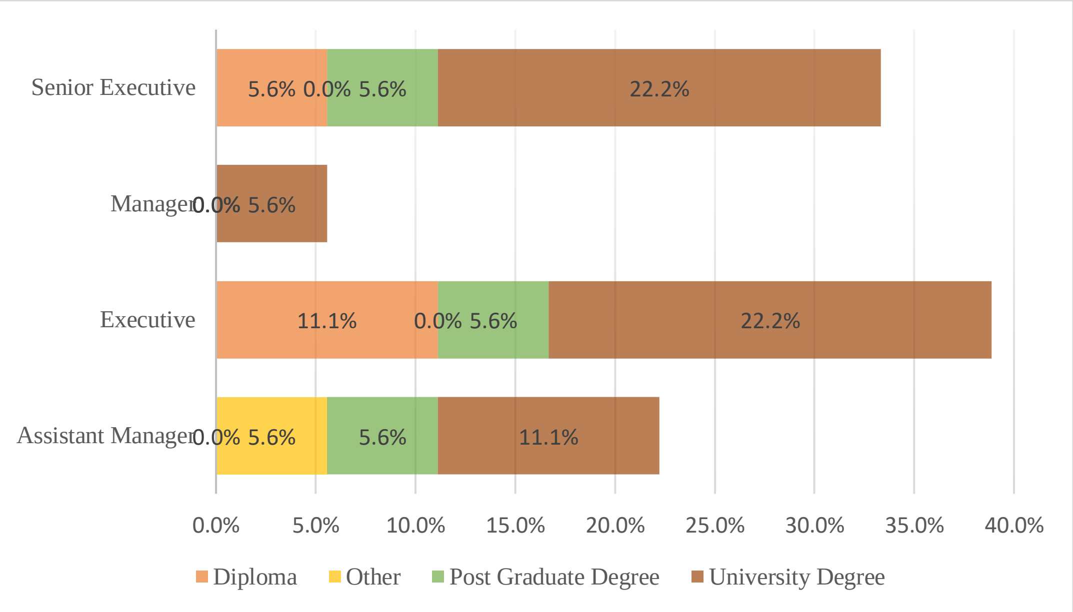


Figure 4.1 : Employment levels and educational level

Handling demand planning information and making decisions based on them require a sound technical knowledge as they are dealing with almost all the levels of the organization. Figure 0.1 confirms the fact even further, as 61% of the employees have a university degree and majority of the executives and senior executives are graduates.

According to the interviews conducted with the top management further emphasizes that these higher education qualifications of the employees makes it easier for the organizations to bring innovative ideas changes to the system as their work force is capable is adapting to the changes quickly.

When looking at each department separately and the level of experience employees bring to each department Figure 0.2 illustrates how equipped organizations are with respect to the level of experience in each team.

According to Figure 0.2, development team has the highest percentage of employees who has a good experience in the field making it easier for the employees to work with all the members of the SC and to handle demand information accurately and faster. Employees with high experience level are mostly in the planning section of the department grooming and leading the respective departments.

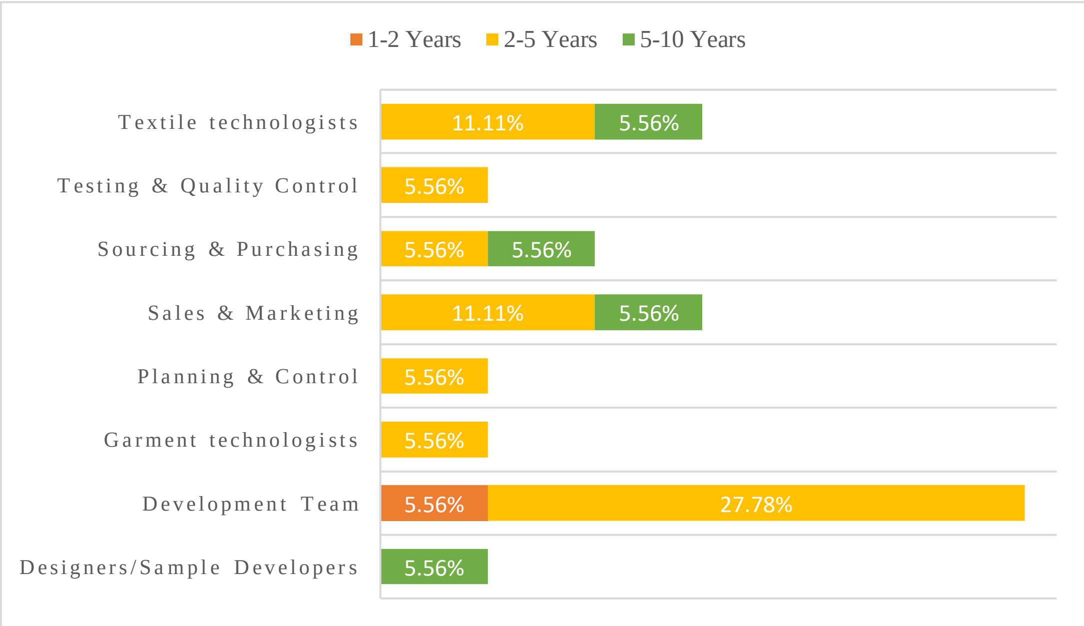


Figure 4.2 : Experience vs Team

Time Spent on The Demand Planning Information Flow by Each Team

Figure 4.3 illustrates how each department spend their work hours dealing with the demand planning information flow. According to the that, development spends the highest amount of time dealing with the information flow.

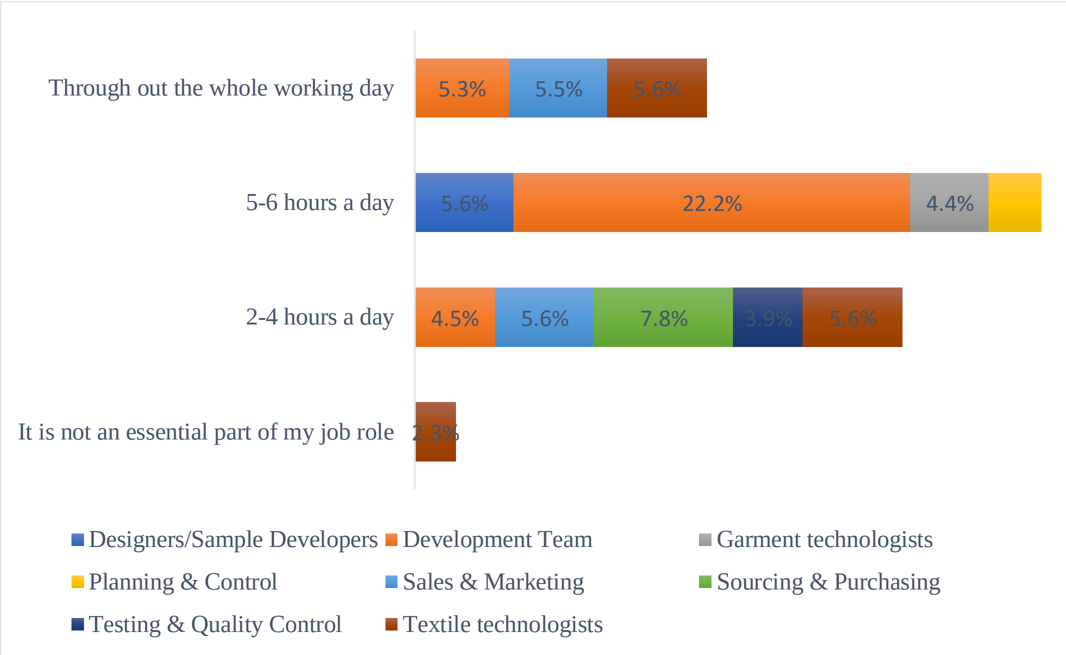


Figure 4.3 : Time spent on the information network

According to industry experts they are the team responsible for making decisions like " what are the designs that the organization should focus the most", " what are the products which holed the highest demand from customers side", " what clothing line to pursue further or which clothing line to invest less capital on" etc..

Second highest department is the sales and marketing department which is the contact point of the Sri Lankan organization with local and international suppliers and customers as well. According to the survey results Testing & quality control department spends less amount of their work hours on the demand planning information flow mainly because their main task is to check the quality of the developed products rather than dealing with the demand for the products.

Time Spent on Demand Planning Information Flow Related Activities

Below Figure 4.4 demonstrates the percentage in which the selected survey sample spends their work hours with respect to each demand planning information flow related activities

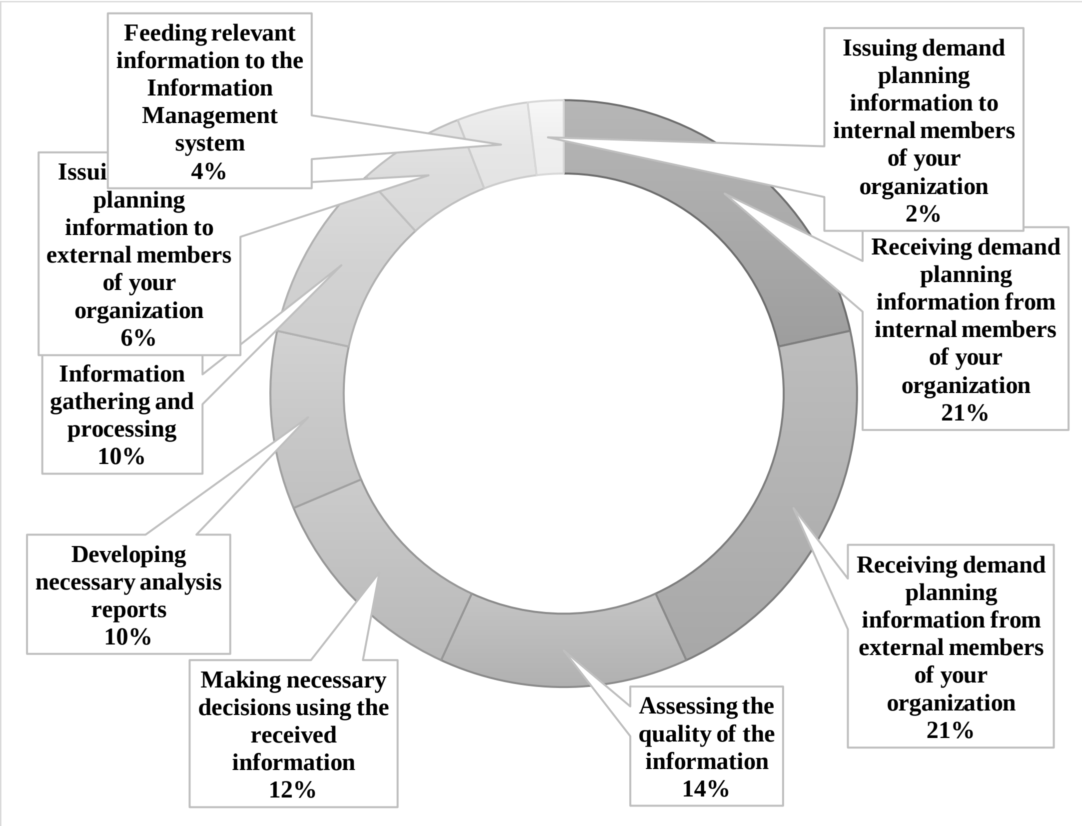


Figure 4.4 : Time spent on demand planning information flow related activities

According to Figure 4.4, 43.2% is allocated to receiving demand planning information from both external and internal members of the organization. Sri Lankan apparel industry is majorly an outsourcing manufacturing industry for the international brands. The result makes sense because most of the time Sri Lankan apparel industry behaves according to the demand planning information provided to them by the customers overseas.

Before moving ahead with the demand planning information, it is necessary to verify the details because apparel organization invests a huge amount of capital in these operations and one flow can cost the organization both money and the reputation they have built up in the industry as well.

Information Communication Technological Tools Used by the Industry

Figure 4.5 illustrates the communication tools used by the apparel organization to communicate demand planning information with the members of their respective SC network.

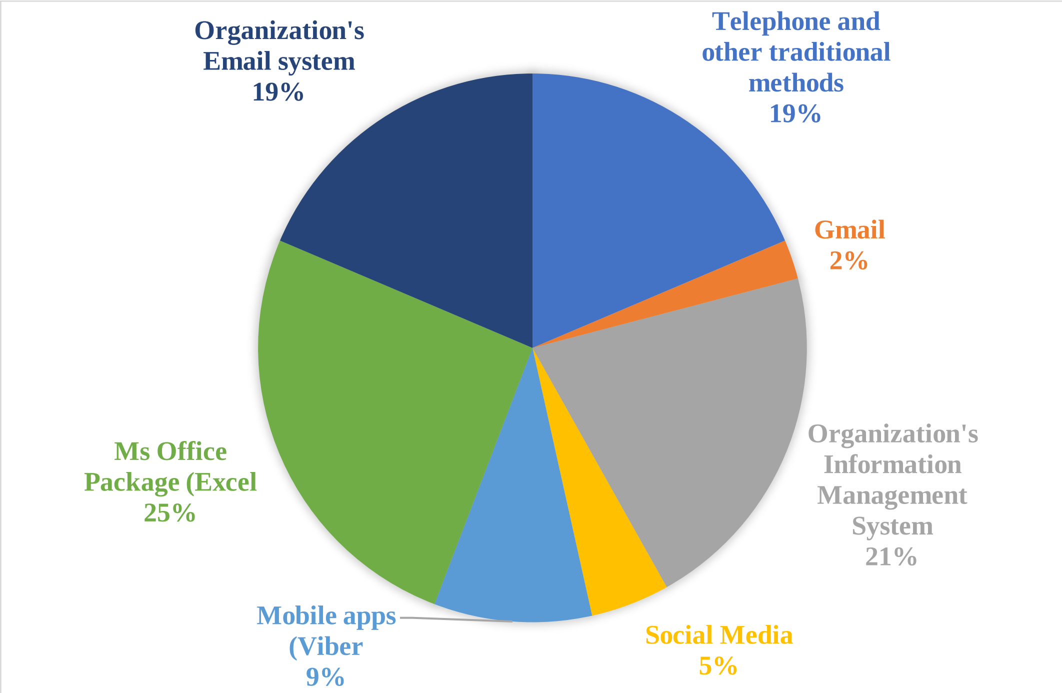


Figure 4.5 : ICT tools

According to the industry experts there is a high demand for MS Office package especially excel because the software enables the SC members to share the information easily and its user-friendly options allows the SC members to share demand planning information more efficiently.

Telephones and mobile apps are very useful for them to share last minute details and to communication verbal information quickly. But Organization’s email system (19%) and information management system (21%) are also used by the members (altogether 40% of the communication operations) because these systems ensures the safety of the extremely private and confidential demand planning information shared with the apparel SC members.

Important Performance Evaluating Factors

The next analysis is very significant as it provides an understanding on how each department value each of the important factors which are to consider in order to improve the demand-planning process with respect to the information that each team is dealing with. Figure 4.6 summarized these factors with respect to the selected sample. These important factors which was developed from the interview data conducted in the pilot survey are listed below.

- Accuracy of the information
- Time Spent on the information network
- Cost involved with the information
- Reliability of the information

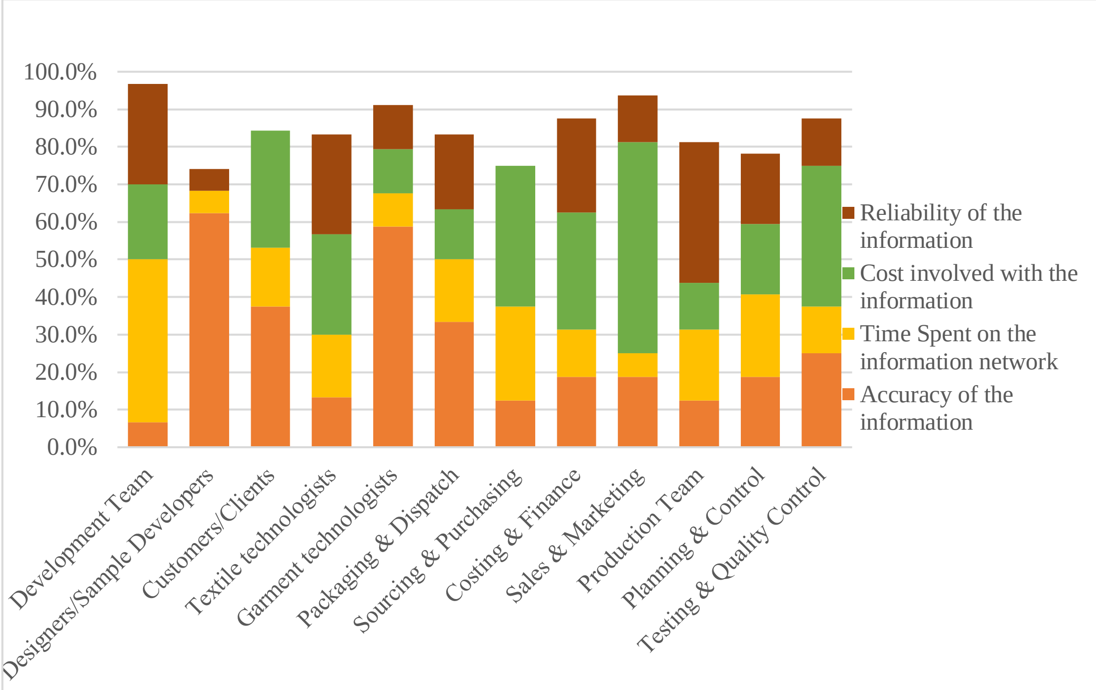


Figure 4.6 : Important operational factors

As illustrated in Figure 4.6, Designers/Sample Developers gives the highest priority to the accuracy of the information (62.4%), Development Team gives the highest priority to the Time Spent on the information network (43.3%), Cost involved with the information flow is the highest priority for the Sales & Marketing team

(56.3%) and Reliability of information is considered as the most important factor for their performance by the Production team (37.5%).

Major Issues Faced by The Organizations with Respect to the Demand Planning Information Flow

Another important aspect of the study is to investigate the issues faced by the Sri Lankan apparel industry with respect to the demand planning information flow operations. Figure 4.7 demonstrates the pareto chart which is developed to provide a brief understanding on how these identified issues impact the information flow performances.

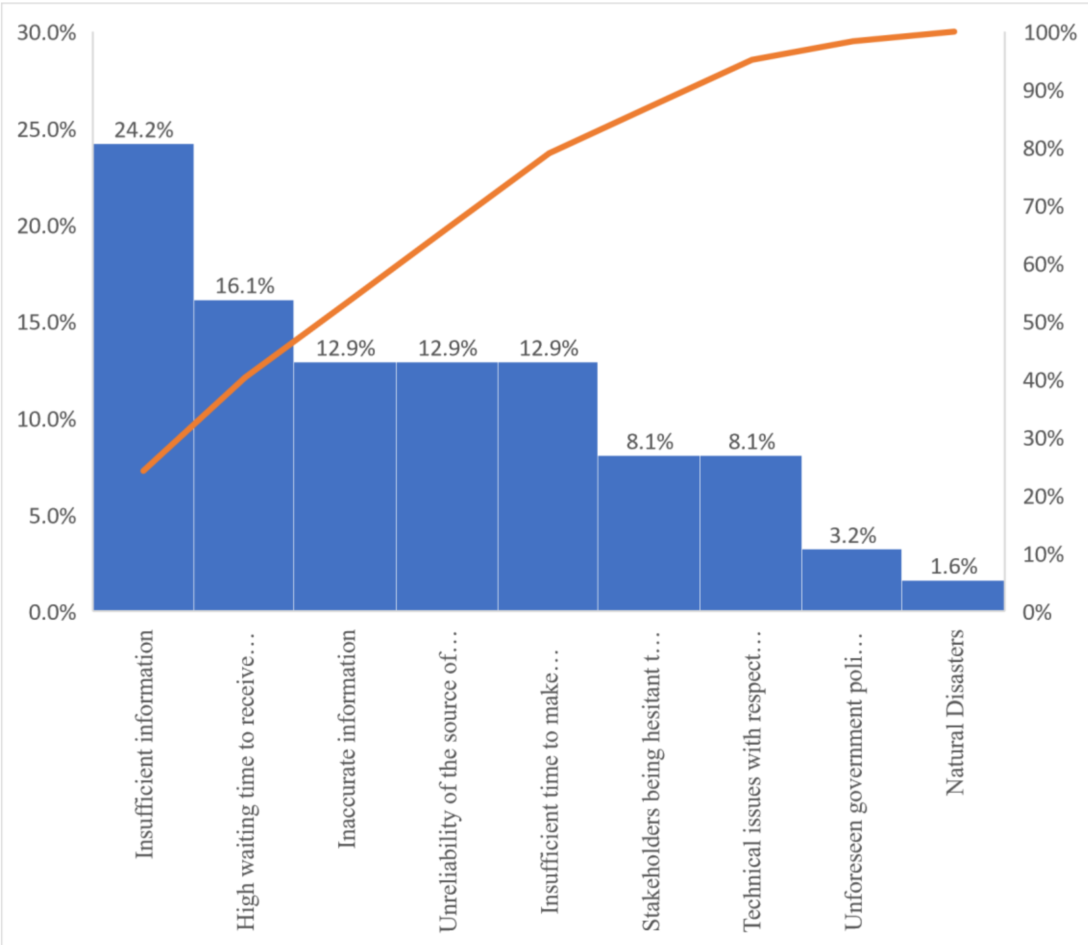


Figure 4.7 : Issues in the demand planning information flow

According to the Figure 4.7, roughly 80% of the problems are occurred due Insufficient information (24.2%) and High waiting time to receive information (16.1%). If the industry can pay attention to mitigate these issues, they can reduce 80% of their problems with respect to the demand planning information flow operations.

Qualities Expected from The Stakeholders to Improve the Efficiency of the Demand Planning Information Flow

After analyzing the characteristics of the industry (how they behave under each circumstance, nature of the work force of the industry etc.) and influencing factors for the behavior of demand planning information flow, Figure 4.8 represent the qualities expected by the members of the SC from fellow SC members to improve the efficiency of the demand planning information flow.

According the below Figure 4.8, Flexibility and responsible operations have been given the highest value (21.5% each), quick response time has been given the third best quality to improve the efficiency of the demand planning information flow.

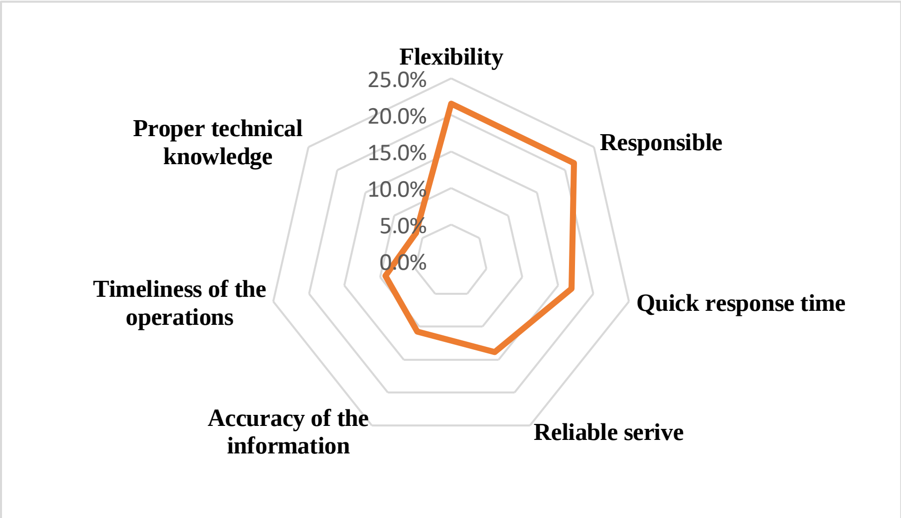


Figure 4.8 : Qualities expected from fellow SC members

All these data analysis have been conducted with respect to the selected sample. Since the sample has been selected including major players in Sri Lankan apparel industry, the above descriptive analysis provides a fair overview of the Sri Lankan apparel industry with respect to the demand planning information flow operations.

Further statistical analysis was carried out in order to prove the significance level of these statements derived from the sample data.

Hypothesis Testing

Relationship Between Performance Measuring Criteria and the Respective Department/Team of the Apparel Organization

Under the question 09 of the survey questionnaire (*The most important factor to consider to improve the demand-planning process with respect to the information you are dealing with from each department*) data has been collected regarding the most important factor to consider in order to improve the demand-planning process with respect to the information dealt by each department.

Using the data in "

Appendix – Two way table representing the performance measuring criteria and each department", chi square test was performed to test whether there is a significant relationship between the performance measuring criteria and the respective department/team of the apparel organization.

- **Developed hypothesis statements to be tested**
  - H_0: There is no significant relationship between the performance measuring criteria and each department
  - H_1: There is a significant relationship between the performance measuring criteria and each department

After running through Minitab software following outputs in Table 4.1 was received.

Table 4.1 : Minitab output for the chi-square test

Chi-Sq = 130.753, DF = 30, P-Value = 0.000
20% cells with expected counts less than 5.

According to the results in Table 4.1, Pearson chi-square statistic is 130.753 and p-value is 0.000. Since p value is less than 0.05 test statistic is in the rejection region which means null hypothesis- H_0 is rejected. Therefore with 95% significance level it can be stated that ***"There is a significant relationship between the performance measuring criteria and each department".***

Can Effective Information Flow Make an Impact on the Demand Planning Process?

Under question 8 (*According to your view, can effective information flow make an impact on the demand planning process?*), survey participants were asked to state their opinion with respect to the impact which ca be made by the optimized information flow in order to enhance the demand planning process.

Out of the 93 responses 84 replied that there is optimized information flow can make an impact on the demand planning process in order to increases its performances. 09 responses were in the "***May be/No***" category. In order to test the statistical validity of this statement "one sample proportion hypothesis test" was performed to compare the proportion of one certain occurring in a population following the binomial distribution with a specified proportion.

- **Developed hypothesis statements to be tested**
    - H_0: $\boldsymbol{p}$ (proportion of employees agrees with the fact that effective information flow can make an impact on the demand planning process) ≤ 0.5
    - H_1: $\boldsymbol{p} > \mathbf{0.5}$

After performing the statistical test using Minitab software following output was generated.

Table 4.2 : Hypothesis test result for the proportions

Test of p = 0.5 vs p > 0.5					
				95% Lower	Exact
Sample	X	N	Sample p	Bound	P-Value
1	84	93	0.903226	0.837204	0.000

According to the results in Table 4.2, p value (0.000) is less than 0.05 which indicates that null hypothesis is in the rejected region or null hypothesis is rejected. Therefore with 95% confidence level it can be stated that "***proportion of employees agrees with the fact that effective information flow can make a significant impact on the demand planning process***" is significantly greater than 0.5.

In other words, it can be statistically proven that ***according most of the perception of the selected population that is the managerial level employees of Sri Lankan***

apparel industry, optimized information flow can enhance the performance of the demand planning process.

AHP Analysis

Building the Structure of The Hierarchy

The first objective of the study is to understand the relationship between "time, cost and accuracy" as parameters to measure the performance of the information flow network of apparel demand planning process. Following criteria are developed in accordance with AHP analysis guidelines.

- **C_1** - Accuracy of the information
- **C_2** - Time Spent on the information flow operations
- **C_3** - Cost involved with the information flow operations
- **C_4** - Reliability of the information

Study has identified nine (09) general activities in the demand information flow. But it would be difficult run AHP analysis with 36 combinations. Therefore these 09 activities have been categorized into three sections as mentioned in Table 4.3.

Table 4.3 : Demand information flow activity categorization

Activities	Categories		
	Receiving demand planning information	**Issuing demand planning information**	**Processing demand planning information**
Receiving demand planning information from internal members of your organization			
Receiving demand planning information from external members of your organization			
Assessing the quality of the information			
Making necessary decisions using the received information			
Developing necessary analysis reports			
Information gathering and processing			
Issuing demand planning information to external members of your organization			
Feeding relevant information to the Information Management system			
Issuing demand planning information to internal members of your organization			

Figure 4.9 demonstrates the AHP Hierarchical structure which has been developed for this study considering the selected research problem, research objectives and all the above-mentioned guidelines.

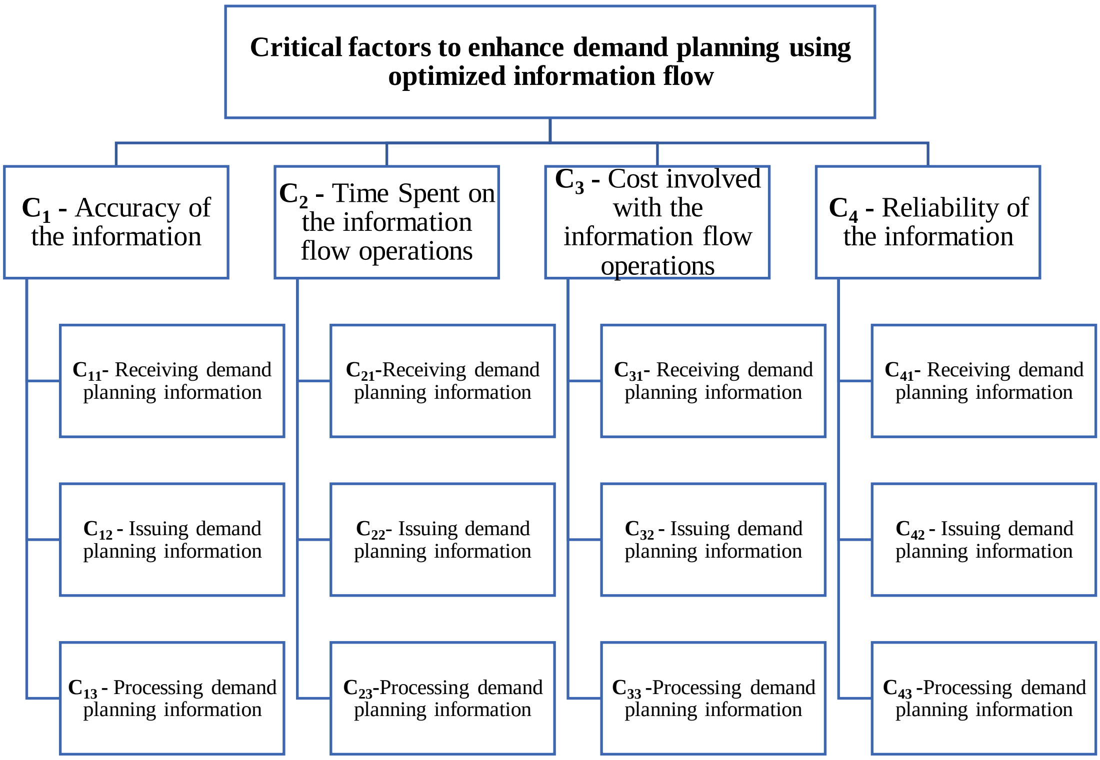


Figure 4.9 : AHP Hierarchical structure

Developing the Pairwise Comparison Matrices

After cleaning and processing the collected data from the surrey following comparison matrices were developed.

- Comparison matric with respect to criteria

Table 4.4 : Initial pair-wise comparison matrix of criteria

	C1	C2	C3	C4
C1	1	0.3659	4.7083	4.7778
C2	2.7333	1	4.7778	3.6667
C3	0.2124	0.2093	1	0.72
C4	0.2093	0.2727	1.3889	1

- The comparison matrix of sub-criteria with respect to criteria C_1

Table 4.5 : The comparison matrix of sub-criteria with respect to criteria C1

C1	C11	C12	C13
C11	1	4.0667	6.3333
C12	0.2459	1	1.4444
C13	0.1579	0.6923	1

- The comparison matrix of sub-criteria with respect to criteria C_2

Table 4.6 : The comparison matrix of sub-criteria with respect to criteria C2

C2	C21	C22	C23
C21	1	3.0952	6.0476
C22	0.3231	1	2.7778
C23	0.1654	0.36	1

- The comparison matrix of sub-criteria with respect to criteria C_3

Table 4.7 : The comparison matrix of sub-criteria with respect to criteria C3

C3	C31	C32	C33
C31	1	4.3333	4.7037
C32	0.2308	1	2.1111
C33	0.2126	0.4737	1

- The comparison matrix of sub-criteria with respect to criteria C_4

Table 4.8 : The comparison matrix of sub-criteria with respect to criteria C4

C4	C41	C42	C43
C41	1	4.3333	4.7333
C42	0.2308	1	0.3333
C43	0.2113	3	1

Deriving the Criteria Weights

Following Figure 0.10, illustrates the calculation followed up to derive weightages given to each criteria with respect to the Sri Lankan apparel industry's information flow evaluation with respect to the demand planning operations.

And the calculations for the results which have been derived using MS Excel are mentioned in the Appendix .

Initial pair-wise comparison matrix of criteria				
	C1	C2	C3	C4
C1	1	0.3659	4.7083	4.7778
C2	2.7333	1	4.7778	3.6667
C3	0.2124	0.2093	1	0.72
C4	0.2093	0.2727	1.3889	1

	C1	C2	C3	C4
C1	1	0.3659	4.7083	4.7778
C2	2.7333	1	4.7778	3.6667
C3	0.2124	0.2093	1	0.72
C4	0.2093	0.2727	1.3889	1
Column Sum	**4.155**	**1.848**	**11.88**	**10.16**

Normalized column sums				
	C1	C2	C3	C4
C1	0.2407	0.198	0.3965	0.47
C2	0.6578	0.5412	0.4023	0.3607
C3	0.0511	0.1133	0.0842	0.0708
C4	0.0504	0.1476	0.117	0.0984

Priority Vector	
	C1
C1	0.3263
C2	0.4905
C3	0.0799
C4	0.1033

Figure 4.10 : Deriving the weightages

With the results derived from the above analysis, main criteria of AHP hierarchy structure can be illustrated as mentioned in the below Figure 4.11 showing the weightages for each criterion.

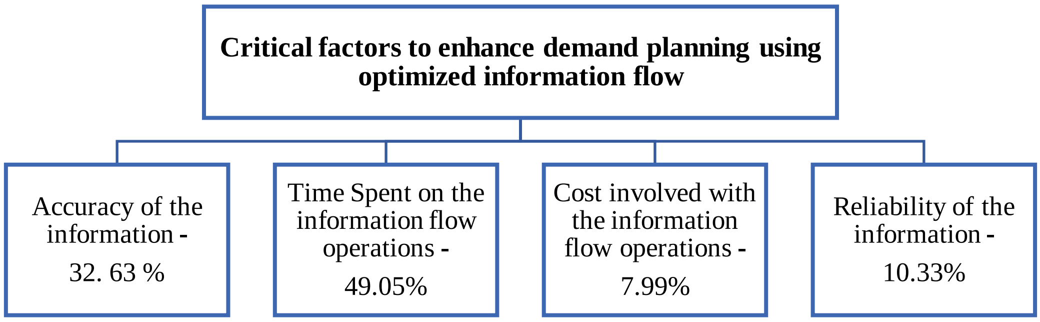


Figure 4.11 : Criteria weights

According to these findings, highest priority, close to 50%, is given to the time spent **on the information flow operations** when evaluating the performance of the demand planning information flow. Second priority is given to the **accuracy of the information** while **reliability** gets the third priority and **cost** is the fourth one compared to these 04 criteria.

Reliability is a factor which is derived from the pilot survey interviews while others are supported by the literature. When analyzing the nature and the definition of the factor it is clear that reliability is an input created by the accurate information received

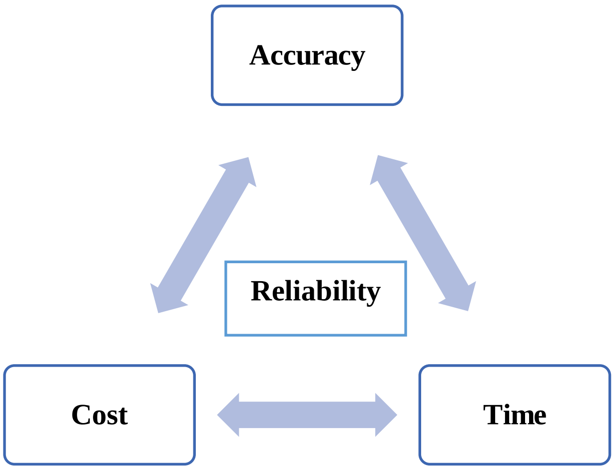


Figure 4.12 : Evaluating criteria of the information flow

at the correct time at a minimum cost (Figure 0.12). In other words, reliability of the information flow is a byproduct of the main three indicators "accuracy, timeliness and the cost" of the demand planning information flow.

Estimating Consistency Ratio (CR)

As mentioned, in the methodology section it is important to test the validity of the results generated through AHP analysis. CR is used to test the random nature of the answers provided by the survey participants and if the CR value is less than 0.1 data set is highly acceptable. If the CR value is between 0.1 and 0.2, the results are also set be in an acceptable stage.

After conducting the relevant calculations (Appendix D), **CR** value for the main Criteria weightages is **0.093** which is less than 0.1 indicating that participants' answers given for the survey are random.

Calculating Weightages for The Sub Criteria

Following the same procedure mentioned in the above section to calculate the criteria weightages and the respective CR value, Table 4.9 represents the sub-criteria weightages and the respective CR values.

Table 4.9 : Sub-criteria weightages and CR values

Criteria	**Weightages**	**CR**	**Sub-criteria**	**Weightages**	**CR**
C_1	32.63%	**0.093 < 0.1**	C_{11}	71.33%	0.0631 < **0.1**
			C_{12}	44.22%	
			C_{13}	14.33%	
C_2	49.05%		C_{21}	66.07%	0.0679 < **0.1**
			C_{22}	45.11%	
			C_{23}	16.97%	
C_3	7.99%		C_{31}	68.03%	**0.1** <0.1276 < **0.2**
			C_{32}	44.05%	
			C_{33}	15.98%	
C_4	10.33%		C_{41}	66.46%	0.0724 < **0.1**
			C_{42}	38.81%	
			C_{43}	16.77%	

According to the results under each criterion, highest concern is given with respect to the performance of the information flow when they are receiving demand planning information.

Summarizing the results derived from the AHP analysis, between the criteria which can be used to evaluate the performances of the demand planning information flow highest priority (49%) is given to the time spent on the information flow, while accuracy of the information gets the second place (33%) and then the reliability and finally to the cost of the operation. And under each of these criteria, information receiving gets the highest concern from the survey participants which impacts the performance of the demand planning information flow.

While time, accuracy and cost of the operation can be declared as independent indicators, reliability is dependent on all the above 03 factors. Although participants might have perceived reliability as an indicator which can measure the performance along with others, when looking into the definition reliability can be measured through the rest of the indicators.

All these indicators can be used to further optimize the information flow to enhance the demand planning process but the scope and the focus of this study is to investigate on how it can be improved with respect to the time on the demand planning information flow.

IASP Analysis

In order to achieve the second objective of the research, methodology is to be proposed in order to model the information flow of the apparel demand planning process.

Modeling the SC network has become very valuable in SCM strategies because it allows not only organize and coordinate processes but also make it easier to visualize the process as well. There are many methods discussed in literature information (Durugbo, Tiwari, & Alcock, 2013, Hansen et al., 1978) to model the flow but in this case IASP analysis has been selected as the most suitable method to model the information flow network.

IASP analysis is the initial step of the LINQ technique ((Thuan et al., 2017) as described the literature review in chapter 02. According to the when modeling information flow using LINQ principles, “information, actions, people, and systems” are the basic building blocks defining the LINQ information flows. It provides an analysis to examine contexts and identify the main building blocks according the basic model. It starts with all available documentation describing the context. It then analyses the texts for identifying the main building blocks of LINQ. The analysis is best performed by coloring appropriate texts in the documents. The colors include green for Information, orange for Actions, blue for Systems, and violet for People. This analysis is named IASP (Hoang Thuan et al., 2019; Thuan et al., 2017)

Case Study Analysis and Critical Path Method

Handling numerous activities throughout the demand information flow and monitoring its performance can be quite hectic to the management without proper techniques and practices. CPM and PERT analysis are such tools which are mainly used in project management which can be used as a solution to this scenario. Those are methods to analyze the tasks involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project Under these techniques (Graham, 2004; P. Lewis, 2001)..

In order to test the above-mentioned framework, case study is selected form the Sri Lankan apparel industry to apply the techniques mentioned above and to derive the critical path of the information flow of the selected case study. in the case time values are deterministic, thus CPM analysis has been carried out to select the critical path for the network.

Modeling the Information Network

Using IASP analysis and the available documents for the case study a project from the Company A has been selected as the case study.

The case study or the project is Under PVH speed programs named “Promptly” which is fallen under Test and Chase category where the time factor is critical. Providing on time delivery with quality garment is the major priority whist cost is a minor priority since the aim was to grab more future opportunities via this innovative manufacturing model.

After the activities have been identified with respect to the information network of the process, following Work Breakdown Structure (WBS) (Figure 0.13) is developed to visualize the process and to identify the sequence of the process.

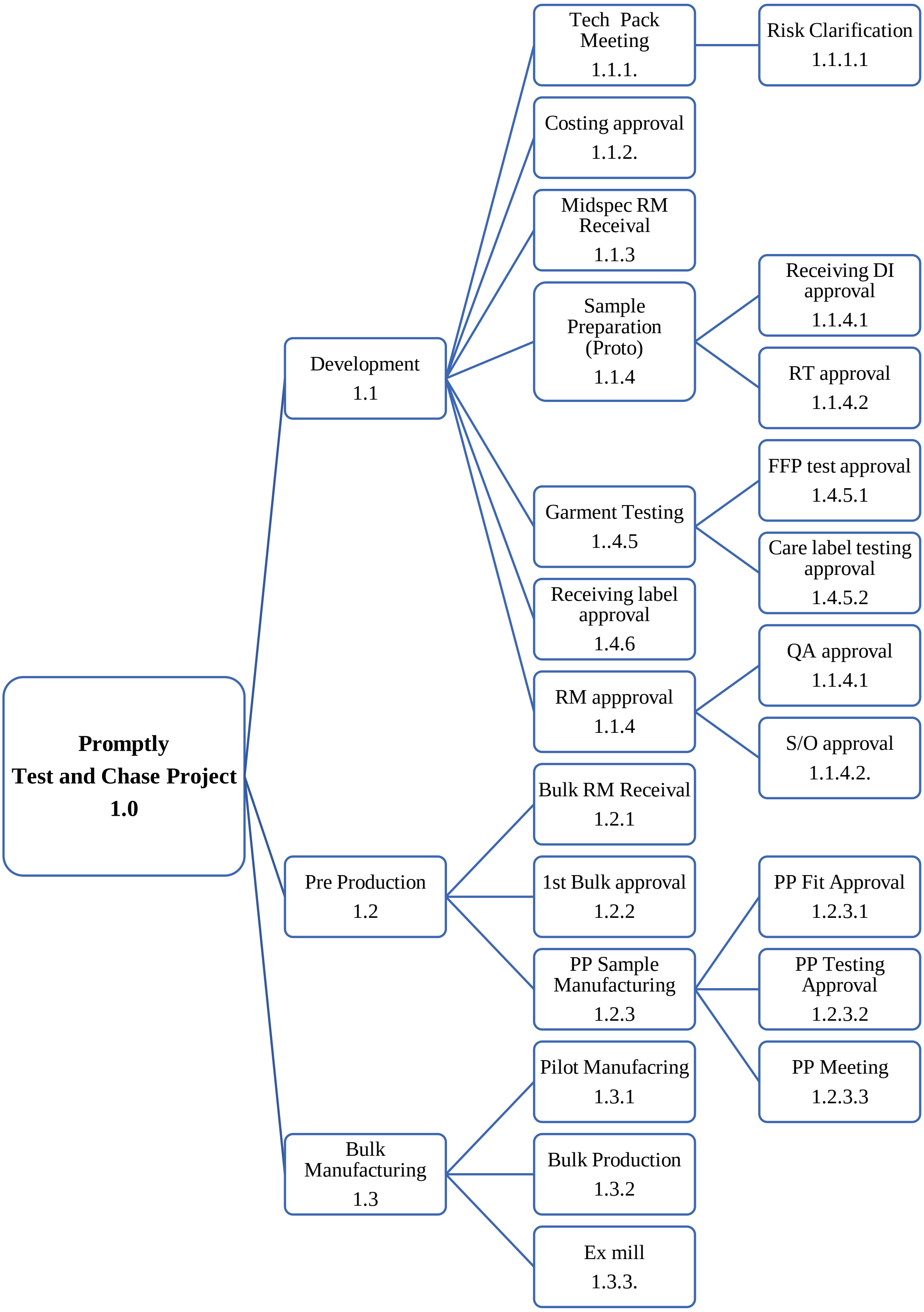


Figure 4.13 : Work Breakdown Structure (WBS)

Identifying the Specific Activities and Milestones of the Project/Process

According to the Company A management, these speed model projects are only started with customer PO receival on bulk order. The initial step is to take a tech pack meeting where all teams have come into one plat form to discuss about the clarifications needed, possible risks and the game plan. In this meeting product development, fabric, technical, bulk merchandizing teams as well as plant teams are involved. In promptly project, specially Company A innovation team is also involved as they are responsible for garment printing.

The milestones of the project can be identified as;

- Costing approval
- DI approval
- 1st Fit approval
- FFP testing approval
- Care label testing approval
- Quality approval
- PP meeting
- Bulk manufacturing
- Ex-mil

After looking at the WBS and other related operational documents, following

Table 4.10 is developed to display each department responsible for the respective task.

Table 4.10 : Task List

WBS no	Task title	Label	Task owner teams	Start date	Due date
1.1	Development				
1.1.1	**Tech pack meeting**			**10/09/2018**	**11/09/2018**
1.1.1.1	Risk clarification	A	Product development team	10/09/2018	11/09/2018
1.1.2	**Costing approval**	**B**	Product development team	**12/09/2018**	**13/09/2018**
1.1.3	**Mid spec RM receival**	**C**	Product development team	**12/09/2018**	**25/09/2018**
1.1.4.	**Sample preparation**			**26/09/2018**	**8/10/2018**
1.1.4.1	Design Integration/proto approval	D	Technical team/Innovation team	26/09/2018	2/10/2018
1.1.4.2	1st Fit approval/Red Tag approval	E	Technical team	3/10/2018	8/10/2018
1.1.5	**Garment testing approval**			**28/09/2018**	**11/10/2018**
1.1.5.1	Fit for purpose testing approval	F	Fabric team	28/09/2018	4/10/2018
1.1.5.2	care label testing approval	G	Fabric team	5/10/2018	11/10/2018
1.1.6	**Receiving label approval**	**H**	Product development team	**12/10/2018**	**15/10/2018**
1.1.7	**RM approval**			**12/09/2018**	**9/10/2018**
1.1.7.1	Lab dip/strike off approval	I	Fabric team/Innovation team	12/09/2018	3/10/2018
1.1.7.2	Quality approval	J	Fabric team	12/09/2018	9/10/2018
1.2	Pre-production				
1.2.1	**Bulk RM Receival**	**K**	Bulk team	**11/10/2018**	**9/11/2018**
1.2.2	**1st Bulk approval**	**L**	Fabric team/Innovation team	**12/11/2018**	**13/11/2018**
1.2.3	**Pre-production sample manufacturing**			**14/11/2018**	**23/11/2018**
1.2.3.1	PP fit approval	M	Technical team	14/11/2018	19/11/2018
1.2.3.2	PP testing approval	N	Fabric team	20/11/2018	23/11/2018
1.2.3.3	PP meeting	O	Bulk/fabric/technical/plant/Innovation	22/11/2018	23/11/2018
1.3	Bulk production				
1.3.1	**Piolet manufacturing**	**P**	Plant team/Innovation team	**26/11/2018**	**27/11/2018**
1.3.2	**Bulk manufacturing**	**Q**	Plant team/Innovation	**28/11/2018**	**12/12/2018**
1.3.3	**Ex-mill**	**R**	Plant team/Bulk team	**13/12/2018**	**27/12/2018**

Table 4.11 : Information flow stakeholders

Receiving	**Activity**		***Processing***	***Issuing***
Fabric Team/Innovative/Technical	**Risk Clarification**	**A**	Product Development Team	Customer/Fabric Team
Development Team	**Costing Approval**	**B**	Product Development Team	Customer
Supplier	**Mid Spec RM Receival**	**C**	Product Development Team	Fabric Team
Product Development Team/Technical Team	**Design Integration/Proto Approval**	**D**	Technical Team/Innovation Team	Customer
Product Development Team	**1st Fit Approval/Red Tag Approval**	**E**	Technical Team	Customer
Technical Team	**Fit for Purpose Testing Approval**	**F**	Fabric Team	Customer / Development Technical, Innovation Teams
Technical Team	**Care Label Testing Approval**	**G**	Fabric Team	Product Development Team/Technical Team
Customer	**Receiving Label Approval**	**H**	Product Development Team	Bulk Team
Innovation Team/Product Development Team	**Lab Dip/Strike Off Approval**	**I**	Fabric Team/Innovation Team	Customer/Innovation Team
Supplier	**Quality Approval**	**J**	Fabric Team	Customer/Supplier/Product Development Team
Customer Approval/Supplier	**Bulk RM Receival**	**K**	Bulk Team	Production Plant
Supplier	**1st Bulk Approval**	**L**	Fabric Team/Innovation Team	Supplier/Production Plant/Bulk Team
Customer	**PP Fit Approval**	**M**	Technical Team	Customer/Production Plant/Innovation Team/Product Development Team
Technical Team	**PP Testing Approval**	**N**	Fabric Team	Customer/Production Plant/Innovation Team/Product Development Team
Bulk/Fabric/Technical/Plant/Innovation	**PP Meeting**	**O**	Bulk/Fabric/Technical/Plant/Innovation	Bulk/Fabric/Technical/Plant/Innovation
Innovation Team/Production Plant	**Piolet Manufacturing**	**P**	Plant Team/Innovation Team	Bulk/Fabric/Technical/Plant/Innovation
Bulk Team	**Bulk Manufacturing**	**Q**	Plant Team/Innovation	Fabric Team
Bulk Team	**Ex-Mill**	**R**	Plant Team/Bulk Team	Customer

Table 4.10 shows the responsible team within the selected company with respect to each task. In order to derive methodologies to manage the time allocation in each activity it is necessary to understand how information is received and issued within these activities. After discussing with the employees of Company A with respect to the selected case study above Table 4.11 is prepared to provide a closer look into their demand information flow.

The values in Table 4.11 indicates how important it is to identify the activities belong to the critical path because then the apparel SC can anticipate the issues they might face, strategies to increase the performance and to have contingency plans accordingly.

Determining the Proper Sequence of the Activities

Considering all these facts , sequence of the activities and under the assumption that "weekends are not considered for duration" following Table 4.12 displays the duration spent for each activity with respect to its information flow.

Table 4.12 :Task Duration with predecessors

	Task/Sub Task	**Activity**	**Predecessors**	**Duration for the information transaction (Days) Dij**
1	Risk clarification	A		1
2	Costing approval	B	A	1
3	Mid spec RM receival	C	A	10
4	Design Integration/proto approval	D	C	5
5	1st Fit approval/Red Tag approval	E	D	4
6	Fit for purpose testing approval	F	D	5
7	care label testing approval	G	E	5
8	Receiving label approval	H	G	1
9	Lab dip/strike off approval	I	A	16
10	Quality approval	J	A	20
11	Bulk RM Receival	K	J, I, B	22
12	1st Bulk approval	L	K	1
13	PP fit approval	M	L, H, F	4
14	PP testing approval	N	L	4
15	PP meeting	O	M, N	1
16	Piolet manufacturing	P	O	1
17	Bulk manufacturing	Q	P	11
18	Ex-mill	R	Q	11

Constructing the Network Diagram

According to methodology mentioned in the chapter 03 in detail ,following Table 4.13 is developed to illustrate *nodes* (from the head event -start to the tail event-finish) , *arcs* (Activities) and the *time spent on demand planning information flow* (**Dij**) in each activity.

Table 4.13 : Nodes and arcs of the network diagram

Activity	**Starting Node**	**Finishing Node**	**Dij**
	i	**j**	
A	1	2	1
C	2	3	10
B	2	6	1
I	2	4	16
J	2	5	20
D1	4	6	0
D2	5	6	0
D	3	7	5
E	7	8	4
F	7	12	5
G	8	9	5
K	6	10	22
L	10	11	1
D3	11	12	0
N	11	13	4
M	12	13	4
O	13	14	1
P	14	15	1
Q	15	16	11
R	16	17	11

Using the details illustrated in the Table 4.12, network diagram has been developed (Figure 0.14) mentioned below.

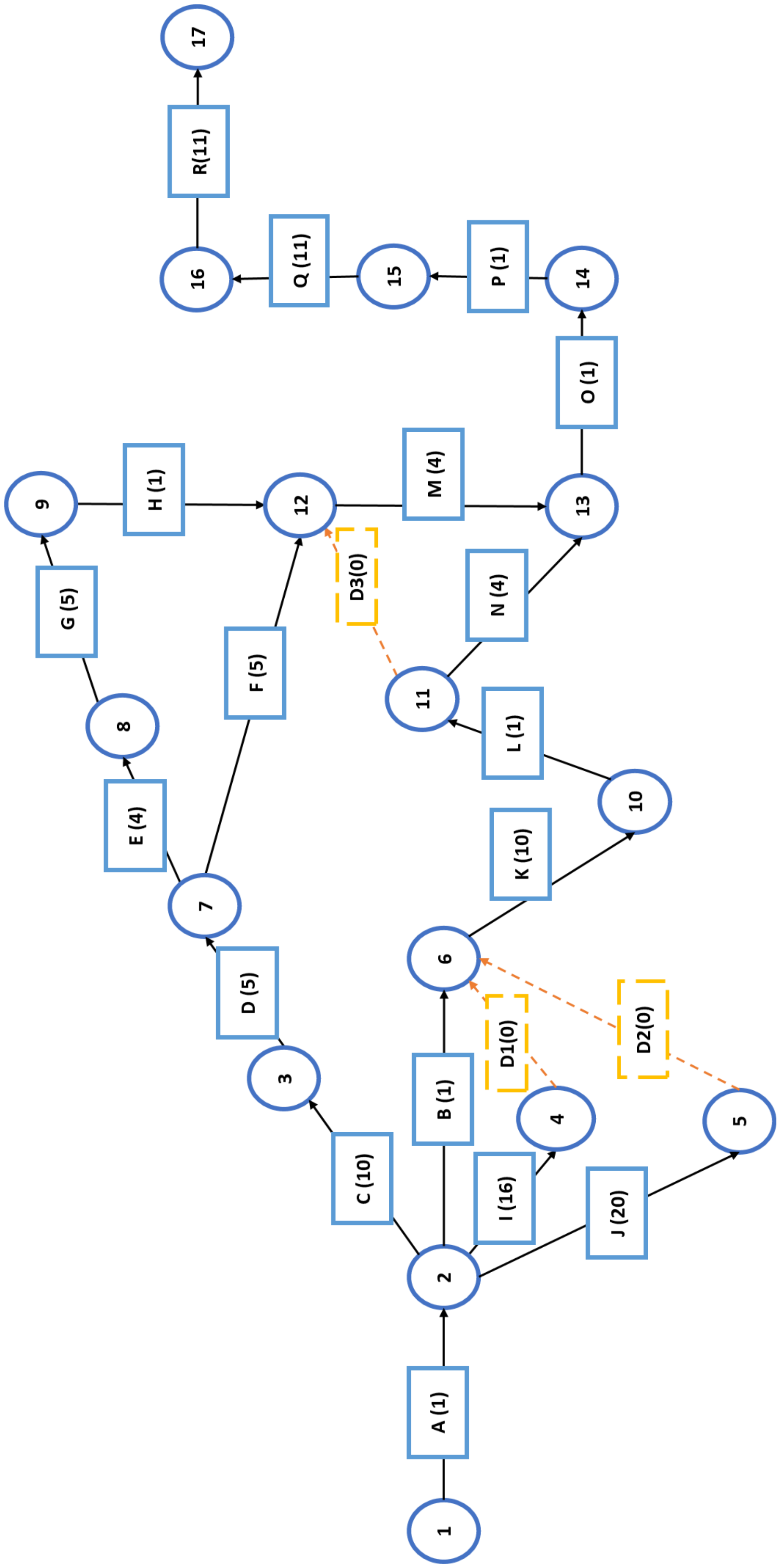


Figure 4.14 : Network diagram

Determining the Critical Path

In order to calculate the critical path of the network diagram illustrated in Figure 0.14, **Earliest Start Time** (ES_j) and the **Latest Finish time (**LF_i) for each node has to be calculated.

$$ES_j = \max \{ES_i + D_{ij}\} \text{ and } LF_i = \min\{LF_j - D_{ij}\}$$

Table 4.14 : ES and LF calculations

Node	**ES i**	**LF i**
1	0	0
2	1	1
3	11	29
4	17	21
5	21	21
6	21	21
7	16	34
8	20	38
9	25	43
10	43	43
11	44	44
12	44	44
13	48	48
14	49	49
15	50	50
16	61	61
17	72	72

According to the above Table 4.14, to complete the demand information flow process it takes 72 days.

After calculating respective ES and LF details in above Table 4.14, critical path for the network can be derived if the particular nodes and activities aligned with the given conditions for the critical path.

For each activity in the critical path,

- $ES_i = LF_i$
- $ES_j = LF_j$
- $ES_j - ES_i = LF_j - LF_i = D_{ij}$

Another method to calculate the critical path is that when ***Total Float*** (TF) and Free ***Float (FF)*** values are derived for each activity, activities that belong to the critical path have zero (0) TF and FF values (Table 4.15).

Table 4.15 : TF and FF calculations for each activity

Activity	**Starting Node**	**Finishing Node**	**Dij**	**TF ij**	**FF ij**
	i	j			
A	1	2	1	0	0
C	2	3	10	18	0
B	2	6	1	19	19
I	2	4	16	4	0
J	2	5	20	0	0
D1	4	6	0	4	4
D2	5	6	0	0	0
D	3	7	5	18	0
E	7	8	4	18	0
F	7	12	5	23	23
G	8	9	5	18	0
K	6	10	22	0	0
L	10	11	1	0	0
D3	11	12	0	0	0
N	11	13	4	0	0
M	12	13	4	0	0
O	13	14	1	0	0
P	14	15	1	0	0
Q	15	16	11	0	0
R	16	17	11	0	0

According to both Table 4.14 and Table 4.15 calculations, path highlighted and colored in Figure 0.15 is selected as the critical path for the selected network.

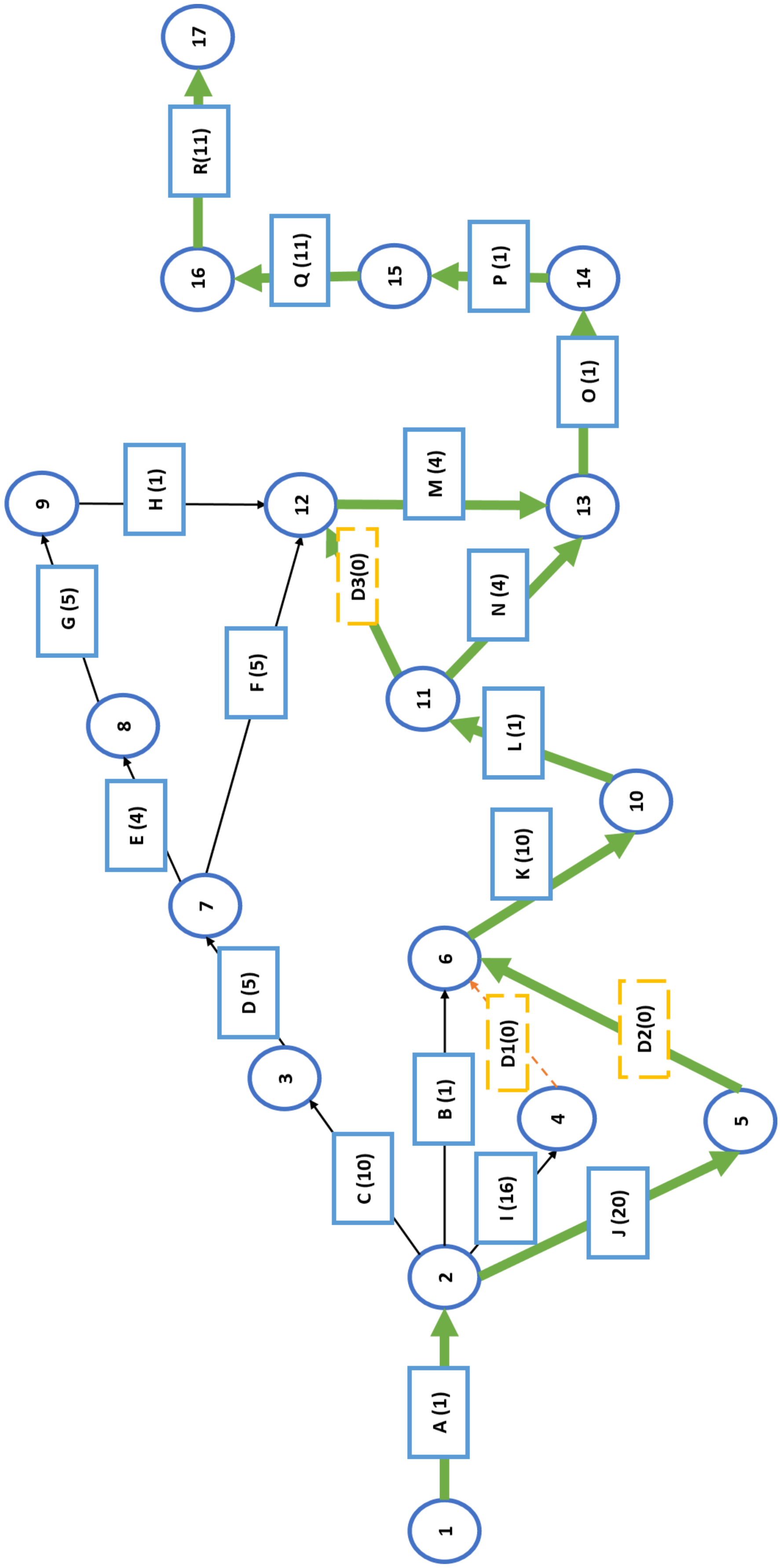


Figure 4.15 : Critical path

According to Figure 0.15, following activities in the Table 4.16 can be identified as the critical path of the process. If the top management can reduce the time spent on handing the demand information in these activities overall time of the process can be reduced.

Table 4.16 : Critical path activities

Risk Clarification - A		
Quality Approval – J		
Bulk RM Receival - K		
1st Bulk Approval – L		
PP Fit Approval - M		**PP Testing Approval - N**
PP Meeting - O		
Piolet Manufacturing - P		
Bulk Manufacturing - Q		
Ex-Mill - R		

Critical Path and Information Flow Duration

Total Float and Free Float Calculations

As mentioned in detail in the methodology chapter, Total Float and Free Float Calculations provide information to SC entities as to how changes can be made in the non-critical activities of the selected network, without delaying the whole project.

- **Free Float:** Amount of time that the activity completion time can be delayed without affecting the earliest start time of immediate successor activities in the network
- **Total Floats:** Amount of time that the completion time of an activity can be delayed without affecting the project completion time

If there is any time delay in the activities of the critical path, the whole process gets delayed. In other words, if the demand planning information related to the critical activities gets delayed more than what is anticipated in the Table 4.17, complete demand information flow gets delayed. Thus, use of critical path is very useful for the managers to understand the activities they need to prioritize and what are the other activities that they can delay without disturbing or delaying the overall process.

Total Float and Free Float concepts assist the SC in this context since these values provide information regarding how each non-critical activity in the selected SC can be delayed without delaying the overall demand information flow.

Table 4.17 : TF and FF for non-critical activities

Activity	**Starting Node**	**Finishing Node**	**Dij**	**TF_{ij}**	**FF_{ij}**
	i	***j***			
C	2	3	10	18	0
B	2	6	1	19	19
I	2	4	16	4	0
D_1	4	6	0	4	4
D	3	7	5	18	0
E	7	8	4	18	0
F	7	12	5	23	23
G	8	9	5	18	0

In other words, it provides details about how managers can allocate resources; "time", for this study among the activities of the SC network. Table 4.17 represent the calculations regarding the non-critical activities.

According to the Table 4.17 data, demand information flow competition time of ***" B and F" can delayed from "19 and 23" days respectively delaying the earlier start time of the immediate successor of that particular activities, "K and M***". Since D_1 is a dummy activity added to assist with the critical path calculations, it is not considered under the actual scenario.

And the demand information flow duration of all the non-critical activities "***C, B, I, D, E, F and G" can be delayed by " 18, 19, 4, 18, 18, 23 and 18" days without delaying the overall information flow duration time of the complete process***.

Conceptual Framework to Approach the Trade-Off Between Project Duration and Cost

Under CPM analysis study has focused on time and derived the critical path with the objective of optimally allocating time to each activity. Time has been given such an importance in the SC because eventually saving time is saving resources within the SC. Thereby overall cost of the SC can be reduced.

However, under this approach direct cost allocated to each activity (in financial terms) and how to manage cost within the SC has not been taken into consideration. When attempting to optimize the time resource within the SC, the cost of a project can be increasing, while using more resources for shortening the completion durations of activities in the project.

Hence it is clear that the trade-off between project duration and cost is that the price of cost is the completion duration and the price of completion duration is the cost (Kelley & Walker, 1959).

The relationship is further explained by the below Figure 0.16 as well.

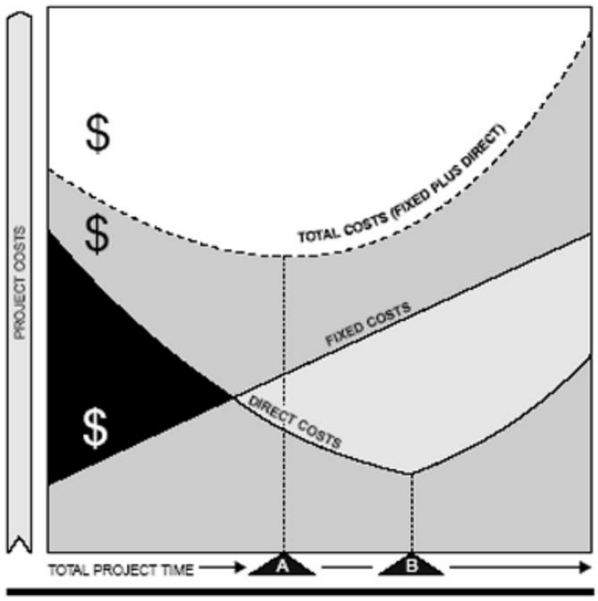


Figure 4.16 : Relationship between project cost and time

Source : (Levy, Thompson, & Weist, 1963)

Estimating the Cost of The Network

When attempting to reduce the cost of the network it is important to understand different aspects of costs associated with the network. The overall cost of the information network can be determined considering costs of every activity in the network, and other relevant income and expenses of the project. Costs of activities can be different from each other in accordance with their completion durations (Sahu & Sahu, 2014).

Crashed Cost

When Attempting to complete a project in shorter than normal duration implies employing more resources to complete every activity in the project. The cost of employing more resources to complete an activity can increase its normal cost. While attempting to complete an activity in a shortest duration, it is inevitable to employ more labors than usual or to make extra (overtime) payment for additional use of existing laborers. This makes the particular activity to account more than normal cost to complete in a shortest time span.

Therefore, the **sum of normal cost plus the additional cost for completing the activity** in a shortest period is known as its **crashed cost**. When every activity is crashed in the project, the total crashed cost of the project equals to normal cost plus additional crashed cost of every activity (Senthilnathan, 2019).

As further explained by (Senthilnathan, 2019) , in relation to an activity, while completing the activity less than its normal duration by utilizing additional resources, it is possible to determine **additional cost per unit of duration saved** and this additional cost per unit of saved duration is known as the **cost slope of the activity**.

$$Cost\ Slope = \frac{Crashed\ Cost - Normal\ Cost}{Normal\ Duration - Crashed\ Duration}$$

Based on the equation above, cost slope for each activity of the selected information flow network can be developed accordingly as illustrated in Table 4.18.

Table 4.18 : Cost slope calculations

Activity	**Predecessors**	**Normal Duration (ND)**	**Crash Duration (CD < ND)**	**Duration saved (DS) = ND - CD**	**Normal Cost (NC)**	**Crashed Cost (CC)**	**Cost Slope = (CC-NC) / (ND - CD)**
A		1	CD1	DS1	NC1	CC1	CS1
B	A	1	CD2	DS2	NC2	CC2	CS2
C	A	10	CD3	DS3	NC3	CC3	CS3
D	C	5	CD4	DS4	NC4	CC4	CS4
E	D	4	CD5	DS5	NC5	CC5	CS5
F	D	5	CD6	DS6	NC6	CC6	CS6
G	E	5	CD7	DS7	NC7	CC7	CS7
H	G	1	CD8	DS8	NC8	CC8	CS8
I	A	16	CD9	DS9	NC9	CC9	CS9
J	A	20	CD10	DS10	NC10	CC10	CS10
K	J, I, B	22	CD11	DS11	NC11	CC11	CS11
L	K	1	CD12	DS12	NC12	CC12	CS12
M	L, H, F	4	CD13	DS13	NC13	CC13	CS13
N	L	4	CD14	DS14	NC14	CC14	CS14
O	M, N	1	CD15	DS15	NC15	CC15	CS15
P	O	1	CD16	DS16	NC16	CC16	CS16
Q	P	11	CD17	DS17	NC17	CC17	CS17
R	Q	11	CD18	DS18	NC18	CC18	CS18

Using Table 4.18 details, following values can be calculated with respect to the information flow network.

- Total duration and cost under the normal circumstances
- Total duration and cost under the crashed scenario

Based on the values, apparel supply chain can make relevant changes to the network flow and test the performance level. Not only that, apparel SC must check whether the critical path is still the same or that has changed according to the crashed values as well.

Based on the objectives, goals set by the apparel organization and using Table 4.18 values, apparel SC can select the optimal network using this method. In this scenario organization must agree on the suitable trade-off between cost and time of the overall information flow to network to enhance the demand planning process.

If they cannot agree on the new process, the same process can be repeated until agreeable optimal solution is decided within the apparel SC (Figure 4.17).

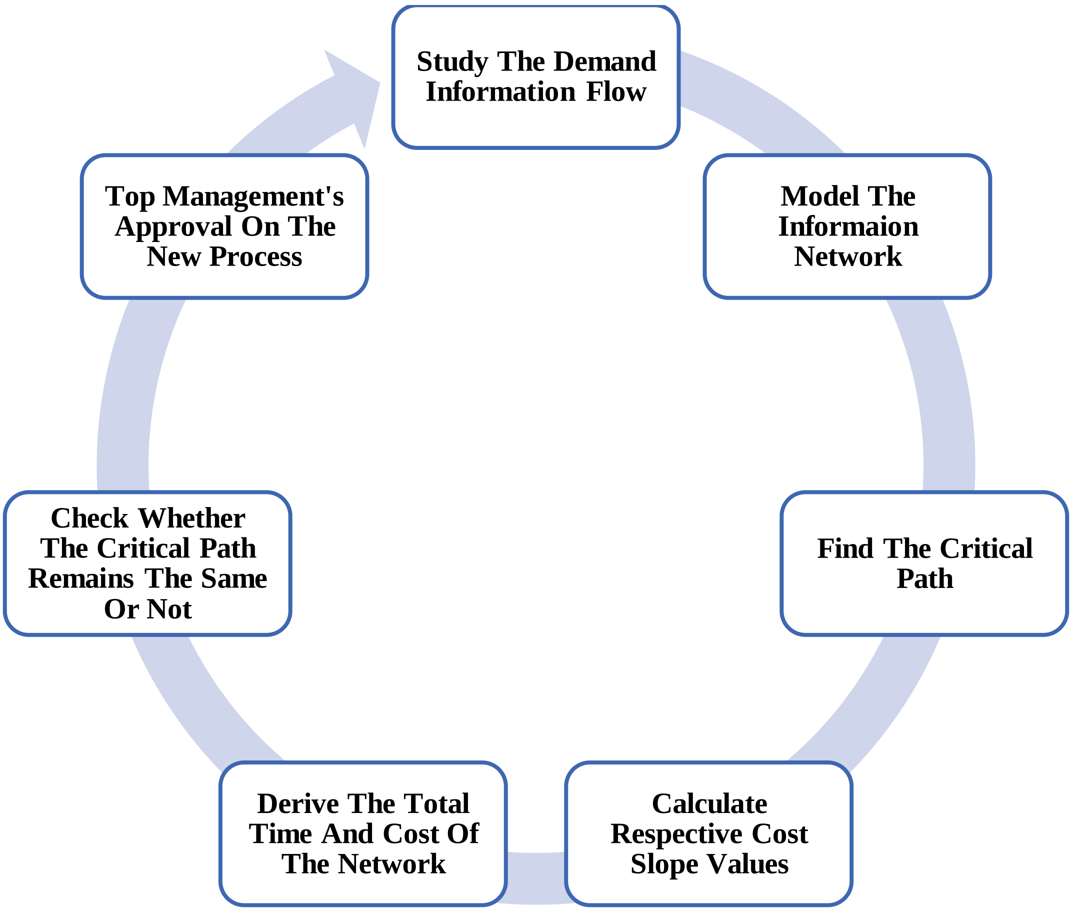


Figure 4.17 : Decision cycle of achieving optimal cost-time tradeoff

CHAPTER 05

5. CONCLUSION

Introduction

Study focus has been given to optimize the information network to enhance the demand planning process by allocating time resource optimally within its information flow network operations. Using a case study, suggested framework has been applied to a real-life scenario and methodology has explained how these results can be used to reduce the wastage of time as resource within the SC.

Summary of the Findings

Based on the analysis carried out in the study following results can be summarized.

Descriptive Analysis

- More than 50% of the employees engage in demand information flow related operations throughout the day and more than 5-6 hours a day.
- 43.2% time of the information flow operations are allocated to receiving demand planning information from both external and internal members of the organization. This is mainly because Sri Lankan apparel industry is an outsourcing manufacturing industry for major international brands.
- Almost all the stakeholders of the information flow use Microsoft outlook, telephones and Microsoft Excel to communicate relevant information with each other.
- Among the respondents, highest priority (30.4%) is given to the "time spent on the operation" to evaluate the performance of the demand planning process. Second priority is given to "Accuracy of information" (28.8%), third place is for the cost of the operation (24.6%) and forth place to the reliability (16.2%).

Hypothesis Testing

- Using hypothesis testing first it is tested “whether there is a significant relationship between the performance measuring criteria and the respective department/team of the apparel organization”. According to the results derived from Minitab software it can be stated that “There is a significant relationship between the performance measuring criteria and each department” with 95% significance level.
- Using the second hypothesis test, it can be statistically proven that according most of the perception of the selected population that is the managerial level employees of Sri Lankan apparel industry, optimized information flow can enhance the performance of the demand planning process.

AHP Analysis

According to the AHP analysis results following weightages are given to each criterion with respect enhancing demand planning process of the apparel industry using optimized information flow.

- $\mathbf{C_1}$ - Accuracy of the information: **32.63%**
- $\mathbf{C_2}$ - Time Spent on the information flow operations: **49.05%**
- $\mathbf{C_3}$ - Cost involved with the information flow operations: **7.99%**
- $\mathbf{C_4}$ - Reliability of the information: **10.33%**

Also, under all the criteria highest priority is given when receiving the demand information from the respective stakeholders.

Information Flow Modeling and CPM Analysis

Case study has been selected to apply the methodology proposed by the study and using ISAP technique and CPM analysis, demand information flow of the selected case study is modeled. Further the critical path of the SC is identified along with Total float and free float values of each activity.

Thus, with the available information SC can alter the time duration spent on the information flow without delaying the complete demand planning process.

Conceptual Framework to Optimize Time and Cost of the Information Flow

Using CPM to identify the critical path and then the concept of FF and TF are very useful to derive an optimized information flow with respect to time variable of the SC. But if the SC wants to enhance the demand planning process further, time spent on each activity must be reduced further. When a certain task is to be performed using minimum possible time, it is inevitable that the cost spent on that activity will increase. This is because more resources of the SC are needed to perform the tasks faster.

At the final stage of the study, a conceptual framework is developed for the apparel industry to have an optimal allocation of time and cost with the objective of enhancing the demand plaining information flow operations.

Suggestions for Future Studies

Study is carried out focusing on allocating time as a resource in the apparel information flow to enhance the demand planning process. In this study, it is assumed that all the other factors like accuracy, reliability and quality of the process will remain the same with the changing time allocate to each operation.

There is a vacancy in the field of analyzing the behavior of the demand planning with respect to these other indictors as well. Researched can be carried out how "accuracy of the demand information flow can be measured to evaluate the performance of the apparel supply chain.

Another suggestion for a future study is modeling the information flow with respect to all the identified indictors and then attempting to optimize the overall SC to enhance the decision-making process of the apparel manufacturing industry.

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APPENDICES

Appendix A: Survey Questionnaire

Optimizing Information Flow to Enhance Demand Planning in Sri Lankan Apparel Supply Chains: A Statistical Approach

This survey is being undertaken to identify what are the factors that influence the effective information sharing in Sri Lankan Apparel Industry. The confidentiality of individual contributions is assured. This questionnaire is being used for academic research purposes only. Please be assured you will not receive any targeted mailings arising from your completion of this questionnaire.
Completion of this questionnaire should take just five minutes of your time – your input is highly appreciated.
Thank you very much!

1. **Current position in the company?**
Mark only one oval.
   - Executive
   - Senior Executive
   - Assistant Manager
   - Manager
   - Top Management
   - Other Managerial Positions

2. **Highest education qualification you have gained?**
Mark only one oval.
   - Advanced Level
   - Diploma
   - University Degree
   - Post Graduate Degree
   - Other

3. **Level of experience in the industry?**
Mark only one oval.
   - Less than a year
   - 1-2 Years
   - 2-5 Years
   - 5-10 Years
   - More than 10 years

4. **Your team in the organization**
Mark only one oval.
   - Development Team
   - Designers/Sample Developers
   - Customers/Clients
   - Textile technologists
   - Garment technologists
   - Packaging & Dispatch
   - Sourcing & Purchasing
   - Costing & Finance
   - Sales & Marketing
   - Production Team
   - Planning & Control
   - Testing & Quality Control

5. **How often you deal with the information sharing process of the organization related to demand planning?**
Mark only one oval.
   - Through out the whole working day
   - 5-6 hours a day
   - 2-4 hours a day
   - It is not an essential part of my job role

6. **What are the demand-planning information related activities you perform in your job role?**
Check all that apply.

- [ ] Receiving demand planning information from internal members of your organization
- [ ] Receiving demand planning information from external members of your organization
- [ ] Issuing demand planning information to internal members of your organization
- [ ] Issuing demand planning information to external members of your organization
- [ ] Developing necessary analysis reports
- [ ] Information gathering and processing
- [ ] Making necessary decisions using the received information
- [ ] Feeding relevant information to the information Management system
- [ ] Assessing the quality of the information

7. **Types of Information and Communication tools being used to share information**
Check all that apply.

- [ ] Telephone and other traditional methods
- [ ] Gmail
- [ ] Organization's Information Management System
- [ ] Social Media
- [ ] Mobile apps (Viber, Whatsapp,Messenger etc..)
- [ ] Ms Office Package (Excel, Word,Outlook etc..)
- [ ] Organization's Email system
- [ ] Other: ____________________

8. **According to your view, can effective information flow make an impact on the demand planning process?**
Mark only one oval.

- ◯ Yes
- ◯ May be
- ◯ No

9. **The most important factor to consider to improve the demand-planning process with respect to the information you are dealing with from each department**
Mark only one oval per row.

	Accuracy of the information	How quickly you need the information for your job role	Cost involved with the information	Reliability of the information	Time spent on each activity
Development Team	◯	◯	◯	◯	◯
Designers/Sample Developers	◯	◯	◯	◯	◯
Customers/Clients	◯	◯	◯	◯	◯
Textile technologists	◯	◯	◯	◯	◯
Garment technologists	◯	◯	◯	◯	◯
Packaging & Dispatch	◯	◯	◯	◯	◯
Sourcing & Purchasing	◯	◯	◯	◯	◯
Costing & Finance	◯	◯	◯	◯	◯
Sales & Marketing	◯	◯	◯	◯	◯
Production Team	◯	◯	◯	◯	◯
Planning & Control	◯	◯	◯	◯	◯
Testing & Quality Control	◯	◯	◯	◯	◯

10. What are the major issues faced by you with respect to the demand information flow in your organization?

Check all that apply.

- [ ] Inaccurate information
- [ ] Insufficient information
- [ ] Unreliability of the source of information
- [ ] Insufficient time to make decisions based on the information
- [ ] High waiting time to receive information
- [ ] Stakeholders being hesitant to take the responsibility of the information
- [ ] Technical issues with respect to the information Management system of the organization
- [ ] Unforeseen government policy changes
- [ ] Natural Disasters
- [ ] Not having enough technical capacity to process the information
- [ ] Other: ____________________

11. What are the qualities you expect from your stakeholders to improve the efficiency of the demand planning information flow

Check all that apply.

- [ ] Reliable serive
- [ ] Timeliness of the operations
- [ ] Proper technical knowledge
- [ ] Flexiblity
- [ ] Responsible
- [ ] Accuracy of the information
- [ ] Quick response time
- [ ] Other: ____________________

Survey Questionnaire: Part 02

12 In the following questions,please mention your opinion in order to select amongst the "Critical factors to enhance demand planning using optimized i
The pairwise comparison scale is used to express the importance of one factor over another

How to select between the options

Example:

Given Options A & B, you can judge their relative importance as shown below example:

If you think the option 'Build Protective Structures' in column **A** is strongly more important than the option 'Improve Building Design' in column **B**, then you mark 5 with (X) on the left hand side.

If you think the option 'Retreat' in column **B** is extremely more important than the option 'Improve Building Design' in column **A**, then you mark 9 with (X) on the right hand side.

A Options	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	B Options
Build Protective Structures	9	8	7	6	X	4	3	2	1	2	3	4	5	6	7	8	9	Improve Building Design
Improve Building Design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	X	Retreat

12 Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), please color the relative importance of options A (left column) to options B (right column).

	Option A	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	Option B
12-1	Accuracy of the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability
12-2	Accuracy of the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost involved
12-3	Accuracy of the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time spent
12-4	Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost involved
12-5	Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time spent
12-6	Cost involved	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time spent

According to your opinion how impotant is "Accuracy of the information" with respect to the following procedures

Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), pleasecolorthe relative importance of options A (left column) to options B (right column).

	Option A	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	Option B
12-7	When you receive information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you process the information
12-8	When you process the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you issue the information
12-9	When you issue the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you receive information

According to your opinion how impotant is "Reliability of the information" with respect to the following procedures

Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), pleasecolorthe relative importance of options A (left column) to options B (right column).

	Option A	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	Option B
12-10	When you receive information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you process the information
12-11	When you process the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you issue the information
12-12	When you issue the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you receive information

According to your opinion how impotant is "Cost involved with the information" with respect to the following procedures

Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), pleasecolorthe relative importance of options A (left column) to options B (right column).

	Option A	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	Option B
12-13	When you receive information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you process the information
12-14	When you process the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you issue the information
12-15	When you issue the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you receive information

According to your opinion how impotant is "Time spent on the information flow" with respect to the following procedures

Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), pleasecolorthe relative importance of options A (left column) to options B (right column).

	Option A	Extremely		Very Strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very Strongly		Extremely	Option B
12-16	When you receive information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you process the information
12-17	When you process the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you issue the information
12-18	When you issue the information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	When you receive information

Appendix B: Chi-square Table Calculations

Departments	**Performance Criteria**			
	Accuracy of the information	Time Spent on the information network	Cost involved with the information	Reliability of the information
Development Team	28	4	0	2
Designers/Sample Developers	12	10	10	0
Customers/Clients	4	10	8	8
Textile technologists	20	6	4	4
Garment technologists	10	10	4	6
Packaging & Dispatch	4	16	12	0
Sourcing & Purchasing	6	8	10	8
Costing & Finance	6	4	18	4
Sales & Marketing	4	12	4	12
Production Team	6	14	6	6
Testing & Quality Control	8	8	12	4

	Development Team	Designers/Sample Developers	Customers/Clients	Textile technologists
1	28 10.43 29.587	12 9.82 0.485	4 9.20 2.943	20 10.43 8.776
2	4 9.85 3.476	10 9.27 0.057	10 8.69 0.196	6 9.85 1.506
3	0 8.50 8.500	10 8.00 0.500	8 7.50 0.033	4 8.50 2.382
4	2 5.22 1.983	0 4.91 4.909	8 4.60 2.508	4 5.22 0.283
Total	34	32	30	34

	Garment technologists	Packaging & Dispatch	Sourcing & Purchasing	Costing & Finance	Sales & Marketing	Production Team
1	10 9.20 0.069	4 9.82 3.448	6 9.82 1.485	6 9.82 1.485	4 9.82 3.448	6 9.82 1.485
2	10 8.69 0.196	16 9.27 4.881	8 9.27 0.175	4 9.27 2.998	12 9.27 0.802	14 9.27 2.410
3	4 7.50 1.633	12 8.00 2.000	10 8.00 0.500	18 8.00 12.500	4 8.00 2.000	6 8.00 0.500
4	6 4.60 0.424	0 4.91 4.909	8 4.91 1.946	4 4.91 0.168	12 4.91 10.242	6 4.91 0.242
Total	30	32	32	32	32	32

	Testing & Quality Control	Total
1	8 9.82 0.337	108
2	8 9.27 0.175	102
3	12 8.00 2.000	88
4	4 4.91 0.168	54
Total	32	352

Appendix C: AHP Weight Calculations

Initial pair-wise comparison matrix of criteria				
	C1	C2	C3	C4
C1	1	0.366	4.708	4.778
C2	2.733	1	4.778	3.667
C3	0.212	0.209	1	0.72
C4	0.209	0.273	1.389	1

	C1	C2	C3	C4
C1	1	0.366	4.708	4.778
C2	2.733	1	4.778	3.667
C3	0.212	0.209	1	0.72
C4	0.209	0.273	1.389	1
Column Sum	**4.155**	**1.848**	**11.88**	**10.16**

Normalized column sums				
	C1	C2	C3	C4
C1	0.241	0.198	0.397	0.47
C2	0.658	0.541	0.402	0.361
C3	0.051	0.113	0.084	0.071
C4	0.05	0.148	0.117	0.098

Priority Vector	
	Weightages
C1	0.326
C2	0.491
C3	0.08
C4	0.103

Appendix D : Consistency Ratio Calculations

Sub Criterias

T	C2	R C21	I C22	P C23	A	R	I	P		R	I	P	X			AX		=	λmax *		λmax	λ	CI	CR
R	C21	1	3.095238095	6.04762		R	1	3.0952	6.047619	R	0.6718	0.6947	0.6155		R	0.6607	R	3.0828			0.6607	4.666			
I	C22	0.323076923	1	2.77778	A	I	0.3231	1	2.777778	I	0.2171	0.2245	0.2827	X	I	0.4511	I	1.1358	=	λmax *	0.4511	2.518	4.666	0.833	0.0631
P	C23	0.165354331	0.36	1		P	0.1654	0.36	1	P	0.1111	0.0808	0.1018		P	0.1697	P	0.4413			0.1697	2.6011			
							1.4884	4.4552	9.825397																

A	C1	R C11	I C12	P C13	A	R	I	P		R	I	P	X			AX		=	λmax *		λmax	λ	CI	CR
R	C11	1	4.066666667	6.33333		R	1	4.0667	6.333333	R	0.7124	0.7061	0.7215		R	0.7133	R	3.4195			0.7133	4.7937			
I	C12	0.245901639	1	1.44444	A	I	0.2459	1	1.444444	I	0.1752	0.1736	0.1646	X	I	0.4422	I	0.8247	=	λmax *	0.4422	1.8648	4.7937	0.8968	0.0679
P	C13	0.157894737	0.692307692	1		P	0.1579	0.6923	1	P	0.1125	0.1202	0.1139		P	0.1433	P	0.5621			0.1433	3.9219			
							1.4038	5.759	8.777778																

R	C4	R C41	I C42	P C43	A	R	I	P		R	I	P	X			AX		=	λmax *		λmax	λ	CI	CR
R	C41	1	4.333333333	4.73333		R	1	4.3333	4.733333	R	0.6935	0.52	0.7802		R	0.6646	R	3.1402			0.6646	4.7253			
I	C42	0.230769231	1	0.33333	A	I	0.2308	1	0.333333	I	0.16	0.12	0.0549	X	I	0.3881	I	0.5974	=	λmax *	0.3881	1.5392	8.7792	2.8896	0.1276
P	C43	0.211267606	3	1		P	0.2113	3	1	P	0.1465	0.36	0.1648		P	0.1677	P	1.4724			0.1677	8.7792			
							1.442	8.3333	6.066667																

C	C3	R C31	I C32	P C33	A	R	I	P		R	I	P	X			AX		=	λmax *		λmax	λ	CI	CR
R	C31	1	4.333333333	4.7037		R	1	4.3333	4.703704	R	0.6928	0.7462	0.6019		R	0.6803	R	3.3411			0.6803	4.9111			
I	C32	0.230769231	1	2.11111	A	I	0.2308	1	2.111111	I	0.1599	0.1722	0.2701	X	I	0.4405	I	0.935	=	λmax *	0.4405	2.1224	4.9111	0.9556	0.0724
P	C33	0.212598425	0.473684211	1		P	0.2126	0.4737	1	P	0.1473	0.0816	0.128		P	0.1598	P	0.5131			0.1598	3.2103			
							1.4434	5.807	7.814815																