ADVANCED SUPPLY CHAIN PLANNING PROCESSES AND DECISION SUPPORT SYSTEMS FOR LARGE-SCALE PETROCHEMICAL COMPANIES

by

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Dissertation presented for the degree of
Doctor of Philosophy (Logistics) at the
University of Stellenbosch

Department of Logistics
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October 2006

DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety, or in part, submitted it at any university for a degree.

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SYNOPSIS

Conventional supply chain integration concepts focus primarily on the internal and external integration of individual supply chains (can be viewed as intra-supply chain integration). Due to the highly integrated nature of petrochemical value chains, related supply chains should also be integrated by taking account of enterprise/industry-wide synergies and interdependencies (can be viewed as inter-supply chain integration). Inter-supply chain integration can typically develop along three dimensions:

- Upstream feed clusters (upstream in the chemical value chain)
- Downstream product clusters (downstream in the chemical value chain)
- Macro logistics network clusters (within and across related logistics networks for liquid bulk, dry bulk, packaged goods and gases)

This dissertation presents a generic framework of applicable intra- and inter-supply chain planning processes that supports related long- (strategic), medium- (tactical) and short-term (operational) supply chain decisions for large-scale petrochemical companies. This type of companies has to manage relative complex supply chains. Highly complex supply chains (due to an extensive product portfolio, supplier base, customer base, manufacturing processes, transportation, and management processes and systems) require far more advanced planning processes than simple supply chains. Advanced supply chain planning processes cover an extended supply chain scope, deal with longer time horizons, and utilize more sophisticated analytical techniques and decision support systems.

An extensive literature study, supplemented by empirical research in the South African petrochemical industry, provided the foundation for the advanced supply chain planning framework concluded in this dissertation. Semi-structured interviews and a questionnaire presented to an informed audience constitute the empirical research conducted. The related best practices, concepts, approaches followed, and level of advancement in three supply chain planning dimensions were derived.

To guide petrochemical companies along the planning advancement journey, the roadmap developed can be utilized for the application and implementation of the advanced supply chain planning framework. This roadmap articulates the advancement stages, dimensions, characteristics, and triggers to advance. Typical characteristics associated with the advancement stages and dimensions provide the means for a company to assess their level of progression. The essential mechanisms that can enable interventions are also articulated.

Keywords: Advanced planning, Decision support systems, Enterprise-wide supply chain planning, Management science, Operations research, Petrochemical industry, Supply chain planning, Supply chain processes, Petroleum industries.

SINOPSIS

Konvensionele konsepte aangaande voorsieningskettingintegrasie is gebaseer op die interne en eksterne integrasie van individuele voorsieningskettings (kan beskou word as intra-voorsieningskettingintegrasie). Aangesien die petrochemiese industrie uiters geïntegreerd van aard is, bestaan daar tipiese interverwantskappe en moontlike sinergieë tussen voorsieningskettings binne ‘n onderneming en die industrie (kan beskou word as inter-voorsieningskettingintegrasie). Inter-voorsieningskettingintegrasie kan tipies ontwikkel in drie prominente dimensies:

- Stroomop voergroepe (stroomop in die chemiese waardeketting)
- Stroomaf finale produkgroepe (stroomaf in die chemiese waardeketting)
- Makro logistieke netwerkgroepe (logistieke netwerkkategorieë van vloeistof massa, droë massa, verpakte produkte en gasse)

Hierdie proefskrif voorsien ‘n generiese raamwerk van toepaslike intra- en inter-voorsieningskettingbeplanningsprosesse wat die verwante lang termyn (strategiese), medium termyn (taktiese) en kort termyn (operasionele) voorsieningskettingbesluite binne grootskaalse petrochemiese ondernemings moet ondersteun. Hierdie tipe ondernemings moet relatief komplekse voorsieningskettings bestuur. Komplekse voorsieningskettings (a.g.v. 'n uitgebreide produkportefeulje, verskafferbasis, klantbasis, vevaardigingsprosesse, vervoer konfigurasie, en bestuursprosesse- en stelsels) benodig baie meer gevorderde beplanningsprosesse vergeleke met eenvoudige voorsieningskettings. Meer gevorderde beplanningsprosesse behels ‘n meer omvattende voorsieningskettingomvang, langer tydshorison, asook die aanwending van meer gevorderde analitiese tegnieke en besluitnemingondersteuningstelsels.

‘n Omvangryke literatuurstudie, gevolg deur empiriese navorsing binne die Suid-Afrikaanse petrochemiese industrie, vorm die grondslag vir die gevorderde voorsieningsketting-beplanningsprosesse afgelei in hierdie proefskrif. Semi-gestruktureerde onderhoude (met ‘n vraelys) is gevoer met ‘n goed-ingeligte belangegroep, en het die basis vir die empiriese navorsing gevorm. Die toepaslike beste praktyke, konsepte, benaderings en vlak van gevorderdheid in voorsieningskettingbeplanning binne drie prominente dimensies is hieruit afgelei.

Die proefskrif voorsien ook ‘n roetekaart aan grootskaalse petrochemiese ondernemings wat hulle kan lei in die aanwending en implementering van hierdie gevorderde voorsieningskettingbeplanningsproses raamwerk. Die roetekaart dui aan: gevorderdheid van stadiums, dimensies, eienskappe, en snellers vir vooruitgang. Die tipiese eienskappe gekoppel aan gevorderdheid en beplanningsdimensies, kan ondernemings help om hul stadium van vooruitgang te peil. Belangrike meganismes wat aangewend kan word om beplanningsintervensies te ondersteun, word ook uitgewys.

Sleutelwoorde: Besluitnemingsondersteuningstelsels, Bestuurswetenskap, Gevorderde beplanning, Ondernemingswye voorsieningskettingbeplanning, Voorsieningskettingbeplanning, Voorsieningskettingprosesse, Operasionele navorsing, Petrochemiese industrie.

ACKNOWLEDGEMENT

I wish to express my gratitude to the following persons who made it possible, and supported me, to complete this dissertation:

Prof Wessel Pienaar, my promoter, for his support, guidance and input to this work.

Mrs Mara Visser and Ms Este Strauss, librarians at JS Gericke Library (University of Stellenbosch), for their effective literature searches.

Participants to the empirical research for their willingness to participate and the highly valued contributions made (Participants listed in Chapter 5).

To Sasol, my employer, for allowing me to complete this dissertation on a part-time basis and funding of the associated costs.

To Benita, my wife, and sons, Jaco and Ian, for their emotional support and tolerance throughout this dissertation.

To Erick Louw, my late father, for his continued belief in me and his encouragement during all my further studies. Dad, I dedicate this dissertation to you.

"Everything comes from God alone.
Everything lives by His power,
And everything is for His glory."
Romans 11:36 (Living Bible)

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Chapter 1: Introduction

Effective supply chain planning is one of the critical ingredients for effective supply chain management. Following a supply chain approach, companies can use integrated planning processes to proactively align the channel partners (internal and external) towards common objectives. Supply chain planning processes support long-, medium- and short-term decision making across the different segments and stages in the supply chain. Seeking for a global optimum, and translating these decisions into feasible tactical and operational plans, assures that the stage is set for world class supply chain execution. Companies with mature supply chain planning processes are far more profitable, hold much less inventory, and have superior delivery performance compared to their less advanced competitors. Large-scale integrated petrochemical companies pose some very specific supply chain planning challenges and opportunities not adequately covered in the generic supply chain literature. This dissertation aims to address the most pertinent of these shortcomings and thereby contribute to the petrochemical supply chain body of knowledge.

This chapter aims to provide the basic supply chain orientation, relevancy and rationale for this dissertation. The major points covered include: a supply chain approach, logistics- and supply chain management definition, the changing business environment, supply chain strategy, planning, supply chain trends and best practices, organisational change, and decision support systems. Subsequent chapters will cover these points in more detail. The purpose, demarcated scope and structure of the dissertation is also outlined.

1.1 Orientation

The following paragraphs provide a basic orientation regarding supply chain theories, practices and approaches. Related literature will provide the reader with the relevant orientation and put the topic of this dissertation in context. The following will be covered:

- Supply chain as a business approach/philosophy
- Logistics and supply chain management orientation
- What constitute business strategy, supply chain strategy and planning

1.1.1 Supply chain approach

A business's value chain provides the context for its supply chain. The original idea of the value chain is based on a process view of organisations. This process view approaches a manufacturing (or service) organisation as a system, made up of subsystems each with inputs, transformation processes and outputs (Porter, 1985:37). The value chain identifies nine strategically relevant activities that create value and costs in a specific business. These value activities are divided into two broad types (relate to Figure 1.1):

- ***Primary activities*** are involved in the physical creation of the product, its sale, its transfer to the buyer and its after-sale activities. Primary activities are divided into five generic categories, namely inbound logistics, operations, outbound logistics, marketing and sales, and service.
- ***Support activities*** provide support for the primary activities and for each other through purchased inputs, technology, human resources, and various company activities. Secondary resources are divided into procurement, technology development, human resource management and company infrastructure.

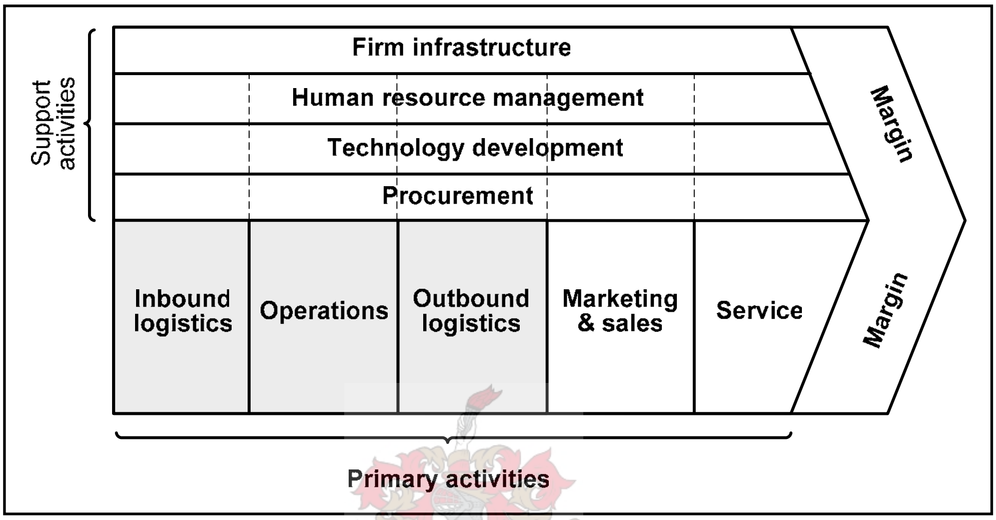


Figure 1.1 : The generic value chain model
[Source: Porter, 1985:37]

A supply chain (viewed as a supply chain of petrochemical products within this dissertation) is the physical representation of a business's value chain. The supply chain forms a critical part of a business's value chain since it covers three of the five primary activities (i.e. inbound logistics, manufacturing and outbound logistics). A strong interface with marketing and sales, as well as service activities, are required to focus the supply chain on the customer's requirements. Many of the physical operational activities in a supply chain could be outsourced (e.g. logistics services, toll manufacturing). Apart from the external suppliers of raw materials, these outsourced parties typically become supply chain partners in the true sense of the word.

Mentzer (2001:2) defines a supply chain as a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer.

A firm's supply chain is predominantly focused externally toward its customers and not just internally focused on its own processes. Supply and demand balancing forms the basis for an aligned value chain.

The supply chain is also often represented as a network similar to the one represented in Figure 1.2. The supply chain network is represented by nodes (facilities) and connected through links that represent direct transportation connections (Shapiro, 2001:4&5). The structure of a supply chain is thus made up of:

- geographically dispersed facilities (where raw materials, intermediate products, or finished products are acquired, transformed, stored, or sold):
  - o *plants* (manufacturing facilities where physical product transformations take place),
  - o *centres* (intermediate facilities) - where products are received, sorted, put away in inventory, picked from inventory, and dispatched but not physically transformed, and
- transportation links that connect facilities along which products flow.

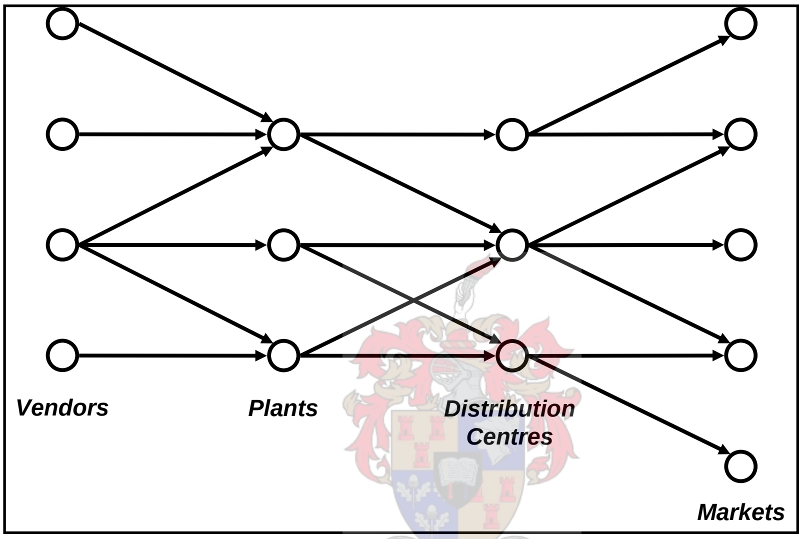


Figure 1.2 : The supply chain represented as a network
[Source: Shapiro, 2001:6]

The supply chain deals with the cycle processes that support the physical, information, financial and knowledge flows for moving products and services from suppliers to end users. Different stages in the supply chain (with different players) are involved, directly or indirectly, in fulfilling a customer's request. These stages include; customer retailers, wholesalers/distributors, manufacturers, and component/raw material suppliers (Chopra & Meindl, 2001:3).

With a broadened supply chain perspective (inter-company cooperation) the supply chain is considered as an extended enterprise and similarly suggests that firms within the entire chain should focus their sequential but cumulative efforts on quality, dependability, flexibility, agility, and finally, cost-efficiency (Chapman et al., 2002:60). The extended enterprise forms the basis of how supply chains may pursue objectives for each of these priorities. Supply chains will compete against supply chains on the same merits that independent firms compete with each other, with the goal of maintaining their competitiveness within a highly dynamic market comprised of rapidly-changing customer requirements (Vokurkca, Zank & Lund III, 2002:14). Figure 1.3 provides a typical integrated view of the extended supply chain.

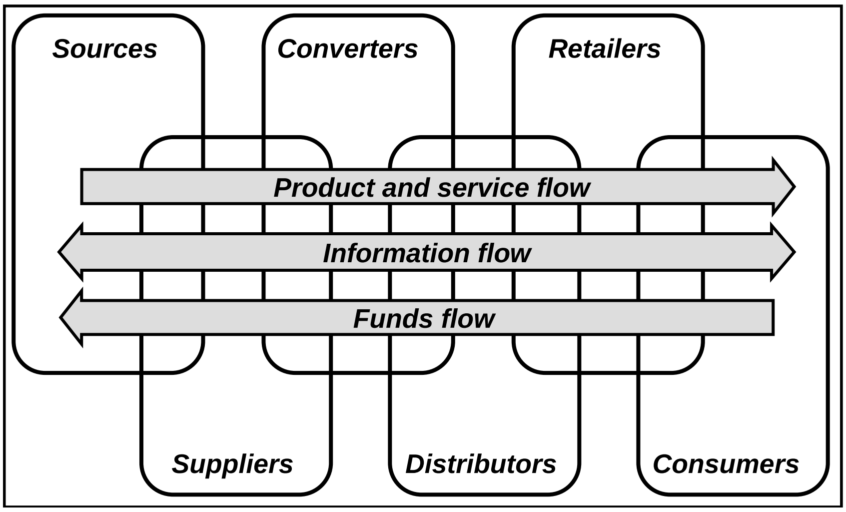


Figure 1.3 : The extended enterprise and the virtual supply chain
[Source: Christopher, 1998a:266]

As with most asset-intensive manufacturing organisations, some sections of the supply chain can either be linked to the direct or indirect value chains (Figure 1.4). In petrochemical companies the ***direct supply chains*** primarily deal with the supply of feedstock, intermediate and final refined products for the end customer. Indirect supply chains on the other hand deal with the supply of hard goods, spares and maintenance equipment for the asset management functions of an enterprise. This dissertation primarily focuses on the direct supply chains. The direct supply chains in a petrochemical business also relate to the supply chain stages/segments ***upstream*** and ***downstream*** of the refineries.

Figure 1.4 also details the typical goods and services required in the direct and indirect supply chains. The demand for logistical services required in the inbound and outbound legs of the supply chain is also dependant on the demand and requirements for feedstock and final products.

The logistics and supply chain concept evolved over time. Logistics originated in military applications and then moved to business logistics application (Pienaar, 2005:79) whereas supply chain started in the textile industry with concepts such as Quick Response (QR), Efficient Consumer Response (ECR), and Continuous Replenishment Planning (CRP) (Lummus, Krumwiede & Vokurka, 2001:427). According to Stuart (1996:18) the difference between supply chain and logistics is that the supply chain has a much wider scope and extends well beyond the organization's borders. Frazelle (2002:8) positioned the supply chain as the network with logistics being the game played in the supply chain arena.

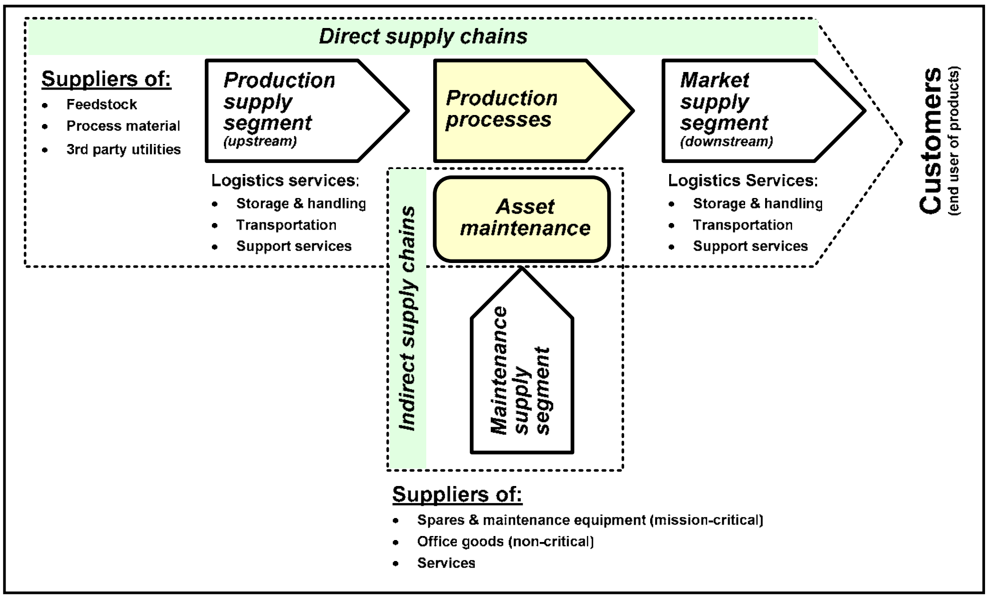


Figure 1.4 : Focus of indirect and direct supply chains

[Source: Adapted from i2 Technologies: 2001]

1.1.2 Logistics- and supply chain management orientation

With the emergence and popularity of Supply Chain Management (SCM), many different definitions were formulated. For the purpose of orientation, a few prominent viewpoints and definition are briefly screened.

According to Zsidisin, Ragatz & Melnyk (2005:48), SCM already emerged as a business concept in the late 1980s, and was the product of several independent developments. These developments include: (a) the emergence of the never-satisfied customer, (b) the shrinking of product life cycles, and (c) the emergence of newer, faster, and cheaper computer hardware and software. Together, these three developments have advanced the concept of supply chain management by encouraging managers to rethink their reliance on owning and controlling operations internally.

The Council of Supply Chain Management Professionals (CSCMP, 2005) defined Logistics- and Supply Chain Management as the following:

> "Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies."

> "Logistics Management is that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements."

According to Christopher (1998a:16-17), logistics management is primarily concerned with optimizing flows within the organization. Supply chain management recognizes that internal integration by itself is not sufficient. Logistics management is essentially a planning orientation and framework that seeks to create a single plan for the flow of product and information through a business. Supply chain management builds on this framework, and seeks to achieve linkage and coordination between processes of other entities in the pipeline (i.e. Suppliers, customers and the organization itself).

The constituent parts of SCM are the (a) the supply chain; the flow and transformation of raw materials into products from suppliers through production and distribution facilities to the ultimate consumer and (b) management; the process of developing decisions and taking actions to direct the activities of people within an organization - planning, organizing, staffing, leading, and controlling. Supply chain management is the process of developing decisions and taking actions to direct the activities of people within the supply chain toward common objectives (McCormack & Johnson, 2001:34).

Supply chain management links all the partners in the chain, including departments within an organization and the external partners, including suppliers, carriers, third-party companies, and information system providers (Lummus, Krumwiede & Vokurka, 2001:429). According to Johnson, Marsh & Tyndall (1999:88) SCM is concerned with the management of the following flows:

- Materials and products flows
- Information flows
- Cash flows
- Processes and workflow

The principles of SCM are of concern to all manufacturing and service provision within organisations, from strategic planning to operations on the shop floor, and to external relationships or operational environments which influence the ability to satisfy 'customer' needs. (Wynarczyk, 2000:124)

Supply chain synthesis is also an approach to enable SCM. Supply chain synthesis is a holistic, continuous improvement process of ensuring customer satisfaction from the original raw-material providers to the ultimate finished-product customer (Tompkins, 2000:77&79). The foundation for supply chain synthesis is grounded in grasping integration (total integration, blurred boundaries, consolidation, reliability, maintainability, and economic progressiveness) as well as grasping change (flexibility, modularity, upgradeability, adaptability, selective operability, and automation supportability).

A key point in supply chain management is that the entire process must be viewed as one system. The performance of each member of the supply chain affects the overall performance of the whole supply chain (Lummus, Krumwiede & Vokurka, 2001:428). All functions that are part of a company's value chain contribute to its success or failure (Chopra & Meindl, 2001:27). Functions do not operate in isolation; no one function can ensure the value chain's success. Failure at any one function may lead to the failure of the overall chain.

Inventory availability is a key determinant of how well a logistics channel runs, because “inventory makes logistics go 'round” (Frazelle, 2002:91). The emphasis is not only on minimising transportation cost or reducing inventories, but rather on a systems approach to logistics management (Bramel & D. Simchi-Levis, 1997:3).

The objectives for SCM are to minimize total supply chain cost, maximize net revenues (gross revenues less total cost) and achieving non-monetary objectives, such as customer service, product variety, quality, and time (Shapiro, 2001:8&9). The traditional objective of SCM is to minimize total supply chain cost for given demand. These costs include:

- Raw material and other acquisition costs
- Inbound transportation costs
- Facility investment costs
- Direct and indirect manufacturing costs
- Direct and indirect distribution centre costs
- Inventory holding costs
- Inter-facility transportation costs
- Outbound transportation costs

1.1.3 Business strategy, supply chain strategy and planning

A ***business strategy*** sets the tone for supply chain strategy. This is specifically true in relation to long term planning. In large scale diversified corporations, planning takes place at various levels (Robinson, 1986:31). These definition and planning decisions run across the following levels:

- ***Corporate level*** (corporate purpose & direction; common corporate mission & composite mission per business unit)
- ***Business level*** (top management, middle management & operating management)
- ***Programme level*** (portfolio planning for resource allocation)

The strategic plan is the process of identifying the long term goals of the entity and the broad steps necessary to achieve these goals over a long-term horizon (De Villiers, 1994:6). Strategy planning should at least address the following three questions:

- Who are we? – Corporate mission statement
- Where do we want to be? – Vision
- How are we going to get there?

According to Evans & Danks (1998:32) three other key issues for business strategy are (provide the basis for competition; related to marketing):

- What products/services should the firm sell?
- What customer segments should the firm serve?
- In what graphical markets should the firm operate?

It is important to achieve strategic fit between the competitive strategy, the product development strategy, and marketing and sales strategy (Chopra & Meindl, 2001:27-40). The supply chain strategy should align with these strategies and also address the supplier strategy, operations strategy, and the logistics strategy. This is achieved through the thorough understanding of the customer (key customer demand attributes and implied demand uncertainty) and by understanding the supply chain (responsiveness / efficiency). Other issues affecting strategic fit are: multiple product and customer segments, product life cycle, and competition change over time.

Acur & Englyst (2006:87) identified three phases in strategy formulation: strategic thinking; strategic planning; and embedding of strategy. The success criteria are mostly associated with effective embedding. A successful strategy formulation process should meet the following success criteria:

- Develop awareness, draw on self-criticism and, not least, incorporate learning from experience, and facilitate decision-making through an adaptive process.
- State goals, achieve a general level of agreement and establish motivation and confidence that the business will be more successful as a result of realising specified plans.
- Assign responsibilities, establish a shared understanding of strategic objectives and priorities at all levels, and co-ordinate the flow of objectives, measures and actions from high to low level.
- Use open lines of communication, involve staff in decision-making, avoid overlapping and conflicted development, and trade off strategic choices to optimize business performance.

Smart businesses are elevating and aligning their ***supply chain strategies*** to the core business strategies. They have come to realize the role that a superior supply chain can play in improving shareholder value (Gattorna & Hanlock, 1999:5).

As indicated in Figure 1.5, the alignment of the supply chain strategy with the business strategy should at least cover the customer service strategy, demand flow strategy, sourcing strategy and supply chain integration strategy.

With reference to Figure 1.5, the following explains the four key related strategies and supporting mechanisms in a bit more detail (Evans & Danks, 1998:32):

- ***Customer service strategy***
  - Supply chain segmentation (customers, product, geography)
  - Cost to serve (ABC costing)
  - Revenue management (market share, price premium, customer behaviour)
- ***Demand flow strategy***
  - Market channel design (direct, wholesaler, retailer, dealer/distributors)
  - Demand planning (level of products and inventory requirement)
  - Supply chain configuration (number, location and role of each supply chain partners)
- ***Sourcing strategy***
  - Make/buy (should we buy/make)
  - Capacity management (where must plans/suppliers be located)
  - Manufacturing management (how production is organized and managed)
- ***Supply chain integration strategy***
  - Integration across the supply chain (degree/extent of integration)
  - Different types of supply chain integration:
    - Information integration (share useful information)
    - Decision integration (planning and control). Decision integration supports the planning and control function of management across multiple firms within the supply chain.
    - Financial integration (terms and conditions)
    - Operational integration (share physical assets)
  - Physical/virtual integration

Supply chain strategies should aim to reduce risk related to exchange rate, duties, government reactions and political instabilities (D. Simchi-Levi, 2000:76). The five fulcrum points to create a deliberate supply chain strategy as a driving force behind the business strategy relate to the following (Helming & Zonnenberg, 2003:2):

- ***Supply chain configuration*** (For different customer segments and different product families, a thread runs backwards from the customer through the delivery, manufacturing and source activities. A key decision in supply chain configuration area relates to asset ownership)
- ***Enabling practices*** (To ensure customer service and supply chain performance)

- ***Strategic relationships*** (This include customers and suppliers)
- ***Organizational*** (Ownership in the wider sense of the supply chain)
- ***Information technology*** (Advances in supply chain planning and managing software)

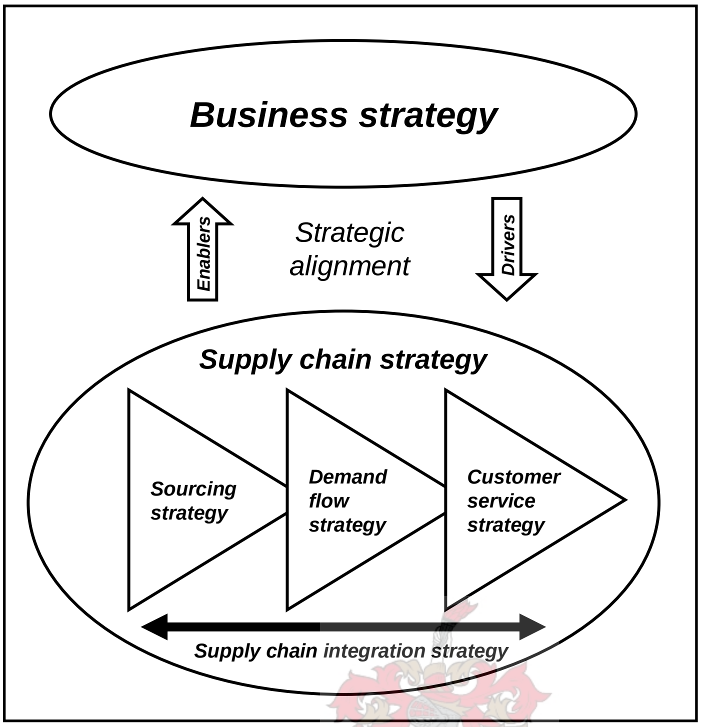


Figure 1.5 : Achieving alignment between supply chain and business strategy [Source: Evans & Danks, 1998:33]

The operational strategy formulation, as part of the supply chain strategic planning process, can be understood from a macro level as a four-step process (Hicks, 1999:28). After considering customer demand, these different steps to make the big decisions include: network optimisation, network simulation (determine how well a proposed supply chain will run), policy optimisation, and design for robustness. The following describes these underlying aspects of the key decisions:

> ***Network optimization***: The basic structure of the network should be determined. The task of structural design means being able to evaluate millions of potential structures and selecting the least-cost network. This is exactly what network optimization models do very well. Utilizing huge math models and highly advanced solution-finding technologies, network optimisation tools have been used widely for strategic planning.
>
> ***Network simulation***: When it comes to finalizing the proposed design or selecting which network design is best out of three or four alternatives, it is necessary to establish how each design will operate in the real world with all its variability. Network simulation is used for this evaluation. Detailed and accurate modelling determine how well a proposed supply chain will run (Predominantly with discrete-event simulation modelling).
>
> ***Policy optimization***: Once a network design is finalized, the task is to come up with the best operating rules (policies) for the supply chain structural objects to follow.

Policies include rules about whether or not inventory should be kept for various products: for example, if full truckload shipments suffice or if less than truckload shipments are needed to achieve the necessary customer service; if the company should make or buy components for each product and main sub-assembly.

Design for robustness: In design for robustness, an effort to is made to evaluate if there are undesirable things that might happen (unplanned events). A robustly designed supply chain will ensure a company's survival under nearly any circumstance.

1.2 Relevancy, related previous work and reason for the dissertation

Gattorna & Hanlock (1999:7) indicate that a superior supply chain has the potential to significantly increase shareholder value through reduced cost, shorten process cycles, and improved communication. Revenue can also be enhanced through customer service, improved responsiveness and differentiation in the market.

Supply chain management costs represents anywhere from three up to fifteen percent of a company's revenue. Distribution costs alone can account for up to fifteen percent of total business costs (Redmond, 1998:49). Companies doing well in its supply chain operations could have a fifty percent cost advantage over its competitors (Murphy & Sherman, 1998:60; Quinn, 1998:39; Mentzer, 2001:337).

Companies that have mastered the "efficient and reliable" stage of supply chain maturity, now look at supply chain as a key differentiator. This naturally leads them to depart from the one size fits all supply chain to explore sector and product-specific supply chain organizations and processes that quickly react to changes in market trends (Brosset, 1999:26).

Supply chain managers in all too many companies are being left behind. They are sucked into the efficiency trap focusing on cost reduction rather than the revenue growth and strategic advantage (Copanico & Byrnes, 2001:32). Supply chain mastery will become the decisive winning factor in most battles for customer market share. The most progressive companies will move from an internally focused cost reduction strategy to an externally focused revenue enhancement one (Taylor & Terhune, 2000:42).

Competitive advantage can be gained through proper supply chain management in the following manner (Jones & Riley, 1992:91):

- recognizing end-user customer service level requirements;
- defining where to position inventories along the supply chain, and how much to stock at each point;
- developing the appropriate policies and procedures for managing the supply chain as a single entity.

Research has shown that aligning-, re-defining-, and integrating key supply chain planning processes could unlock substantial business benefits (Supply-Chain Council, 2000:39). This allows for these types of initiatives (also with enabling technology) to have payback periods of less than one year. Table 1.1 indicates typically achievable benefits across industries.

Table 1.1 : Supply chain enhancement benefits
[Source: Supply-Chain Council, 2000:39]

Delivery performance	16% – 28% Improvement
Inventory reduction	25% – 60% Improvement
Fulfilment cycle time	30% – 50% Improvement
Forecast accuracy	25% – 80% Improvement
Overall productivity	10% – 16% Improvement
Lower supply-chain costs	25% – 50% Improvement
Fill rates	20% – 30% Improvement
Improved capacity realisation	10% – 20% Improvement

1.2.1 Changing business environment and supply chain trends

According to Shapiro (2001:25) most companies are undergoing radical change. These major changes being experienced include globalization, e-commerce, enterprise resource planning systems, business process re-engineering, organizational learning and change management, and integrated supply chain management.

The markets served by businesses have become more volatile and hence less predictable (Chapman et al., 2002:59). Just-in-time practices have increased vulnerability of supply chains (risk of supply chain disruptions, internally or externally). Supply chain complexity is increasing and supply chains are getting increasingly lengthy. Christopher (1998a:23) indicates that the logistics environment has also been faced with increasing customer service expectations, time compression, globalization of industry, as well as organizational integration.

Supply chain management has emerged as one of the major areas for companies to gain a competitive edge (Lee, 2002:105). Managing supply chains effectively is a complex and challenging task due to the current business trends of expanding product variety, shorter product life cycles, increased outsourcing, globalization of businesses, and continuous advances in information technology.

Supply chain complexity has increased, and products and channels have become more divergent (Cecere, 2006). Each supply chain has its own rhythm that needs to be studied and refined for optimum response. As supply chains develop, they increase in complexity. The number of linkages to be managed increases and communication of a common goal becomes more difficult. Supply chain members have also become more dependent on each other (McAdam & McCormack, 2001:118).

A growing number of large firms are rationalizing and decentralizing their operations by retaining core skills and drawing their additional needs from the market place. In the process they are moving to a more distributed method of production, encompassing all activities from upstream raw material input to downstream distribution of final goods, commonly referred to as, for example, extended enterprise, supply chain tunnels, lean production, and supply chain network (Wynarczyk, 2000:123). It has also been argued that new information, and production and managerial technologies are changing the balances of transition costs. This new form of organizing production is networked structures based on specialisation and interdependencies between partner businesses in the supply chains. An increasing number of enterprises are becoming part of supply chains. Their performance are influenced by not only the overall management of supply chain activities, but also by business and enterprise culture, sector, and markets specific legislation and regulations within, with whom they interact and operate.

According to AMR, the basis of competition for winning companies in today's economy has become supply chain superiority (Friscia, O'Marah & Souza, 2004:2). Supply chain leadership means more than just low costs and efficiency; it requires a superior ability to shape and respond to shifts in demand. AMR Research calls this new model for value chain excellence the Demand-Driven Supply Network (DDSN). DDSN replaces the push model of the 20th century factory-based business with a customer-centric pull model that embeds product innovation, manages demand proactively, and utilizes stochastic optimization methods to deal with variability (see Figure 1.6).

The new competitive paradigm places the firm at the centre of an interdependent network – a confederation of mutual complimentary competencies and capabilities – which competes as an integrated supply chain against other supply chains. The key focus is on network management and integrated processes. This requires collective strategy development, win-win thinking and open communication.

There is also a shifting focus from value chains (Porter's model) to value groups and value networks which enables new value creation (IBM, 1999:11). Value groups are more modularized with processes, skills and tools formed in value add processes, value support processes, and enabling processes. Value networks/clusters are a number of value groups linking upstream, intermediate, and downstream value groups.

The chemicals industry is at an "inflection point" in supply chain and manufacturing capability. The traditional focus on optimising functional areas won't be enough to maintain and sustain profitability.

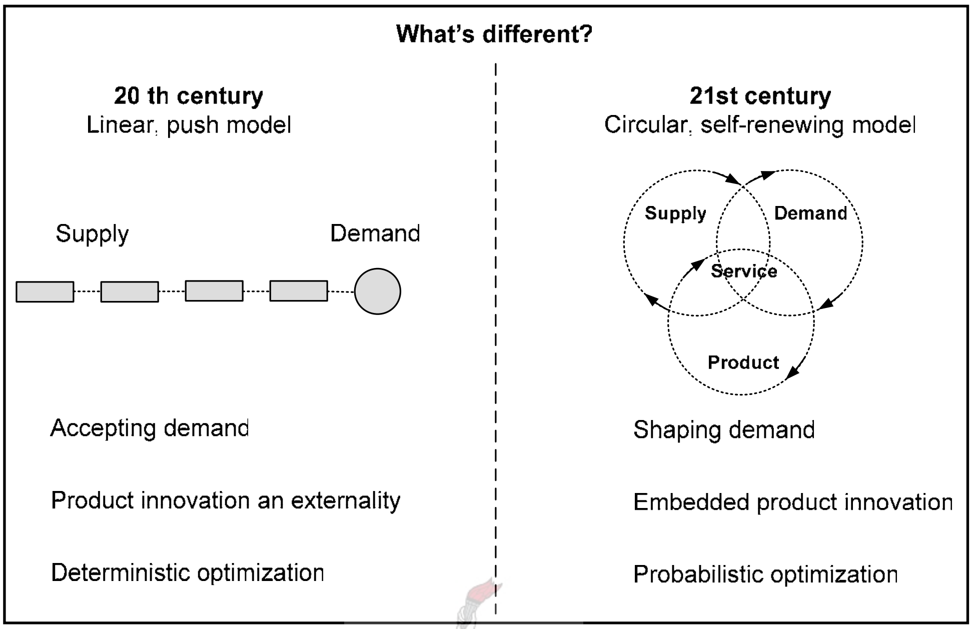


Figure 1.6 : DDSN in the 21st century supply chain
[Source: AMR Research, 2004:3]

Companies in the bulk chemicals industry continue to encounter hurdles that may slow their sustained growth and profitability (Aspen Technology, 2003:3). This is driven by factors including petrochemical cycles, the emerging dominance of international competitors, increased customer expectations, commodity price pressures, and stringent environmental and safety requirements. To address these issues, chemical companies must achieve a number of critical things:

- They must have active visibility of the enterprise and identify events that require action
- They must have the agility to react dynamically to unplanned events and make profitable decisions based on real-time accurate information
- They must execute reliably and deliver on time to maintain customer loyalty
- They must produce and deliver high quality products at low cost and high operating rate
- They must ensure KPIs are monitored, managed, and improved

The Petroleum industry's thinking about the supply chain is still in its infancy (Schwartz, 2000:50). It is a victim of the silo mentality. Breaking down existing silos may be tough because the oil industry is organized around highly specialized business processes/units which encourage fragmentation. This industry has formed into silos which are very confidential with their information. These business silos don't unify demand and full cost data across functions.

1.2.2 Organizational changes needed

Managing the supply chain with conventional organizations is a problem (Christopher, 1998a:216-217). The major barrier to a supply chain approach is organizational. Most companies are organised on a functional basis. Functions managed by senior managers that guard their territory inevitably leads to inventory built up at functional boundaries, the pipeline costs (to the customer) are not transparent, these functional boundaries impede process management, and conventional organizations present many faces to the customer.

Another problem with traditional firms is that they are primarily short-term focused (Demming & Petrini, 1992:9). A short-term planning horizon results in constant fire fighting. It does not support a proactive approach that anticipates and solves problems before they become expensive.

Bonner (2001:18) also indicates that many companies are still organized into functional areas. While it can be argued that such a structure gives in-depth knowledge in a particular area, it can also be argued that it promotes an "island" mentality. It is readily apparent that communication, cooperation and coordination between these functional areas is sadly lacking, with the emphasis on ensuring performance at the "local" level. According to Jones & Riley (1992:99) the barriers to a supply chain management approach include tradition, organizational, legal and non-integrated management systems.

Historically, business has been managed around two focus areas: customers and operations. Customer-facing organizations work mainly from the business plan; work through the sales force; want flexibility; and avoid negative exceptions to customer satisfaction. An operations-focused organization is driven by production demand; wants a cost effective service; expects minimal levels of inventory; and hates SKU proliferation. However, customers and products should not be viewed by volume/revenue but rather by profitability – and then integrate the customer-facing and operations focused parts of the organization (A new way to maximize contribution). Only 13% of leading companies report having consistent linkage between customer-facing and operations-focused parts of their organization (working together does not come naturally) (Sabath, 2003:62).

The key features of leading edge logistics organizations are the following (Christopher, 1998a:257):

- Overriding commitment to customers
- Emphasize planning
- Encompass significant span of functional control
- Commit to external alliances with service suppliers

- Have highly formalized logistics processes
- Place a premium on operational flexibility
- Employ comprehensive performance measurement
- Invest in state of the art information technology

1.2.3 Decision making and supply chain planning processes in the spotlight

It is no longer appropriate to base decisions and actions only on prior experiences and assumptions. Decision-making must become fact based. Measurements must be across company boundaries and provide information on overall supply chain performance (Vakurka & Lummus, 2003:55). Because organizations depend on the measurement and analysis of performance, measurements must derive from the organization's strategy and provide critical data and information about key processes, outputs and results. Supply chains need to share and take action on data and information, not assumptions and emotions. Performance analysis and problem solving must be based on reliable and relevant information.

According to Pienaar (2005:71) the decision-making process should assure that decisions reached are quantitatively sound and did consider the various tradeoffs (costs & service) and coordination involved.

King & Wright (2002:24) states that broken supply chains are cemented together with stock so that the cracks do not show. Fundamental structural problems are thus avoided. The point of fracture of most supply chains is the connection between demand management and supply management.

Long- and short-term tactical supply chain planning has thus far been mainly ignored by managers and consultants (Shapiro, 2001:43). According to Bramel & D. Simchi-Levis (1997:7) managers and consultants typically resort to one of the following for solutions:

- People tend to repeat what has worked in the past
- Use the "rule of thumb"
- Apply the experience and intuition of logistics experts and consultants

Sophisticated decision support systems are now available to optimise logistics and supply chain strategic decision. These systems apply techniques that have been developed in the operations research and management science research communities. An increasing number of managers in a wide range of companies are seeking to manage their supply chains based on facts, that is, data and proper analytical methods (Shapiro, 2001:25).

As supply chains evolve/develop over time and integrating processes become prominent, decision making and a pro-active approach with longer time horizons becomes the norm for excellence. The petrochemical industry, however, still has a lot of ground to cover before it can reach some of the supply chain benefits reported in other industries.

The logical steps in decision making can also be viewed to comprise the following to encapsulate the interaction between information systems and decision modelling (Koutsoukis et al., 2000:642):

a) Data (-base) modelling involves defining relationships between data items leading to a relational data model, or identifying categories that are then used to define multidimensional tables, leading to a multidimensional database.

b) Decision modelling involves the development of models that are used for decision-making. (not only linear, nonlinear, or discrete optimization models; also simulation, cluster analysis, for costing, data mining and other analytical models)

c) Model analysis and investigation involves descriptive analysis of the results; this leads to insight, and knowledge in respect of a given decision problem.

A mix of optimization techniques, common sense, business-best practices, and political savvy are required to develop and implement a workable solution. There are typically plenty of common sense, best practices, and political savvy to go around in most organizations. What is often lacking are the analytical resources required to model and solve logistics problems (Frazelle, 2002:15).

Business will not continue to succeed or prosper unless it continues to offer good customer service in the form of accurate delivery commitments and supply chain streamlining. In a complex environment, these tasks cannot be executed successfully without optimization engines (proper analytical tools) to enable them (Peterson, 1999:2). Quantitative models provide companies with decision support as well as insight for better management of supply chains (Keskinocak & Tayur, 2001:70).

But how does this apply to the decisions that need to be made in the supply chain? Supply chain management is about, “Getting the right product, at the right place at the right time”. Supply chain planning decisions is about determining, “Which is the right product, where is the right place, and when is the right time?” (Stemmet, 2002:4). The latter is the prime focus for supply chain planning in this dissertation.

1.2.4 Supply chain planning

Supply chain planning is rapidly gaining attention as a key differentiator for companies in an increasingly competitive global environment (Shen, Lee & Van Buskirk, 2001:68). Koutsoukis et al. (2000:657) indicate that strategic planning and operational management of supply chains are two leading decision problems in supply chain management. According to Mulani (2001:27) advanced planning has now gone well beyond the factory and into the supply chain. Enterprises now use integrated planning processes for the sole purpose of building a master plan for procurement and supply.

The benefits of adopting supply chain management and advanced planning cannot be achieved by one company alone, due to a companies' focusing on its own core competencies. This brought about new challenges for the integration of legal separate firms and the coordination of material, information and financial flows not experienced in this magnitude before. To a large extent, this then encompasses the new supply chain management philosophy. (Stadtler & Kilger, 2000:1).

According to results of a supply chain benchmarking study conducted by The Performance Measurement Group (PMG), well-developed supply chain planning processes are critical to achieving a competitive advantage (Wawszczak, 2003). The study shows that companies with mature planning practices are 38% more profitable than average companies, 22% lower levels of inventory and 10% greater delivery performance. The companies that combine mature planning processes with advanced planning systems gain added performance improvements (e.g. including 27% greater profitability).

> *"Planning drives the supply chain. It orchestrates the flow of materials and resources, getting them to the right location at the right time, in the right sequence. Effective planning balances demand and supply, internal and external objectives, all in a constantly changing environment. Mastering supply chain planning can provide a major competitive advantage".*

The removal of national barriers to international trade, combined with the increased sophistication of the customer, means companies must integrate now. Too much emphasis is placed on Information Technology (IT) led integration with insufficient attention given to the physical network, process and management methods, third party alliances or organizational structure. The potential benefits of full integration have not yet all been achieved. The biggest barriers to modifying a company's logistics systems are internal and people related. The change process is left unmanaged ten times out of ten. The principal source of resistance to change is employee attitude (Ribbers, 1994:26).

The chemical industry is still faced with the required shift in their supply chain focus from integrating internally to integrate across overall enterprises and from suppliers to end-customer (Boulanger & Eckstut, 2000:11). Although companies believe that SCM can help their competitive drive, they recognize the tension that exists between SCM's competitive enhancement potential and the inherent difficulty of collaboration. Establishing seamless processes that bridge organization boundaries are an appropriate goal, but establishing them is anything but easy (Fawcett & Magnan, 2002:360).

1.2.5 Technology, systems and advancement

Many companies, across many industries, have reflected a need for tools and technologies that can help move strategic decisions into a fact-based approach. The tools and techniques that perform this function are, in fact, the next generation of supply chain software applications. These tools will leverage the data provided by IT, but will use powerful engineering and operations research algorithms to move supply chain strategic planning decisions into an orientation of an operational supply chain strategy (Hicks, 1999:27).

Gattorna & Hanlock (1999:6) states that technology tools are enhancing the capabilities of managers to make decisions within their own companies and between the organizations that comprise an industry's supply chain. Companies started to realize that they need a new generation of decision support system to filter the rivers of information now available. They will have to transform that information into constructive action (Greis, Olin & Kasarda, 2003:19).

Industries will continue to evolve from vertical silos of production and distribution to dynamically assembled and disassembled communities of resources and partnerships (Peterson, 1999:4). Supply chain planning tools will be used to manage, coordinate and optimize the various trading partners. Enterprises are moving from Material Requirement Planning (MRP) systems to Advanced Planning and Scheduling (APS) point solutions and onward to inter-enterprise supply chain planning integration.

Peterson (1999:5) also indicates that enterprises operate the various planning applications in a static, stand-alone environment. They start with the optimization of the overall supply chain to determine supply sources and then feeding the results to the factories and distribution centres in a batch or manual mode for local optimization, having little interactive ties between the two. The supply chains are being optimized on a daily or weekly basis, but that plan becomes outdated as soon as an event occurs that changes the plan.

Although spreadsheets have become widely used for supply chain analysis, there are two major problems with spreadsheets based planning (Shen, Lee & Van Buskirk, 2001:69). These problems are the proliferation of spreadsheets and the inherent difficulty of sharing them.

Although the value of an integrated view of the supply chain is compelling, Mitchell (2003:14) indicates that there are still a number of obstacles to true SCM. The following are some of the main obstacles:

***Organizational*:** Traditional performance measures must be redesigned to guide the migration towards cross-functional and cross-enterprise business processes

***Technology*:** Large packaged applications are still geared towards functional groups, i.e.:

- Engineering; computer aided design
- Supply chain; advance planning and scheduling
- Procurement; e-sourcing
- Accounting; enterprise resource planning

Business intelligence: Cost data is littered across multiple systems; Business Intelligence systems are being layered on top.

Bailey (as interviewed by Kelly, 1998:23) indicates that companies have also started to integrate their logistics with sophisticated computer systems. Logistics 'hit a wall' because it was viewing all aspects of the enterprise, such as transport, warehousing or retailing, separately. Companies thought that if they improved the individual aspects of logistics by purchasing better trucks or installing more sophisticated warehousing they would solve their problems, but this did not happen. Recently, integrated information technology has emerged where the primary task is not simply the accumulation of data, but rather the intelligent utilisation of that data. This use of information allows more intelligent business decisions to be made.

From an extensive benefits assessment, it was found that through the qualitative and quantitative benefits of Advanced Planning and Scheduling (APS) systems and other supply chain point solutions, most of the benefits relate to supply chain planning (Compared to supply chain execution). This is largely due to existing applications covering and providing solutions in the supply chain execution domain that are predominantly transactional focused. Supply chain planning was found to be the needed “missing/underdeveloped” link between supply chain strategy and actual operations (Sasol Logistics, 2002a:19).

1.2.6 Drive for supply chain excellence and the application of supply chain best practices

Lummus, Alber & Vokurka (2000:82) indicate that identified and applicable best practices, if implemented, could dramatically improve the overall performance of a supply chain.

Supply chain means much more than “fixing logistics”, it means focusing the organization on its clients and aligning people on critical processes that cut through functional silos. The performance of these critical processes, such as demand management, is directly linked to the tight integration of the supporting information management systems. Experience shows that supply chain excellence requires pulling both those two levers simultaneously (i.e. organizational and enabling technology). Supply chain is about state-of-the-art change management (Brosset, 1999:21)

D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:7) poses the question:

> *"What inhibits a firm to apply best practices to improve their supply chain performance?"*

The answer lies in the following major issues:

- The ***supply chain is a complex network*** of facilities and organizations with different, conflicting objectives,
- ***matching supply and demand is a major challenge*** (this is predominantly due to planning for lead time – time delay between actual realising of demand and committing resources well in advance),
- ***system variation over time*** (due to seasonal fluctuations, trends, advertising and promotions, competitors price strategies), and
- ***many supply chain problems are new*** (shortening of product life cycles, over proliferation of products, significant price declines of product).

With markets and customer expectations changing quickly, supply chain has not only to respond, but to anticipate new trends (Stadtler & Kilger, 2000:317). This is one area where advanced supply chain planning can make a significant contribution. The focus of SCM is changing (IBM, 1999:14). The leaders are focusing on revenue enhancement, diversifying and differentiating while the followers are focusing on cost reduction, standardisation and simplification.

Findings from combined research done by Accenture, INSEAD, and Stanford University, indicated what it means to be a supply chain leader (D'Avanzo, Von Lewinski & Van Wassenhove, 2003:42). ***Key finding one:*** Senior executives at leading companies view supply chains as critical drivers of shareholder value and competitive differentiation. ***Key finding two:*** Leading companies incorporate supply chains into the business strategies and devote significant attention to designing integrated operations models. ***Key finding three:*** Leading supply chain companies build innovation into their operations models, with particular regard to outsourcing, internal/external integration, and matching supply and demand. ***Key finding four:*** Leading supply chain companies rigorously execute against their strategies and capabilities, and they constantly adapt them to changing market needs. They typically drive end-to-end process excellence across the operating model. They foster a process oriented, collaborative culture within and across organizations. They develop company-wide high level metrics.

1.3 Problem statement and objective of this dissertation

An opportunity exists to contribute to this field of study (integrated supply chain planning processes) by tailoring a solution for the petrochemical industry. From the literature study, it became evident that limited supply chain and supply chain planning literature are available that specifically focus on applicable solutions for the petrochemical industry. Most supply chain literature focus on individual supply chain solutions and not the typical interdependencies found between petrochemical supply chains. Since the nature, dynamics, business drivers, competitive pressures and challenges applicable to supply chains in the petrochemical industry differ substantially from other industries, a tailored solution could add new knowledge to this field of study.

The primary objective of this dissertation is to extract, compare and relate the relevant available knowledge in this field of study, and relate it to the petrochemical industry's supply chain structures and conduct. This would include contributions from pure academic, consulting practices, technology providers and industry views and business realities. Subsequently, a generic framework of relevant supply chain planning processes will be developed for the applicable supply chain interdependency dimensions found in large scale petrochemical companies. These dimensions relate to the potential value that can be unlocked through supply chain planning process integration and advancement.

The appropriate enabling Operations Research (OR) technique(s) for the relevant supply chain planning processes will be positioned. The relevant categories of decision support systems that utilise these OR techniques, will also be positioned and related to application areas for supply chain planning in petrochemical supply chains.

This dissertation will aim to add knowledge to this field of study, by developing a theoretical supply chain planning framework that could be applied to organizations in the petrochemical industry (ultimately aimed at enhancing their competitiveness). Areas for further research will also be indicated.

1.4 Research methodology

A proper literature study was conducted to capture knowledge gained through relevant studies and appropriate publications. The literature study aims to lay the theoretical foundation regarding a supply chain and supply chain management approach. References cover at least the last decade to relate to the progress made and build on the foundation laid by logistics and supply chain thought leaders. Published and grey literature electronic searches were undertaken to identify published literature in the following journal databases: Emerald, EBSCOhost, Nexus, Compendex, InfoTrac and

Science Direct. This was supplemented through online internet search engines related to the keywords of this dissertation.

Since limited supply chain and supply chain planning literature are available that specifically focus on applicable practices in the petrochemical industry, empirical research was done to obtain more information. The empirical research comprised of the following:

- Semi-structured interviews with identified stakeholders were conducted to clarify best practice, concepts and approaches, followed by key academia, consulting practices, industry leaders and technology providers.
- A questionnaire was used (and completed in the interviews) to assess the level of advancement in the identified planning business processes along relevant different supply chain dimensions.

The literature study and first portion of the empirical research (interviews) form the basis for developing a generic framework of relevant planning processes along the identified supply chain dimensions. The results from the questionnaire indicate the South African petrochemical industry's level of advancement and the potential benefit that could materialise.

Because of the small population size in South Africa related to this dissertation, key stakeholders in the industry were identified and used as a mechanism to support the findings and recommendations. One large global petrochemical company and one large scale related process-industry company, which have substantially advanced in this field, were also approached.

1.5 Demarcation of the field of study

This dissertation is focused on supply chain planning processes relevant to the petrochemical industry. There is a clear distinction made between supply chain planning and execution processes. Supply chain execution processes will be positioned relative to supply chain planning processes but will not form part of this dissertation. As indicated in paragraph 1.1.1, this dissertation focuses on direct supply chains in the petrochemical industry.

The relevant decision support systems (DSS) and related operational research (OR) techniques are positioned. An indication is also given on how DSS and OR can enable and enhance supply chain planning processes. The focus is not to go deep into information technology, but to indicate the high level functionality required. No quantitative models were developed, but a qualitative framing of the OR techniques required were derived.

Large scale petrochemical companies in South Africa are the prime focus of this dissertation. Although the number of these companies is relatively small, their unique challenges are significant. The resulting framework for this dissertation could also be applied to small to medium sized chemical organizations, although they might not be faced with the same complexities than that of large scale petrochemical companies.

1.6 Further breakdown and structure of the dissertation

The literature study is documented in Chapters 1 to 4 and constitutes an extensive repository of related concepts. To assist the reader in navigating through this repository of concepts, an index (at the end of this dissertation) provides an ordered list of the abbreviations, acronyms and terms used with the page numbers on which they are mentioned. The results from the empirical research conducted, are presented in Chapter 5. In Chapters 6 the recommended supply chain planning approach/framework is derived. Chapter 7 provides a roadmap for the application and implementation of the recommended framework. A brief description of the content of each chapter and its focus are presented below and describe the structure and logical flow for this dissertation.

Chapter 1: “Introduction”. This chapter aims to provide the basic supply chain orientation, relevancy and rationale for this dissertation. The major points covered include: a supply chain approach, logistics- and supply chain management definition, the changing business environment, supply chain strategy, planning, supply chain trends and best practices, organisational change, and decision support systems. Subsequent chapters will cover these points in more detail. The purpose, demarcated scope and structure of the dissertation is also outlined.

Chapter 2: “Advanced supply chain planning processes and operations research application” *(part of literature study)*. This chapter establishes the literature study’s primary reference for supply chain planning processes and the related role that operations research applications play. The relevant literature regarding business processes, advancement in business processes and supply chain processes are presented. The supporting operations research and management science applications for decision support are also screened.

Chapter 3: “Decision Support Systems (DSS) and typical roadmaps for interventions” *(part of literature study)*. This chapter examines the relevant literature regarding DSS and roadmaps for executing improvement interventions. Advanced supply chain planning requires the appropriate enabling information technology. The mayor types of DSS are portrayed and positioned. Because supply chain and logistics performance (measured by appropriate metrics) play such a vital role in building sound business cases, a number of paragraphs is devoted to literature findings in this regard.

Roadmaps and strategies for interventions are also screened including the major issues of managing supply chain projects, business case development, organizational development and change management.

Chapter 4: "Overview and challenges of the petrochemical industry; Areas of improvement in integration" *(part of literature study)*. This is the last chapter in the literature review and provides the required orientation about the petrochemical industry. The fundamental differences between process/petrochemical manufacturing businesses compared to other discrete manufacturing businesses are illustrated. Supply chain planning challenges and problems to solve are related to the typical nature, structure, current situation, level of advancement, organizational issues, and opportunities for improvement in the petrochemical industry.

Chapter 5: "Findings and deductions from empirical research". This chapter provides the results of the empirical research conducted. The findings and deductions from the interview questionnaires completed were analyzed, and are presented here. Semi-structured interviews (combined with a limited advancement questionnaire) were conducted with key stakeholders. The purpose of the interviews were to gain better industry understanding, assess appropriate supply chain planning practices and to determine the level of advancement in a number of supply chain planning related areas. Experts and credible participants from the petrochemical industry, consultancy, enabling technology suppliers and academia took part in this empirical research.

Chapter 6: "Synthesis and recommended advance supply chain planning framework". This chapter concludes on what is believed to be an appropriate supply chain planning approach/framework for the decisions faced in large scale, integrated petrochemical companies. The structure of the framework consists of: an appropriate philosophy, concept, guiding principles, typical petrochemical supply chain decisions, the supply chain planning processes themselves and how planning processes should be enabled.

Chapter 7: "Roadmap for the application and implementation of the recommended framework". A proposed roadmap for the application and implementation of the recommended framework is presented in this chapter to guide a petrochemical company along the journey. This roadmap starts by articulating the advancement stages, dimensions, characteristics and motive for progression. Typical characteristics associated with the advancement stages and dimensions provide the means for a company to assess their level of progression. The essential mechanisms that can enable interventions are also articulated. Finally, a roadmap for an intervention related to advance supply chain planning processes is proposed.

Chapter 2: Advanced supply chain planning processes and operations research application

This chapter establishes the literature study's primary reference for supply chain planning processes and the related role that operations research applications play. The relevant literature regarding business processes, advancement in business processes and supply chain processes are presented. The supporting operations research and management science applications for decision support are also screened.

2.1 Business processes and supply chain processes

A number of businesses still view their organizations as a collection of functions, and not as an interrelated system of highly integrated processes (McCormack & Johnson, 2001:34). For companies to compete in the future, they will need to reassess the strategic importance of their processes (new economic models).

A business process orientation emphasizes process (as opposed to hierarchies), with a special emphasis on outcomes. This focuses the organization, for instance on customer satisfaction. A business process orientation's key elements include:

- ***Process management and measurement*****:** Measures that include aspects of the process such as output quality, cycle time, process cost, and variability compared to the traditional accounting measures.
- ***Process jobs*****:** Jobs that focus on process, not functions, and are cross-functional in responsibility (e.g. product development process owner rather than research manager).
- ***Process view:*** The cross- functional, horizontal picture of a business involving elements of structure, focus, measurement, ownership, and customers.

The integration of business processes should address global, regional and local issues across the major business processes, data repositories, systems and ventures. Process owners and sub-process owners must be established and kept accountable on the performance in these processes. The balanced scorecard can be used as a mechanism to roll up performance to management cockpits.

2.1.1 Business processes in general

Processes can be regarded or defined as a series of linked, continuous, managed activities that contribute to an overall outcome (Manrodt & Fitzgerald, 2001:110). Each process has a specific starting and ending point and typically transcends across functional boundaries within a company. A business process can also be viewed as a series of actions directed towards a particular aim (Microsoft Encarta Reference Library 2002).

For two companies to send information back and forth and do business, they need to have a common understanding of their business processes (Hill Jr., 2000:62). This principle plays a vital role in integrating supply chains.

Francis (2004:3) indicated the following benefits of a process focus. It helps to:

- manage the business. (*through visibility of how work actually gets done)*
- compete more effectively. (*the knobs and levers are explicit)*
- create real improvements. (*not just move bottlenecks around)*
- improve multiple areas. (*performance measures are controlled independently)*
- improve coordination between teams (v*isibility of relationships and consequences)*
- streamline and accelerate business change. (*rather than silos of change with unpredictable approach)*

2.1.1.1 Categories of business processes

A vast number of business processes exist in organizations (AMR Research, 2001a). They typically fall in categories related to supply chain management; corporate finance; customer relationship management; business intelligence; knowledge management; security management; storage management; network management; systems management; enterprise asset management; financial operations; financial services; plant management; procurement; product life cycle management ; content management; workforce relationship management. These process categories were later re-categorised by AMR Research (2005) into:

- Compliance and governance
- Demand and revenue management
- Finance and performance management
- Human capital management
- Manufacturing & production operations
- Product lifecycle management
- Service lifecycle management
- Sourcing and procurement
- Supply chain management

According to Bright (2002) major classes of business processes that exist in an organization are:

Enabling processes**:** Covers strategies and business planning processes.

Developing processes: Include developing capability, as well as "balance business development" activity which are more tactical in looking at product/markets and balancing capabilities and physical infrastructure.

Operating processes: Include in "develop and maintain optimization framework" tactical planning through using / building models with longer planning horizons or for particular events.

Supporting processes: There will also be processes that surround the core business processes (e.g. manage finance, manage knowledge, and manage assets).

Hunt (1996:2) indicates that there are mainly three categories of business processes:

Customer processes: Processes that result in product or service that is received by an organization's external customer. Examples include: marketing and sales; product/service development and introduction; manufacturing; distribution; billing; order processing; customer service.

Administrative processes: Processes that produce products or services that are invisible to the external customer but essential to the effective management of the business. Examples include: formal strategic and tactical planning; budgeting; training; facilities management; purchasing; information technology (IT) management.

Management processes: Includes actions managers should take to support the business processes. Examples include: goal setting; day-to-day planning; performance feedback; rewards; resource allocation.

According to Deloitte & Touche (as referenced by Botha, 2003:15), another generic way that organizations can group business processes by using the following categories:

- Manage and lead the enterprise
- Resource to product
- Product to cash
- Procurement to payment
- Manage people
- Manage logistics

APQC (2005) also provides a process classification framework. A distinction is also made between operations processes and management and support services:

Operations processes

Develop vision strategy

Design and develop products and services

Market and sell products and services

Deliver products and services

Manage customer service

Management and support services

Develop and manage human capital

Manage information technology

Manage financial resources

Acquire, construct, and manage property

Manage environmental health and safety

Manage external relationships

Manage knowledge, improvement, and change

According to the author's experience, the following also provide categories of business process activities used by businesses for managing their organisation:

- Business planning and management
- Technology management
- Maintenance management
- Process and operations management
- Marketing, liaison and distribution
- Logistics & supply chain
- Business enabling management (financial, procurement & supply, legal, information technology, insurance, and people management)

2.1.1.2 *Business process approach*

A business process approach is more than work flow (Keen, 1997:17). From the business process re-engineering school of thought, processes can be viewed as:

- "a collection of activities that takes one or more inputs and creates an output that is of value to the customer,"
- "a structured, measured set of activities designed to produce a specified output for a particular customer or market," or
- "a specific ordering of work activities across time and space, with a beginning, an end, and clearly identified inputs and outputs."

The idea of "processes as work flows" - with clearly definable inputs and outputs, and discrete tasks that follow and depend on one another in a clear succession – comes from the tradition of industrial engineering (as the term reengineering suggests). Work flow is only one kind of process, though. Business processes are the key to coordination, rather than for workflow only.

The "process as work flow" definition excludes many processes that have no clear inputs, flows, and outputs. These are examples of other types of processes (not work flow):

- Governing management succession
- Acquisitions
- Manager-staff relations
- Management development
- Incentives and promotions

A business process allows for the sequencing of recurrent processes and back-and-forth interactions between business teams. A process is any work that meets the following four criteria: it is recurrent; it affects some aspect of organizational capabilities; it can be accomplished in different ways that make a difference to the contribution it generates in terms of cost, value, service, or quality; and it involves coordination."

Trying to assess the importance of all a company's business processes can be a mammoth task (Keen, 1997:26). A salience/worth matrix (illustrated in Figure 2.1) can aid in the assessment of what value processes really are. Its primary purpose is to give managers a tool for understanding their companies' processes - an understanding that will enable them to make informed decisions about which processes to invest in, and which kind of investments to make.

Salience	***Worth***	
	Assets	**Liabilities**
Identity		
Priority		
Background		
Mandated		

Figure 2.1: The salience/worth matrix
[Keen, 1997:26]

The "Salience" categories can be defined as:

- ***Identity*** (An identity process is one that defines the company for itself, its customers, and its investors. It differentiates a firm from its competitors and is at the heart of the firm's success.)
- ***Priority*** (Priority processes are the engine of corporate effectiveness. They strongly influence how well identity processes are carried out and where a firm stands relative to its competition.)
- ***Background*** (Background processes are a necessary support to daily operations. Many administrative and overhead functions are background processes.)
- ***Mandatory*** (Mandated processes are those a company carries out only because it is legally required to do so. Regulatory reporting and filing tax returns are obvious examples.)
- ***Folklore*** (Processes that are carried out only because they have always been implemented in the past. As they serve no purpose and create no economic value, they are always liabilities and should be abandoned when discovered.)

The "Worth" categories can be defined as:

- ***Assets*** (any process that returns more money to the firm than it costs is an asset)
- ***Liabilities*** (A process that costs more than it returns is a liability)

Taking a look at all the business processes identified and managed by organisations, one can be overwhelmed by the "Process Swamp" (Keen, 1997:40). (relate to paragraph 2.1.1.1 and Figure 2.2)

Davenport (as quoted by Keen, 1997:41), a thoughtful commentator on business processes, argues that "most companies, even large and complex ones, can be broken down into fewer than twenty major processes" (E.g. Dow Chemical, has nine). Andersen Consulting has also published a database that identifies 170 important business processes. It is thus important for a firm to identify the major processes. "Major business processes" are those processes that have, or might have, an important impact on a firm's value and associated success. Determining the salience (importance) of a given business process involves the following sequential elimination (see Figure 2.3):

- If the process is not an identity one, is it priority?
- If not priority, is it background?
- If not background, is it mandated?
- If it is none of these, it must be a folklore process.

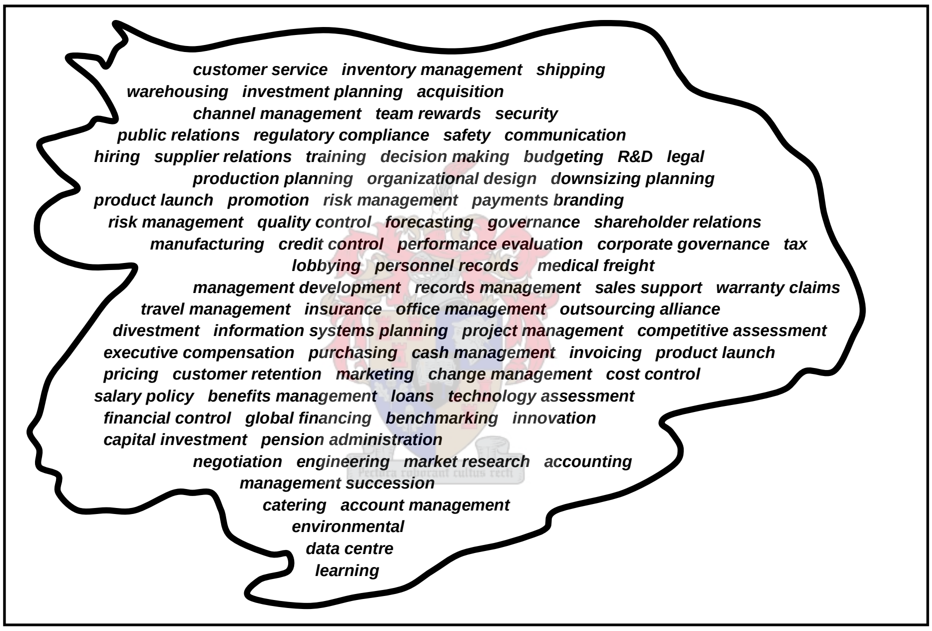


Figure 2.2 : The process swamp

[Source: Keen, 1997:43]

To determine a business process's worth to the firm, managers have to answer two questions (Keen, 1997:57) (Also depicted in Figure 2.4):

- Approximately how much capital does the firm have tied up in the process?
- Does the process generate a positive cash flow after the cost of the capital has been deducted?

Hubbing is one of the mechanisms that can assist with integration and making processes more cost effective. The concept of hubbing brings work that had been spread across multiple departments and functions to one point (Keen, 1997:99). Hubbing is particularly important to large-scale enterprises. It is best suited to, and can even transform, decision-centred customer-service processes in which each unit traditionally handles only parts of the decision. Hubbing also puts the entire decision in the hands of one employee (or key stakeholder group). Hubbing, based on computer networking technology, is responsible for a major shift in the organisation of work and has demonstrated its worth as a provider of customer service at the moment of value. When hubbing is based on incompatible systems, the pieces of the process cannot be fully integrated.

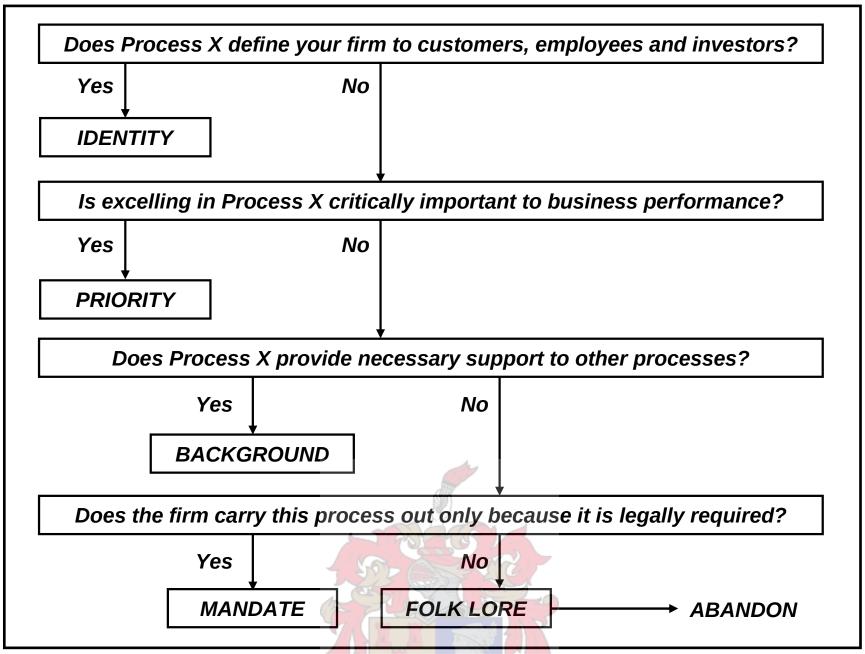


Figure 2.3: Evaluating the process portfolio
[Source: Keen, 1997:47]

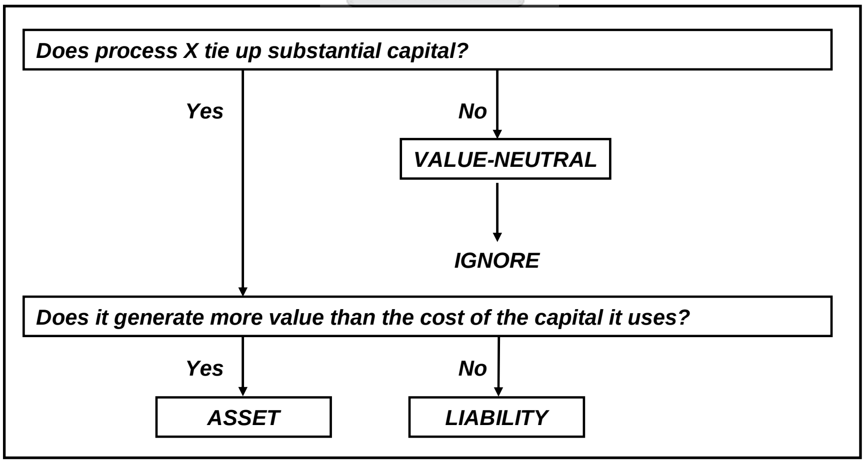


Figure 2.4 : Determining process worth
[Source: Keen, 1997:58]

A company can also define the degree of integration in terms of reach and range as defined by the following and represented in Figure 2.5 (The two together enables convenient, fast, and responsive customer service):

- ***Reach*** refers to who can connect to a firm's service process and where that connection can be made.
- ***Range*** is a measure of how many kinds of information can be directly and automatically shared within the system.

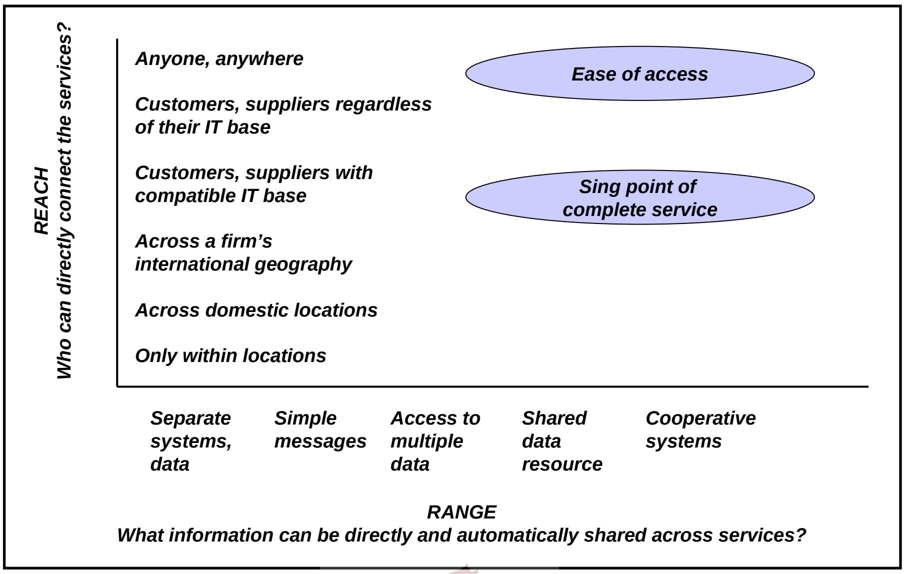


Figure 2.5 : The business dimensions (level of IT integration)
[Source: Keen, 1997:102]

2.1.1.3 *Business processes management*

Rummier & Brache (as quoted by Hunt, 1996:2) indicate that business processes management is "How to manage the white space on the organization chart". They also indicate that the process level is most probably "the least understood and least managed level" of business enterprise performance. Processes are rolling along (or, frequently, stumbling along) in organizations, whether we attend to them or not. We have two choices: we can ignore processes and hope that they do what we want, or we can understand them and manage them. A business process is a series of steps designed to produce a product or service. Some processes (such as the programming process) may be contained wholly within a function. However, most processes (such as order processing) are cross-functional, spanning the 'white space' between the boxes on the organization chart.

The pivotal link between business enterprise performance and individual performance can be established through the three process-based variables (Hunt, 1996:6):

- process goals (derived from three sources: business enterprise goals, customers' requirements, and benchmarking information)
- process design (as-is and to-be), and
- process management. (process goal management, performance management, resource management, process interface management)

2.1.1.4 Process improvement and reengineering

Process redesign aims at changing strategic value-add business processes and the systems, policies and organizational structures that support them, in order to optimize productivity and the flow of work (Schulman et al., 1999:71). Process reengineering can be viewed as the fundamental analysis and radical redesigning of business practices and management systems, job definitions, organizational systems, believes and behaviours in order to achieve dramatic performance improvements.

According to Kemm (2002:22) reengineering means finding out exactly what you are doing, and what you should be doing. If you want to change something (where there's reengineering to gain from) you need to go back to first principles in your mind to find out what to change and why.

Business process reengineering (BPR) is typically long term projects with future payback that re-models the entire process. It takes the base case of the present process model through an assessment and then determines the future process model required to meet business requirements. The gap must be closed through redesign (See Figure 2.6). The goal is to identify non-value add activities that do not increase customer satisfaction (Dawe, 1996:114). Eliminating non-value add work and simplifying process activities can significantly improve performance. Process improvements also set the stage for effective systems and people deployment.

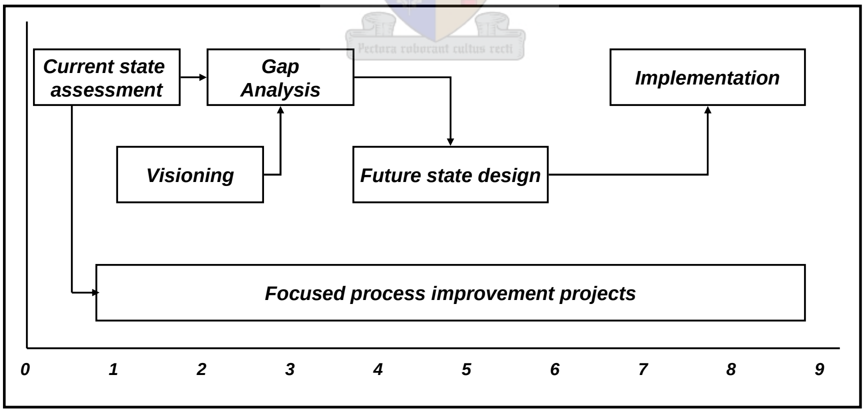


Figure 2.6 : BPR work plan and timing
[Source: Dawe, 1996:114]

According to Keen (1997:96) the processes best suited to streamlining mainly involve clear, linear sequences of activities with well-defined criteria for moving from one step to the next. Manufacturing, administrative, and production processes are typically good candidates. Design, research, and other processes that involve flexibility, judgment, and collaboration generally are not. By using Total Quality Management (TQM), the following main principles apply:

- Embrace the long term
- Genuinely empower workers
- Reduce variability
- Manage by fact
- Remove waste everywhere
- Generate continuous improvement

Because EVA (Economic Value Add) is what matters (not process benefits per se) the cost of streamlining may outweigh the gains. Thus not all processes are candidates for streamlining.

A survey conducted by Forrester Research with 26 SCM executives in large-scale US manufacturing firms, showed that 46 percent of interviewees believed that poor supply chain performance related to the difficulty in getting processes and people adjusted to changes (Radjou, 2003). This finding related to the survey question "What are the major factors that impede your supply chain performance?" (See findings in Figure 2.7)

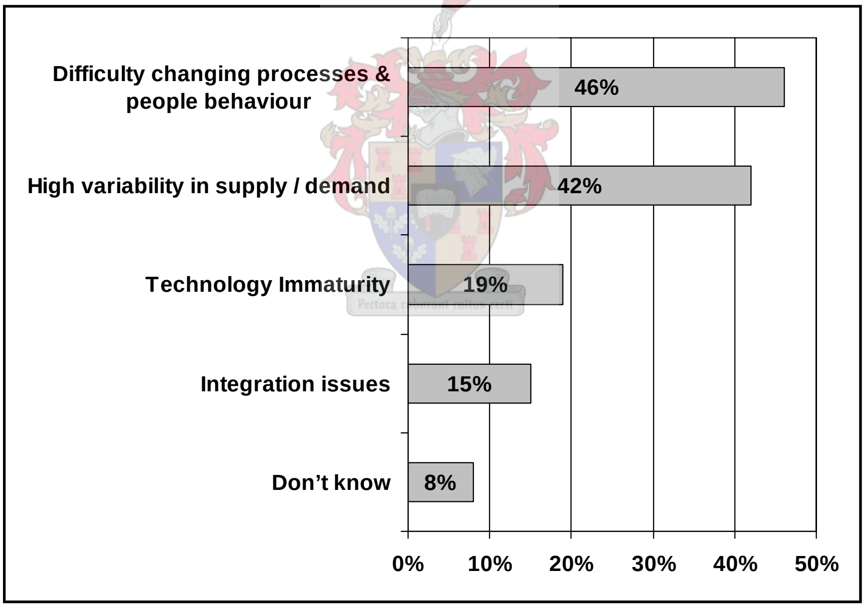


Figure 2.7 : Major factors that impede supply chain performance (2003 - 2008) [Source: Radjou, 2003]

According to Roth (as quoted by Schlegel & Smith, 2005:19), for companies to be competitive, they will need an integrated supply chain approach that has a sound supply chain strategy coupled with a process improvement model and enabling technology. Companies that want to be out on the leading edge will need to extend beyond the company's own four walls and connect to key supply chain partners as well.

Focused Process Improvement (FPI) is short-term projects for immediate payback. This is also known as continuous process improvement (Part of the TQM approach). However, just focussing on this, could cause missing the longer term need of the organization (Dawe, 1996:114).

Curtice (2005) advised companies to match the approach to process improvement with their expectations for the outcome. Approaching process improvement on three distinct levels (incremental improvement, redesign, and rethink) can help formulate the right approach. Business process improvement efforts can be grouped into three levels:

> ***Incremental Improvement*** calls for small, local teams to come together and explore how a process can be enhanced, typically addressing issues of cost, quality, or cycle time. The whole Total Quality Management (TQM) movement and its various offshoots fall into this category.
>
> ***Redesign*** involves a more formal approach to improvement. At least some project personnel are assigned to the effort on a full time basis. The scope typically covers a large, perhaps cross-functional business process, and project oversight is embodied in a steering group of some sort, with regular progress reporting. Redesigning the Order-to-Pay process might be an example.
>
> ***Rethink***. It entails a more fundamental and wide-ranging examination of processes in a major segment of the business that might, for example, conclude that a process should be outsourced.

Typical process design steps that can be used are (Collinge, 2000:22):

- Define all the discrete activities
- Define all the outputs
- Define all the inputs
- Find out who is responsible for each activity
- Draw all the activities on a time / responsibility framework (See Figure 2.8)
- Critically appraise the process map to confirm that it accurately and adequately represents the process
- Creatively review the process to identify how the process time can be reduced, and waste that can be eliminated
- Draw up and implement a process improvement program

2.1.1.5 Business processes mapping

Process mapping is an analytical tool and proven methodology for identifying the current "As-Is" business processes and can be used to provide a "To-Be" roadmap for reengineering product and service business-enterprise functions (Hunt, 1996:1).

Hunt (1996:14) states that the fundamental concepts of process mapping are based on the idea of structured analysis. A process map considers activities, information, and interface constraints simultaneously. The basic process mapping concepts can be summarized by the following key points:

- Understand a process or system by creating a "map" that graphically shows things (objects or information) and activities (performed by men or machines). The process map is designed to properly relate both things and activities.
- Distinguish which functions a system should perform, from how the system is built to accomplish those functions. The distinction must be clearly evident in the process map.
- Structure the process map as a hierarchy with major functions at the top and successive process map levels revealing well-bounded details. Each process map should be internally consistent.

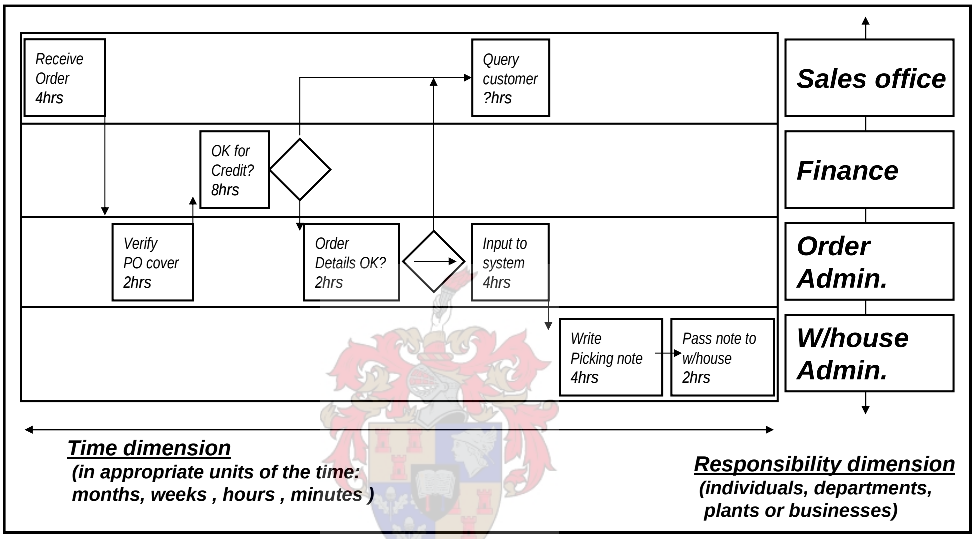


Figure 2.8 : A cross functional activity process flowchart example

[Source: Collinge, 2000:24]

Process mapping tools can be divided into three general categories (Hunt, 1996:20):

- ***Flow Diagramming Tools.*** At the most basic level are flow diagramming and drawing tools that help define processes and workflows by linking text descriptions of processes to symbols.
- ***CASE Tools.*** These tools provide a conceptual framework for modelling hierarchies and process definitions. They are typically built on relational databases and include functions that provide linear, static, and deterministic analysis capability.
- ***Simulation Tools.*** Simulation tools provide continuous or discrete-event, dynamic, and more sophisticated analysis capability. Simulation tools typically provide animation capabilities that allow the process designer to see how customers and/or work objects flow through the system.

2.1.2 Supply chain processes and advancements

With the term “supply chain” emerging on the business scene only about a decade ago, it spoke of a process management concept and sparked a hope that senior management would finally see value in investing in a well-orchestrated supply chain. In the time since, the concept has taken root. Integration is the most common theme related to the objectives of a supply chain orientation (Cavinato, 2002).

Increasingly, supply chain management is being recognized as the management of key business processes across the network of organizations that comprise the supply chain. While many have recognized the benefits of a process approach to managing the business and the supply chain, most are vague about what processes are to be considered, what sub-processes and activities are contained in each process, and how the processes interact with each other and between the traditional functional silos. Streamlining cross-company processes is the next great frontier for reducing costs, enhancing quality, and speeding operations (Croxton et al., 2001:13). Andel (1996:31) indicated that planning can be viewed as one of the key supply chain processes.

2.1.2.1 Supply chain processes

AMR defined the generic supply chain management processes into a number of major categories (AMR Research, 2001a). These major processes categories are (The related sub-processes are indicated in Figure 2.9):

- Supply chain planning
- Supply chain execution
- Supply chain event management
- Supply chain performance management
- Reverse logistics/ returns management

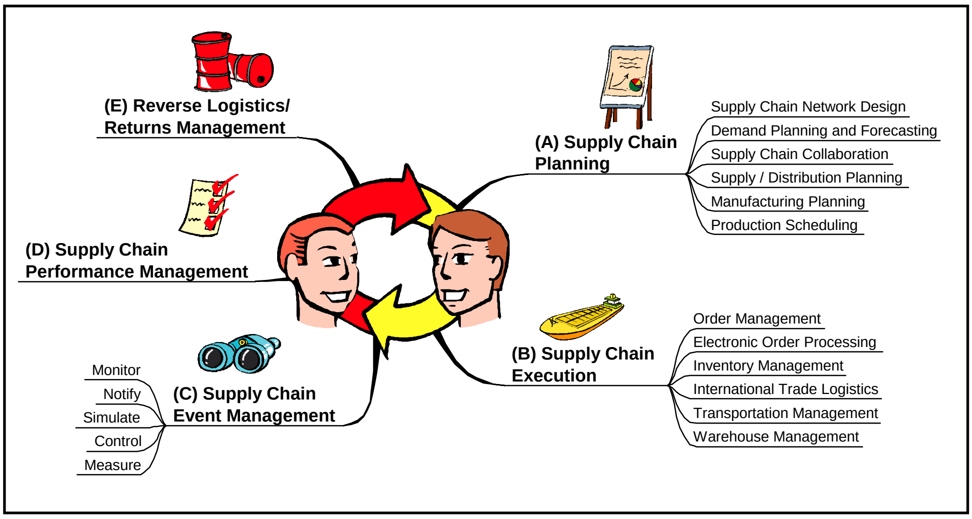


Figure 2.9 : Generic SCM processes and sub-processes
[Source: AMR Research, 2001a]

Using the frameworks in Figure 2.3 and Figure 2.4, supply chain planning can be viewed as a priority process since it influences how well identity processes are carried out. Since supply chain execution processes play a critical role in customer fulfilment, it can be viewed as an identity process.

According to the ARC Advisory Group (2002,3-4) world class supply chain management (SCM) requires both effective planning (SCP) and efficient execution (SCE). SCM focus on combining doing the right things (planning), and doing things right (execution). Supply chain process management (SCPM) is the glue that binds together the different focuses of SCP and SCE. SCPM provides global, real-time visibility into events, key performance indicators (KPIs), and decision support around exceptional situations. SCP comprises demand management or forecasting, network or multi-facility planning, production planning, distribution or replenishment planning, and transportation planning. SCE comprises order management, availability or capability to promise, warehouse and transportation management, and international trade. International trade covers tariffs, landed cost calculations, and export documentation. The interdependencies between these planning and execution processes are illustrated in Figure 2.10.

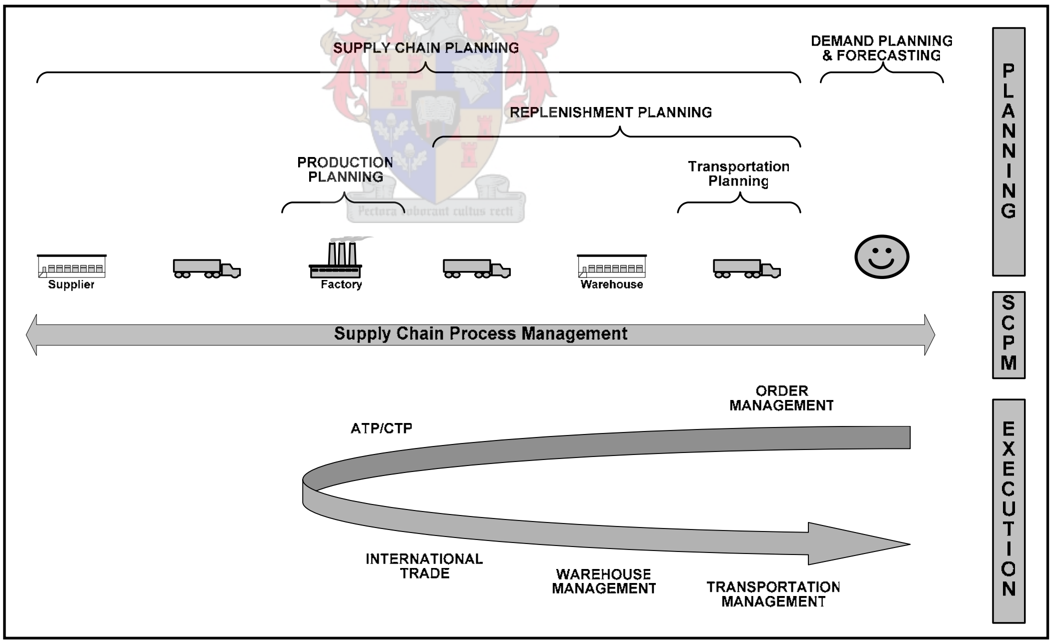


Figure 2.10 : Planning should direct and guides execution
[Source: ARC Advisory Group, 2002:2]

The Supply-Chain Council also provides an operations reference model for integrated supply chain processes spanning from the suppliers' supplier to the customers' customer (as illustrated in Figure 2.11). The SCOR model (Supply Chain Operations Reference Model) combines elements of business process engineering, benchmarking, and leading practices into a single framework (Bolstorff

& Rosenbaum, 2003:2). Under SCOR, supply chain management is defined as these integrated processes of: PLAN, SOURCE, MAKE, DELIVER, and RETURN. Each of these processes includes:

- ***PLAN***. Assess supply resources; aggregate and prioritize demand requirements; plan inventory for distribution, production, and material requirements; and plan rough-cut capacity for all products and all channels.
- ***SOURCE***. Obtain, receive, inspect, hold, issue, and authorize payment for raw materials and purchased finished goods.
- ***MAKE***. Request and receive material; manufacture and test product; package, hold, and/or release product.
- ***DELIVER***. Execute order management processes; generate quotations; configure product; create and maintain customer database; maintain product/price database; manage accounts receivable, credits, collections, and invoicing; execute warehouse processes including pick, pack, and configure; create customer-specific packaging/labelling; consolidate orders; ship products; manage transportation processes and import/ export; and verify performance.
- ***RETURN***. Defective, warranty, and excess return processing, including authorization, scheduling, inspection, transfer, warranty administration, receiving and verifying defective products, disposition, and replacement.

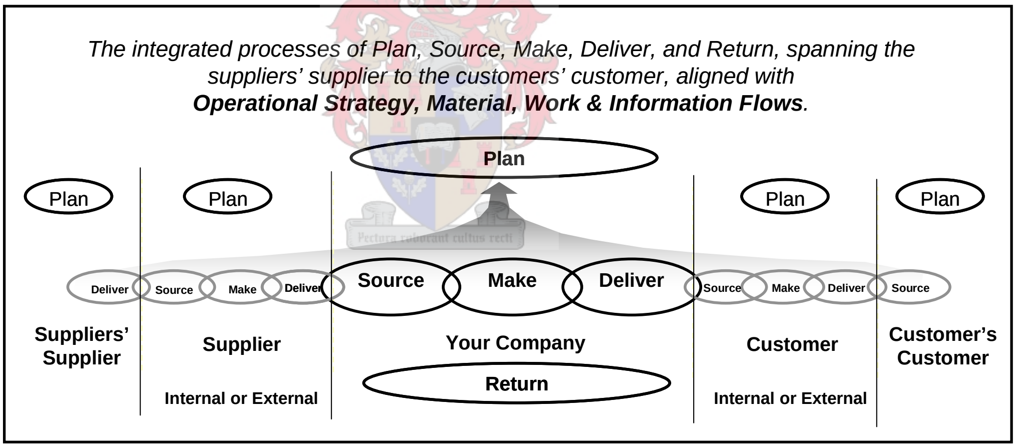


Figure 2.11 : SCOR is organized around five major management processes
[Source: Bolstorff & Rosenbaum, 2003:3]

The SCOR model includes the following three levels of process detail:

LEVEL ONE defines the number of supply chains and how their performance is measured.

LEVEL TWO defines the configuration of planning and execution processes in material flow, using standard categories like stock, re-order, and engineer-to-order.

LEVEL THREE defines the business process used to transact sales orders, purchase orders, work orders, and return authorisations, replenishment orders, and forecasts.

The supply chain can also be viewed as **a sequence of processes and flows (cycles**) that take place within and between supply chain stages and combine to fill customer need for a product (Chopra & Meindl, 2001:7). The following cycles can be viewed as some key processes: customer order, replenishment, manufacturing, and procurement. Depending on where supply meets actual demand, supply chain processes act either according to a “push” or “pull” view.

> ***PULL PROCESSES***; Execution is initiated in response to customer orders.
>
> ***PUSH PROCESSES***; Executed in anticipation of customer orders.

Dawe (1996:112) views a supply chain process as **a collection of activities** with a discernible (distinct) beginning and ending, as well as suppliers, customers, inputs and outputs. A common approach is to break the supply chain mega-process into three major processes: (a) Sourcing, (b) Production, and (c) Logistics. These processes are cross-boundary and include the related activities that link the supply chain's vendors to its customers. The customer focus is the strength of the process approach and it replaces the traditional internal focus on budgets, total cost, or capital return with customer-centric performance measures such as order fulfilment, on-time delivery, perfect orders, invoice accuracy, and (the ultimate measurement) repeat sales. The supply chain mega-process can be summarised as follows:

> ***SOURCING*****.** This process includes all the activities related to acquiring resources for the supply chain, including raw material, sub assemblies, finished products and services such as contract manufacturing and third-party logistics. This process is undergoing a transition in many companies from a tactical “purchase at the lowest price” approach to strategic vendor partnership using a "lowest total cost of ownership" approach.
>
> ***PRODUCTION*****.** Production tends to deal with many tactical issues in its daily effort to output volumes of quality products and services. This process continues to be the backbone of most companies and is generally considered the core competency.
>
> ***LOGISTICS.*** This is a purely service activity combining strategic planning and tactical operations. It is strategic in the design of networks to deliver the right products to the right places at the right time in the right quantity and at the right cost. It is tactical in the execution of the numerous, complex operating tasks in material handling, warehousing, inventory control and transportation needed to accomplish the plan. Logistics has a unique position in that it is not only cross-functional, but cross-process as well. Logistics is often viewed as a service stream running throughout the supply chain in three segments: (a) Upstream inbound logistics, (b) Mid-stream production logistics, and (c) Downstream outbound logistics.

The global supply chain forum identified eight key processes that make up the core of supply chain management (Croxton et al., 2001:14). In his article “Eight Essential Supply Chain Management Processes”, Lambert, (2004:18) indicated that these key supply chain management processes must be linked throughout the supply chain:

***CUSTOMER RELATIONSHIP MANAGEMENT*:** The customer relationship management process provides the structure for how the relationship with the customer is developed and maintained.

***CUSTOMER SERVICE MANAGEMENT*.** The customer service management process is the firm's face to the customer. It provides the single source of customer information, such as product availability, shipping dates and order status.

DEMAND MANAGEMENT. The demand management process needs to balance the customers' requirements with the firm's supply capabilities.

ORDER FULFILMENT. Effective order fulfilment requires integration of the firm's manufacturing, logistics and marketing plans.

MANUFACTURING FLOW MANAGEMENT. The manufacturing flow process deals with making the products and establishing the manufacturing flexibility needed to serve the target markets.

SUPPLIER RELATIONSHIP MANAGEMENT (Procurement). Supplier relationship management is the process that defines how a company interacts with its suppliers. (a mirror image of customer relationship management)

PRODUCT DEVELOPMENT AND COMMERCIALIZATION. Supply chain management includes integrating customers and suppliers into the product development process in order to reduce time to market.

***RETURN MANAGEMENT*.** While many firms neglect the return process because management does not believe it is important, this process can assist the firm in achieving a sustainable competitive advantage.

Ernst & Young (as references by Buys, 1997:3) indicates that the macro supply chain business process flows are represented by the following (inter-relationship indicated in Figure 2.12):

- Demand planning and forecasting
- Distribution planning
- Manufacturing planning / rough-cut capacity planning
- Finite capacities scheduling
- Materials plan
- Deployment planning
- Transportation planning

A supply chain can also be characterized as **"the mother of all processes"** because it includes the entire collection of activities by which a company plans, produces, and distributes products to customers. These activities may be characterized as three different processes (Dershin, 2000:75) i.e.:

- Physical processes (manufacturing, transportation, warehousing)
- Information processes (recording transactions, statistical forecasting)
- Business processes (planning, sourcing, deployment, and logistics)

Lockamy III & McCormack (2004:1197) also proposed seven categories of key **supply chain management planning decision**: operations strategy planning, demand management, production planning and scheduling, procurement, promise delivery, balancing change, and distribution management.

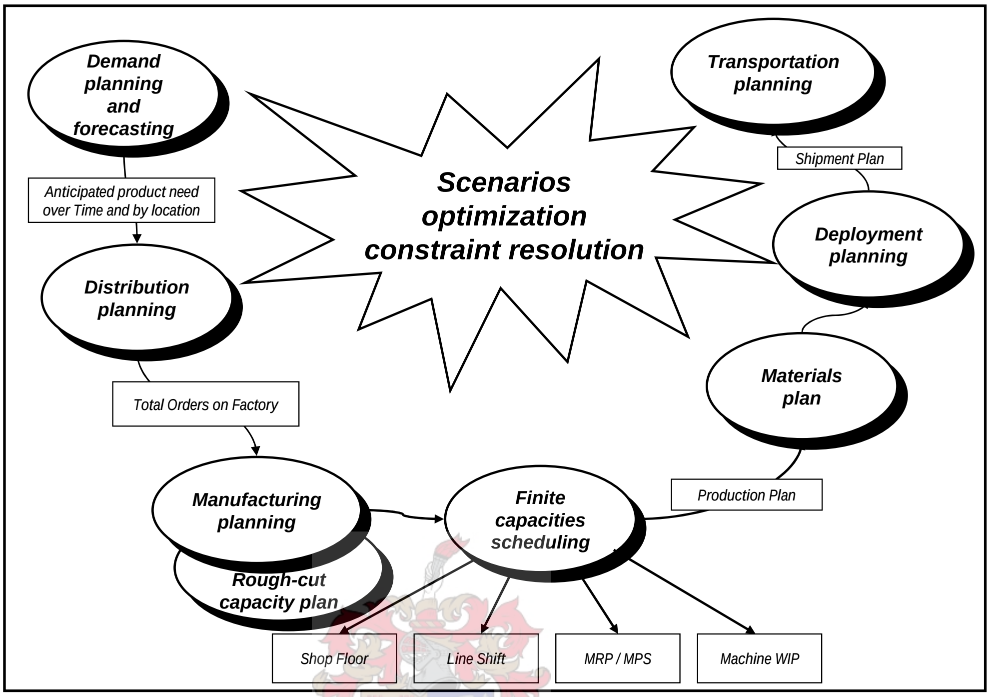


Figure 2.12 : Information and process flow inter-relationship
[Source: Ernst & Young (as presented by Buys, 1997:3)]

2.1.2.2 *Mapping supply chain processes*

As indicated in Figure 2.13, one method of mapping supply chain processes is on a **value add chart.** This can assist in determining which activities add costs and which add value (Christopher, 1998a:111). Costs are normally associated with production, storage, transportation, and time cost of money, while value relates to time, place and form utility.

To redesign chain processes, one has to describe them thoroughly, analyze their relationships with other processes, and focus on total supply chain performance (Van der Vorst & Beulens, 2002:419). Supply chain business process mapping plays a crucial role for analysis. Two typical useful mapping tools can be used for this purpose. These are:

- ***Organization descriptive language*** (for describing the inputs, transformation and outputs off each business process in the supply chain) – see Figure 2.12 for an example.
- ***Event process chain modelling*** (for describing the dynamic behaviour of the supply chain processes) - see Figure 2.8 for an example.

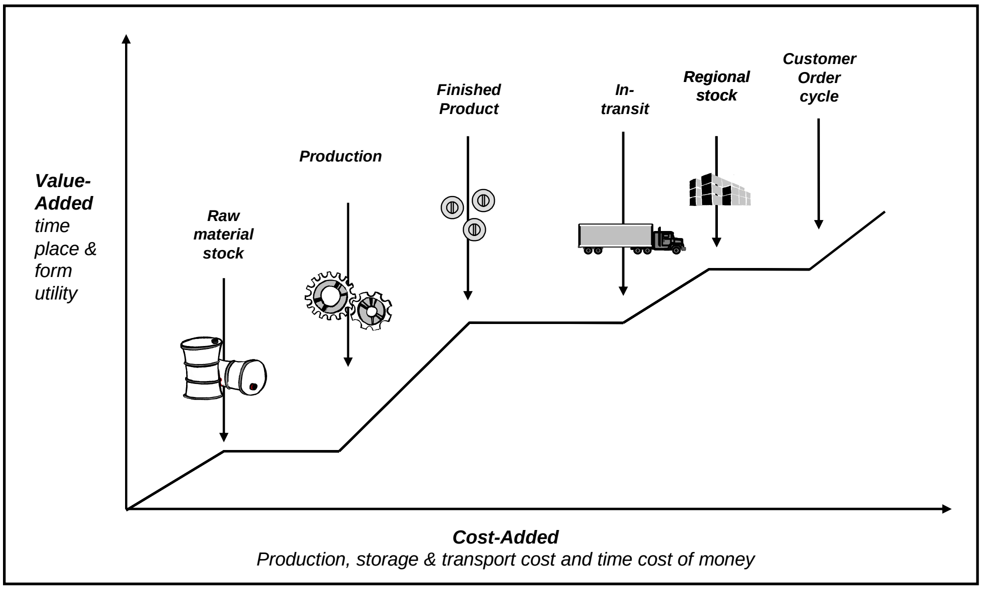


Figure 2.13 : Which activities add costs and which add value?
[Source: Christopher, 1998a:111]

Mapping business processes can also be done by using the **Integration Definition for Function (IDEF) modelling technique** (FIPS PUBS, 1993:7). IDEF0 specifically is a modelling technique based on combined graphics and text that are presented in an organized and systematic way to gain understanding, support analysis, provide logic for potential changes, specify requirements, or support systems level design and integration activities. An IDEF0 model is composed of a hierarchical series of diagrams that gradually display increasing levels of detail describing functions and their interfaces within the context of a system. Figure 2.14 provide a visual representation of the typical hierarchical structure of an IDEF0 diagram.

The SCOR approach to process mapping considers both work and information flow (Bolstorff & Rosenbaum, 2003:168). The basic swim diagram (also referred to as event process chain modelling or cross functional flow diagrams) contains the main functional departments that have some role in the process being mapped. (E.g. warehouse, purchasing, accounts payable and the supplier). A swim diagram then illustrates how tasks are carried out in the organization by placing the appropriate process step in the appropriate swim lane. In cases where there are multiple functions participating in tasks, the process step is drawn across all appropriate swim lanes. The sample SCOR baseline business blueprint (as illustrated in Figure 2.15) indicates how integrated supply chain processes should work together (Bolstorff & Rosenbaum, 2003:181).

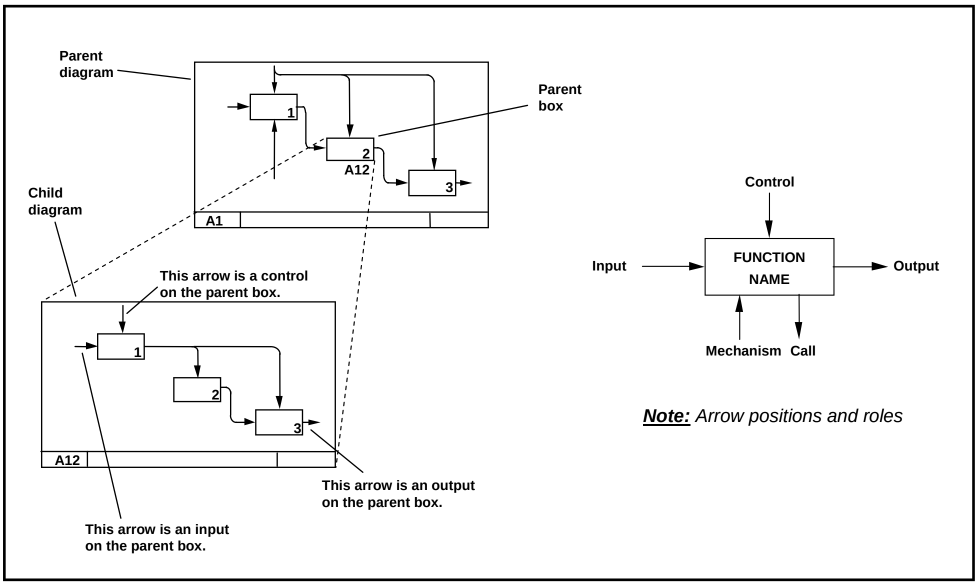


Figure 2.14 : IDEF0 hierarchical series of diagrams
[Source: FIPS PUBS, 1993:7]

2.1.3 Aligning and Integrating supply chain business processes

With the supply chain management momentum moving forward, there is a need to firstly integrate the separate processes within the organization, then to integrate the processes external to the organization in a attempt to more closely connect the organization with its customers and suppliers (Andel, 1996:34).

Business process re-engineering (BPR) can be used as a technique to aid in aligning and integrating supply chain business processes. BPR is also defined as the means by which an organization can achieve radical change in performance (as measured by cost, cycle time, service and quality) through the application of a variety of tools and techniques that focus on the business as a set of related customer oriented core business processes, rather than a set of organizational functions (Waller, 1999:185). The primary objective of BPR is intended to boost competitiveness in the operations network through simpler, leaner and more productive processes.

Integrating processes across the supply chain require some of the following prerequisites (Christopher, 1998b:281):

- It must reduce the supplier base (Cannot integrate with all)
- Joint strategy determination with channel partners (replace attitudes and habits with trusts and commitment)
- Cooperation starts from the top
- It is not sufficient to have only one point of contact between channel partners (e.g. only sales and procurement)

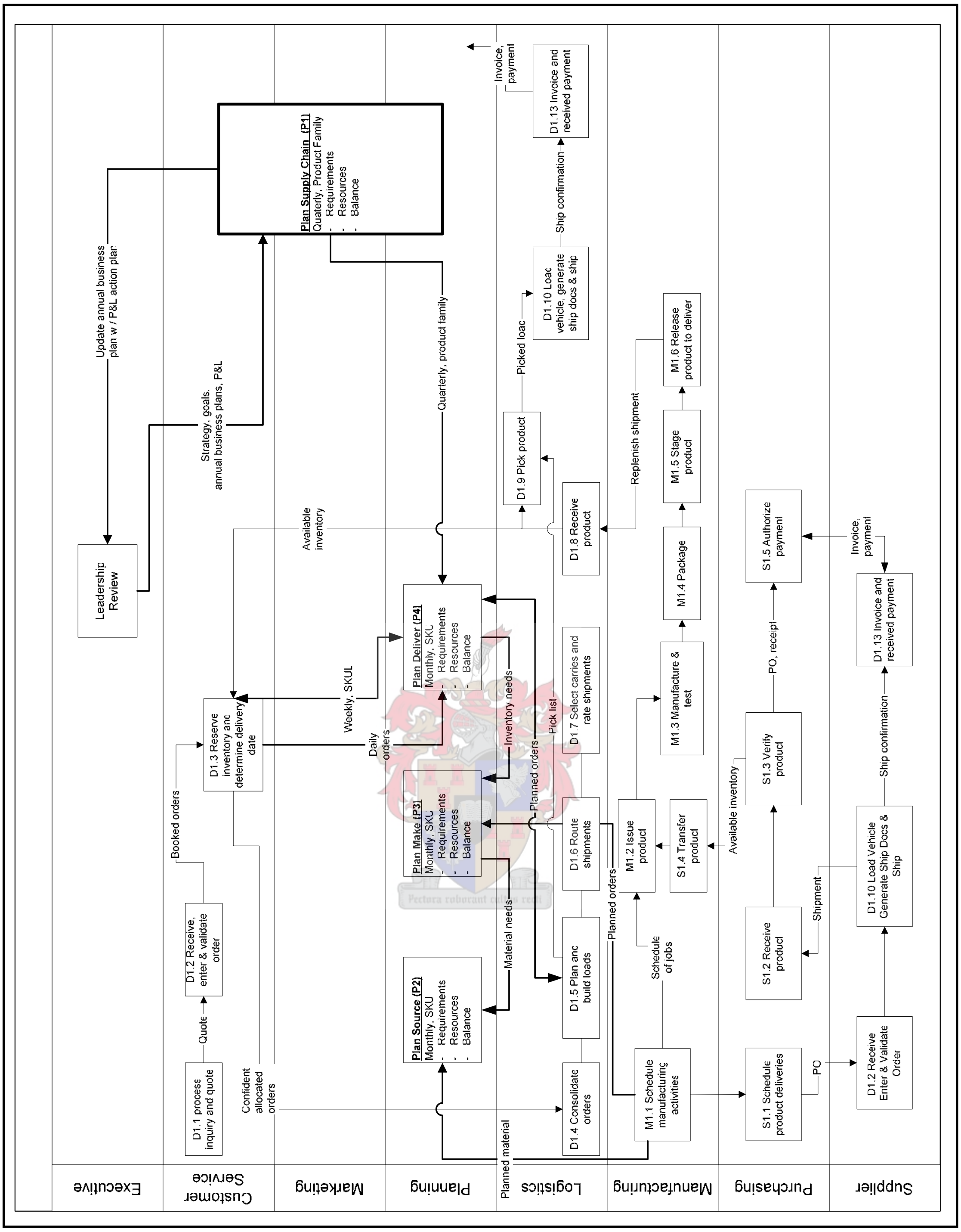


Figure 2.15 : Sample SCOR baseline business blueprint
[Source: Bolstorff & Rosenbaum, 2003:181]

2.1.4 Supply chain business processes and organizational issues

Most of the barriers to integrate an organization through SCM are organizational, not technical. Past research into human- and organizational decision-making has shown that timeless issues of ignorance, superstition, conflict, and self-seeking behaviour are still around (Shapiro, 2001:25).

For supply chain business processes to work properly, a firm needs to restructure its conventional vertical oriented organizations to horizontal market facing businesses (Christopher, 1998a:222). With globalization, logistics becomes the key integrators and enabler to manage the flow of material and information.

From the 2003 “supplychainforesight” research results (Barloworld Logistics, 2003:25), managers in SA understand that service enhancement and cost reduction are the prime objectives of supply chain reform. They however realise that the successful achievement of these objectives may be hampered by two issues:

- a functional approach to improvement objectives (silo-based improvement rather than integration - the greatest cost, service and competitive benefits flow from cross-functional, process-based optimization and integration)
- an indication that there are weaknesses in the planning, forecasting, staff skill level and collaboration areas

More detail on the organizational challenges and issues are reviewed in Chapter 3.

2.2 Literature review on supply chain planning and advancements

The following paragraphs review literature related to the topic of supply chain planning and the advancement made in this field. This literature spans published research, textbooks and relevant articles.

Supply chain planning covers the processes of forecasting, capacity management, netting against available inventory and ordering from suppliers where lead times are long. Supply chain execution, on the other hand, is the process of managing material flows through the supply chain in response to real demand or inventory replenishments in the chain (Inger, Braithwaite & Christopher, 1995:251).

According to Shapiro (as referenced by Shen, Lee & Van Buskirk, 2001:69) supply chain planning is the coordination and integration of the activities that happen at manufacturing plants and distribution centres with the purpose of making better supply chain decisions.

Advanced planning and scheduling (APS) deals with the planning problems in a supply chain (PWC, 1999a:103). To a large extent it focuses on constrained planning (multiple constraints in supply chain exist) with real time processing (to react fast to changes) and aiming to integrate (along the supply chain and the different time spans - as indicated in Figure 2.16). Macquet (2002:1) reinforces this view by stating that Supply Chain Planning (SCP) addresses all layers of planning – strategic, tactical, operational and execution – across the extended supply chain, from supplier's supplier to customer's customer. It covers the four elements of demand management, sourcing, production and distribution.

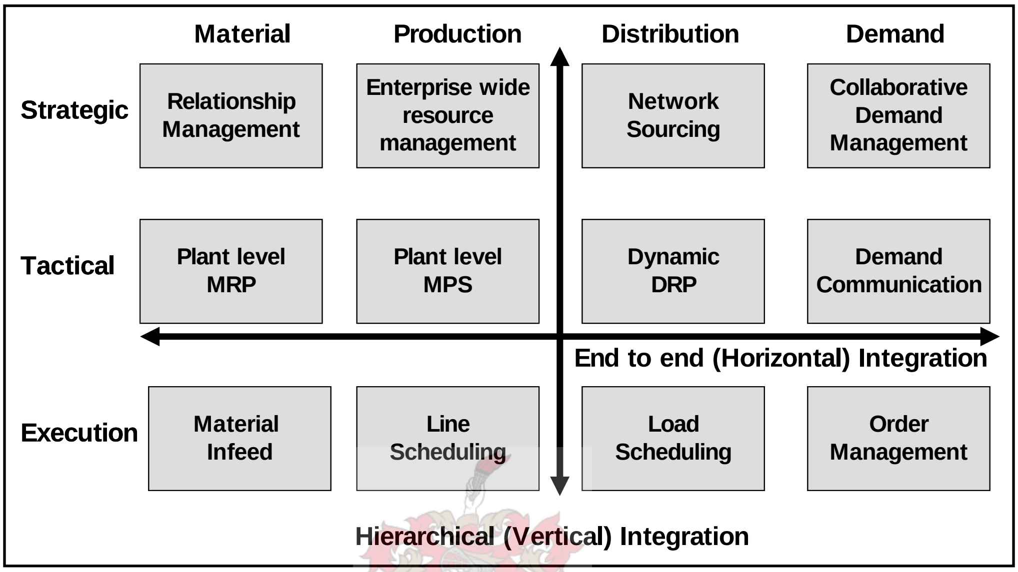


Figure 2.16 : The supply chain planning response
[Source: PWC, 1999a:103]

Non-process specific solutions fall short of addressing the complexity and characteristics of the process industry (Aspen Technology, 2003:11). As indicated in Figure 2.17, the real value of advanced planning solutions is predominantly found in the strategic and tactical processes. These planning processes include strategic planning & network design, tactical enterprise level planning, distribution planning & scheduling and plant planning & scheduling.

2.2.1 Advanced supply chain planning approach

Supply chain planning has evolved from Oliver Wight's concept of batch processed time-phased reorder point calculation (i.e., MRP) for stand-alone manufacturing and distribution planning, to a dynamic, integrated synchronization of the enterprise and its trading partners (Peterson, 1999:4). No longer can an enterprise remain competitive by running a weekly distribution and/or manufacturing plan, and then reacting manually to the inevitable exceptions that occur after that point.

Many organizations have focused on optimizing manufacturing scheduling. However, determining the correct supply chain plan can be more important than optimizing an individual plant schedule. Capacity planning is more than just a manufacturing issue and needs to account for demand and distribution requirements as well (Peterson, 1999:6).

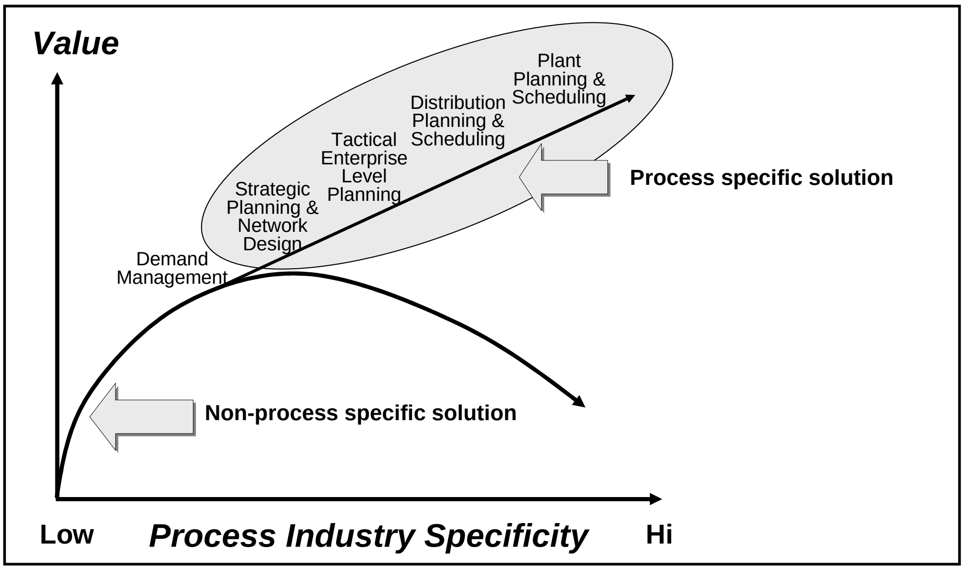


Figure 2.17 : Process industry solution requirement

[Source: Aspen Technology, 2003:11]

The challenge of integrated advanced planning really lies with process integration (Mulani, 2001:27). The greatest challenge is to ensure that the supply chain parts cooperate with each other and stay focused on a single objective. Advanced planning has to cross not only the functional silos within your enterprise, but also the corporate barriers across the supply chain.

The concept of time phased planning and the resulting capacity plans enable users to identify future constrains with enough possible time to pursue alternatives (Martin, 2001:62-63). The constraint occurs when their supply chain does not have enough capital, people, equipment, or space to acquire, transport, manufacturer, and/or sell product.

To manage constraints across a supply chain, companies must match the supply and demand of capital, people, equipment, and space across every node in the supply chain from suppliers to the retail store (Martin, 2001:64). Managing constraints across a supply chain would involve matching these two variables (supply and demand) at each node. Supply side constraints typically include manufacturing capacity, space, people and equipment. On the demand side, the best is to start with real demand at the retail outlets (final customer). It is normally difficult to get the true demand due to noise factors (i.e. promotions, forward buys, end-of-quarter or end-of-year inventory pushes, price wars and new product introduction). Suppliers should thus try and get as close to visibility of pure customer demand as possible.

The physical execution of the supply chain is made up of a number of processes. (Tennant, 2002:1). These processes typically include inbound logistics, production, warehousing and outbound logistics. Depending on a specific firm, these core processes repeat themselves to eventually make up a complete supply chain from source, (e.g. mining) through to the end consumer (e.g. fuel at retail outlet). The supply chain is supported by infrastructure that comprises people, information and assets (working and fixed capital). Procurement feeds into a supply chain and the supply chain delivers customer service. Planning – a process that runs from the customer 'backwards' to the source – is key to supply chain success and consists of demand forecasting and management as well as supply management (relate to Figure 2.18). The essential systems to support planning are generally known as Advanced Planning Systems (APS). The development of a sound supply chain strategy is critical to the delivery of good results. Performance measurement across the complete supply chain is also most important and contributes to supply chain success. When understanding what constitutes a whole supply chain it is important to consider all the players including not only the suppliers manufacturer, and customer, but also the various service providers involved (warehousing, distribution, transport, global logistics, forwarding and clearing, IT providers and others).

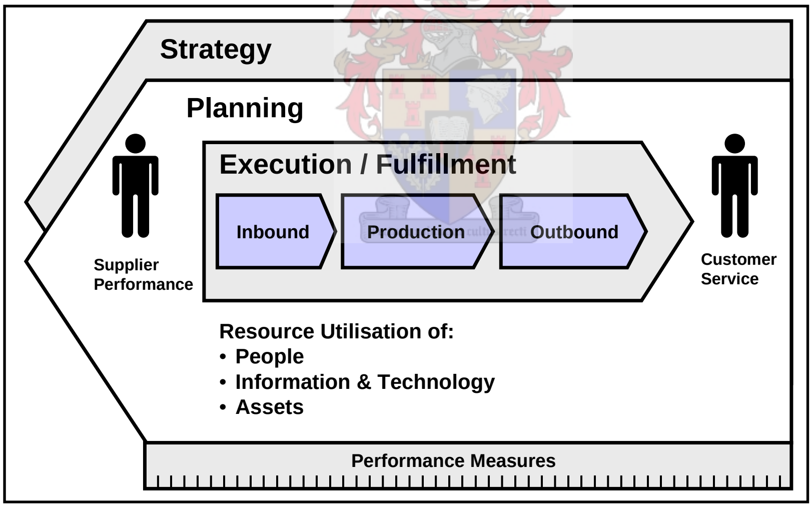


Figure 2.18 : Supply chain framework
[Source: Stuart; 2002:1]

In the adoption of advanced supply chain planning, it is advisable to move the decision-making through three advancement stages (Bermudez, 2003). Initially the focus must be on information visibility. All the required information for the applicable supply chain planning processes must be accessible. The next stage allows for enabling "what-if" tools for planners to test the implications of a specifics scenario or course of action. Only when planners have adopted these stages of sophistication can a company start to automate some supply chain decision-making processes with appropriate optimization algorithms.

2.2.2 Supply chain planning, decision phases and time horizons

Ample literature and theories are available that describe the different decision phases & time horizons found in supply chain planning. Although extensive, the following paragraphs review this literature with the purpose of having a sound basis for the preparation of this dissertation's empirical research.

According to La Londe (2005) planning still puzzles even the most sophisticated executives. Part of the problem with the planning process is that the world is changing at an exponential rate (bringing its share of uncertainty and making planning more difficult). Planning in these turbulent environments that they operate in poses some tough challenges for the supply chain executive, or any other business executive for that matter (uncertain oil price, and volatile commodity prices). What's required is for firms to develop a solid approach and understanding of the planning process itself. Planning usually occurs along three dimensions: (1) operational planning, (2) tactical planning, and (3) strategic planning.

> ***Operational planning*** is a day-to-day activity that keeps the lights on, the factory humming, and the goods moving to the customer. An operating plan can be daily, weekly, monthly, quarterly, or some other traditional time bucket. The objective of operational planning is to make certain that all elements of the business process are integrated (that is, raw materials, human resources, factory capacity, shipping capability, customer orders, and so forth) according to plan. Variance analysis is used to fine-tune the operating plan.
>
> ***Tactical planning*** is typically short-term (less than one year) in response to some event in the firm's business environment. It could be a price war that develops at the retail level or an unexpected strike at a key supplier factory. In any case, the tactical plan changes the operating plan and, depending on the duration, could change the strategic plan. The high price of oil is a good example. If this is viewed as a short-term blip in process, it is handled by a customized tactical plan. On the other hand, if the spike in energy prices is viewed as a more permanent change, its impact is recognized in the strategic plan.
>
> Management typically views ***strategic planning*** as the most difficult of the three planning processes. Strategic planning usually deals with scenarios that will occur within the next year or longer from the current date. A generally accepted rule is that strategic planning applies to the period in which it is possible to make scale changes in the firm's business environment. That is, factories can be built, production can be outsourced, new products can be developed, acquisitions or divestitures of assets or operating divisions can be made. The typical planning period for the firm's strategic plan is one to five years.

Rolling time horizons are used in supply chain planning. Typically, a long range plan is reviewed and updated each year. For a five-year planning horizon (strategic plan), the current year is subtracted and a new fifth year is added to the strategic plan. The net result is a “rolling” five-year strategic plan.

Supply chain decisions typically differ in their time horizons, impact and reach (across the supply chain). Three distinct decision phases in the supply chain domain exist (Chopra & Meindl, 2001:6). These are:

SC Strategy & Design - Defines the constraints for planning decisions
SC Planning - Defines the constraints for supply chain execution decisions
SC Operations - Relates to the SC Execution decisions

According to Bramel & D. Simchi-Levis (1997:3) the logistics decisions can also be classified on three levels:

- Strategic level (decisions with long lasting effect on the firm)
- Tactical level (decisions typically taken up to quarterly)
- Operational level (decisions typically taken daily)

The wide spectrum of issues that have to be dealt with, relate to distribution network configuration, production planning, inventory control, cross docking, integration of inventory and transportation, vehicle fleet management, truck routing, packing problems, delivery time windows, and pickup and delivery systems.

The related decision support systems also serve a specific purpose at each of the decision levels (D. Simchi-Levi, 2000:77). Their typical function is as follows:

At strategic level – aids with designing your Logistics network
At tactical level – aids with three types of decisions (demand planning, production planning and distribution planning)
At operational level – aids with decisions regarding: routing vehicles, dispatching drivers, develop production schedules, assigning jobs to individual machines; day-in day-out activities.

Schmidt & Wilhelm (2000:1519) states that multi-national logistics networks deals with the decisions related to strategic, tactical and operational issues. The ***strategic*** level designs the logistics network, including prescribing facility locations, production technologies and plant capacities. (The objective is to maximise total profit, including the fixed cost of investment to open facilities and the variable cost of manufacturing and distribution, including 'border crossing fees' that might be incurred in transit.) The ***tactical*** level prescribes material flow management policies, including production levels at all plants, assembly policy, inventory levels, and lot sizes. The ***operational*** level schedules operations to assure in-time delivery of final products to customers.

The ARC Advisory Group (2002,5) also indicate that the key distinction between the different timeframe within SCM is related to the degree of flexibility managers have to changes that occurs. The following describes the different timeframes and the focus differences:

Strategic timeframe: the time required to change key assets - i.e., to erect a new plant, close a distribution centre, launch a new product. It typically covers a few months to a few years.

Tactical timeframe: roughly the length of supplier contracts, or a supplier's lead-time. It typically covers a week to a few months.

Operational timeframe: the time taken to receive and fulfil an order or the life of a customer contract. It typically covers a few days to a few weeks.

Execution timeframe: the frequency of order updates to operators on the shop floor. It typically covers a day, but can be shorter. For instance, the period of a picking wave in a warehouse.

As referenced by Pienaar (2005:81) Ghiani, Laportte & Musmanno indicates that logistics management revolves around planning, organising and executing / controlling logistics processes from strategic, tactics and operational level. These processes relate to logistics decisions and can be classified according to the following planning levels with different time horizons (combined with previous work by Vogt, Pienaar & De Wit (2002:54)):

Strategic level

- Decisions with long lasting effect on the firm; provide broad direction the business will allow
- Aggregated data - grouping individual products into product families and aggregating individual customers into customer zones
- Capacity Creation (1 to 5 Years horizon; reviewed every 6 - 12 month intervals)

Tactical level

- Decisions taken any time between once every month and once a year
- Tactical decisions are based on disaggregated data
- Capacity Allocation & long lead-time Scheduling (6 months horizon; reviewed weekly)

Operational level

- Decisions typically taken daily
- Operational decisions are customarily based on very detailed data
- Short term Scheduling & Control, Customer Orders (4 weeks horizon; reviewed daily)

The dynamic nature of a supply chain requires that the different decisions must be derived from one plan and use a rolling time horizon. The typical supply chain planning horizons / decision phases, purpose and planning tasks are indicated in Table 2.1 and illustrated in Figure 2.19 (Fleischmann, Meyr & Wagner, 2000:58 & 63):

Table 2.1 : Supply chain planning horizons/decision phases, purpose and planning tasks [Source: Fleischmann, Meyr & Wagner, 2000:58 & 63]

Time Horizon	***Purpose***	***Focus & Planning Tasks***
Long-term planning	Decisions of this level are called strategic decisions and should create the prerequisites for the development of an enterprise supply chain in the future. They typically concern the design and structure of the supply chain and have long term effects, noticeable over several years.	Product program and strategic sales planning; Physical distribution structure; Plant location and production system; Materials program and supplier selection; Co-operations
Mid-term planning	Within the scope of the strategic decisions, mid-term planning determines an outline of the regular operations, in particular rough quantities and times for the flows of resources in the given supply chain. The planning horizon ranges from 6 to 24 months, enabling the consideration of the seasonal development.	Mid-term sales planning; distribution plan; master production scheduling and capacity planning; personnel plan; material requirements planning; Contracts
Short-term planning	The lowest planning level has to specify all activities as detailed instructions for immediate execution and control. Therefore, short term planning modules require the highest degree of detail and accuracy. The planning horizon is between a few days to three months.	Short-term sales plan; Warehouse replenishment and transport planning; Lot-sizing and machine scheduling, shop floor control; Short term personnel planning, ordering materials

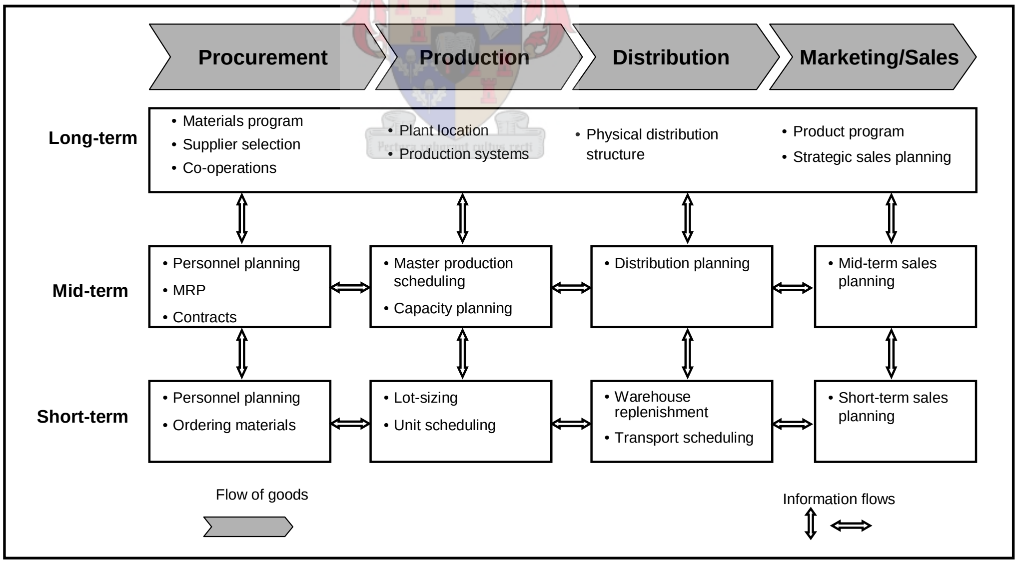


Figure 2.19 : The supply chain planning matrix
[Source: Fleischmann, Meyr & Wagner, 2000:63]

According to Vogt, Pienaar & De Wit (2002:54) the planning hierarchy can also be divided into the following planning levels (with associated purpose):

Strategic logistics planning provides the broad direction the business will allow (typically one to five years time horizon; six to twelve months review period).

Masters planning has as its major purpose to create capacity (nine to twelve months time horizon; quarterly review period).

Masters scheduling plan within the capacity created during master planning (six months time horizon; weekly review period).

Customer order processing relates to operational activities that are scheduled and prioritized (four weekly time horizon; daily review period).

From a logistics software perspective, a pyramidal viewpoint can be taken relating to the various focuses. This can be represented by the following (Andel, 1996:34) (also refer to Figure 2.20):

Top of pyramid – Represents the managerial realm, where strategies are mapped out and resources allocated (conceptual view). From there on down the pyramid, functions gradually filter into the grass roots of operations (Discrete domains).

Strategic level – Customer service programs, distribution network planning, and inventory deployment.

Tactical level – Study the transit times, inventory management, carrier selection, and fleet management.

Operational level – Manufacturing capacity, fleet routing and scheduling and shipment consolidation

Transactional level – Process controls

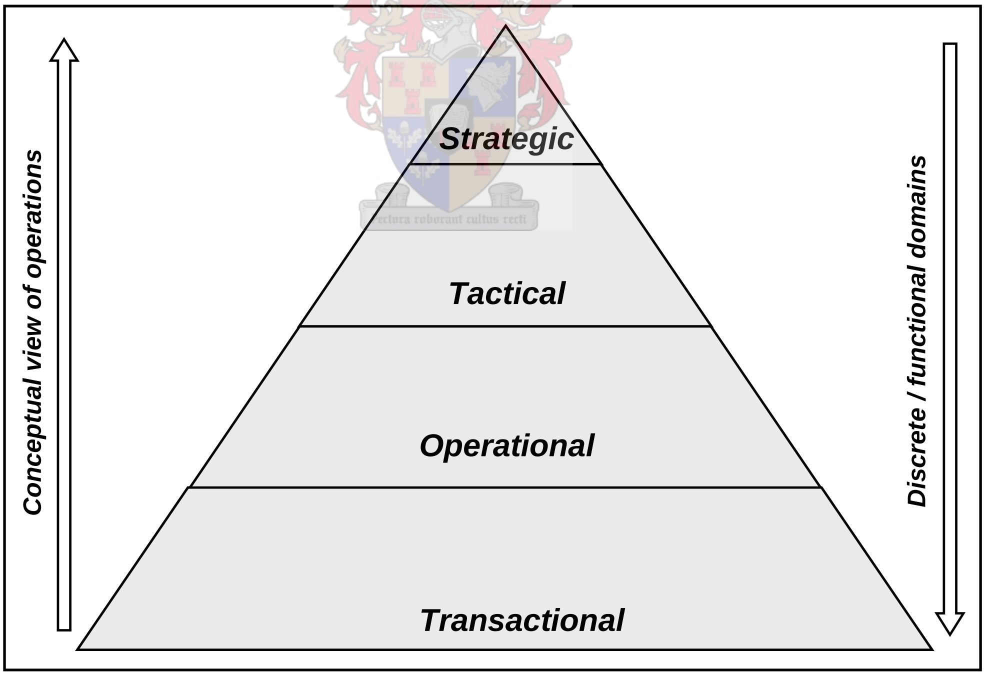


Figure 2.20 : The enterprise pyramid
[Source: Andel, 1996:34]

According to Bayer Technology Services (2002?:4), supply chain management can be grouped into three focus areas:

Strategic supply chain design deals mainly with matters emanating from the management board level of a company. These include:

- network optimization;
- support for investment/divestment decisions in the supply chain (cross-site inventory reduction, site decisions/planning, site-specific capacity expansion/ reduction, bottleneck analysis);
- product life cycle management (product launch, risk analysis, portfolio optimization);
- optimum setting of supply chain parameters (safety stocks, lot and campaign sizes);
- business process reengineering (design and modification of processes, implementation of new/modified processes);
- optimized marginal income; and
- selection and piloting of enabling tools.

Tactical and operative supply chain planning focuses on production-related requirements which include:

- implementation and customization of standard systems & APS tools;
- contingency planning;
- replenishment planning/Vendor Managed Inventory (VMI);
- optimized capacity utilization;
- lot size and campaign planning; and
- training, support and maintenance.

Supply chain controlling is concerned with monitoring changes and reviewing the results achieved, for example through:

- conceptual support for supply chain controlling; and

  (measurement of performance using Key Performance Indicators (KPI), inventory controlling, identification/optimization of service level)
- system based support in supply chain controlling

The decisions for supply chain management can be classified into two broad categories; strategic (longer term) and operational (shorter term) (Ganeshan & Harrison, 1995:2). The four major decision areas in supply chain management are:

- ***Location*** (typical strategic decisions)
  - The geographic placement of production facilities, stocking points and sourcing points
  - Size, number, and the location of these - possible paths by which the product flows through to the final customer
- ***Production***
  - Strategic decisions: what products to produce, which plans to produce them in, manufacturing capacity, the allocation of suppliers to plants, plans to DC's, DC's to customer markets.
  - Operational decisions: detailed production scheduling, a master production schedules, scheduling production on machines and equipment maintenance, workload balancing
- ***Inventory***

  - Strategic decisions: Inventory targets / goals
  - Operational decisions: deployment strategies (pull vs. push), control policies (order quantities, re-orders point and safety stock levels)
- ***Transportation*** *(distribution)*
  - Strategic decisions: modal choices
  - Operational decisions: routing, scheduling

Planning should occur both at tactical and strategic levels and from short term through to long term (Stuart, 1996:18). Deployment planning, shipment planning, load planning and route scheduling are examples of short term planning. Demand planning, including forecasting, can occur from short-term daily forecasting through weekly and monthly to long-term five years plans. Strategic logistics planning includes channel and network design. Supply planning includes the distribution plan, capacity plan for warehouse and transport as well as production plans, taking capacity and materials into account. Controlling inevitably leads to the interface between logistics and finance, and can include activity-based-costing. Controlling also includes non- financial performance criteria which are as important as financial ones.

2.2.2.1 Long-term supply chain decisions

Strategic planning decisions are concerned with defining the long-term objectives of a firm (Miller, 2001:2). These decisions assure that a firm has the proper resources and assets necessary to support its long-term objectives. Typical strategic supply chain and logistics issues are:

- Plant and warehouse locations, missions and relationships (i.e., network infrastructure and design)
- New plant locations and sizes, and plant closings
- New warehouse locations and sizes, and warehouse closings
- Plant and warehouse capacity levels
- Plant and warehouse technology and equipment acquisition
- Plant and warehouse design
- Mix of owned assets vs. third party resources utilized (i.e. outsourcing decisions)
- Transportation network and transportation providers
- Order fulfilment approach (e.g. make-to-order vs. make-to-stock)

De Villiers (2004:11) provides the following definition for Logistics Strategic Planning:

> "Logistics strategic planning is a unified, comprehensive, and integrated planning process to achieve competitive advantage through increased value and customer service, which results in superior customer satisfaction (where we want to be), by anticipating future demand for logistics services and managing the resources of the entire supply chain (how to get there). This planning is done within the context of the overall corporate goals and plan."

These decisions will have a significant effect on the firm for a relatively long time period (several years into the future). The major issues are infrastructure and overall capacity levels. Typically the level of risk and uncertainty associated with a decision increases as the time period in the future, which a decision will impact, grows more distant.

Although supply chain design and logistics network design are closely linked, there are subtle differences in the scope and focus for these two domains. The following paragraphs are concerned with more detail related to long term supply chain decisions.

a) Strategy formation framework

As indicated earlier (paragraph 1.1.1), logistics is concerned with the flow of raw materials, parts, work-in-process, and finished products needed to ensure that the company customers receive finished products at the correct time, in the correct location, an in the correct amounts. It is not concerned with plans regarding manufacturing processes, transformations, or resources, although manufacturing facilities might be treated as arms-length suppliers to the logistics network. This typically relates to the ***logistics strategy formation*** framework developed by Andersen Consulting (referenced by Shapiro, 2001:287) as illustrated in Figure 2.21. The driving force underlying the design and operation of a company's logistics supply chain is its customer service strategy. This framework depicts the structural, functional and implementation elements of logistics strategy formation.

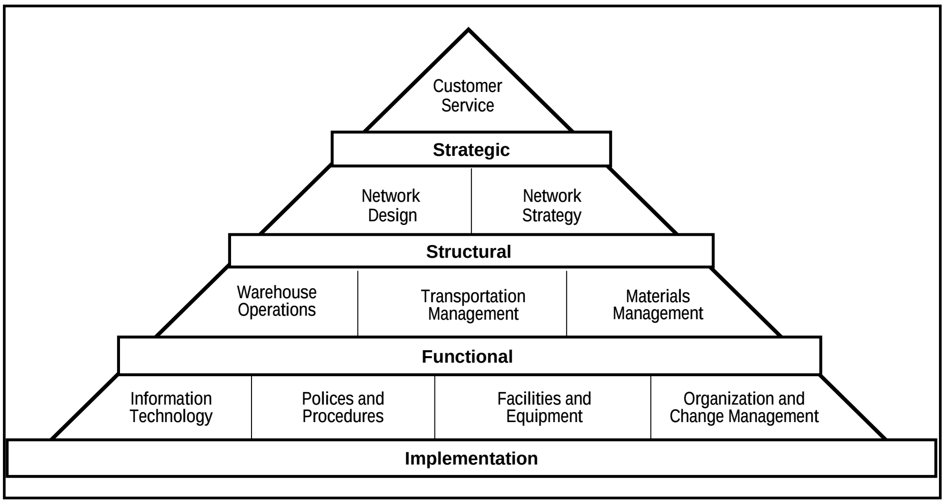


Figure 2.21 : Elements of logistics strategy formation framework.
[Source: Shapiro, 2001:287]

Once the firm's strategic goals have been articulated, it must identify ***structural*** elements for implementing its strategy; which are its network design and its network strategy. The ***functional*** elements of the framework evaluate and fill out details regarding structural decisions. Decisions are about warehouse operations, transportation management, and materials management (which refer to processes and systems for managing flows and inventories across the entire network). The final level of the framework, ***implementation***, involves people, business processes, and IT to support and execute the strategy.

The framework for logistics strategy formation (discussed above) can be adapted to define a framework for a ***manufacturing company's supply chain strategy formation*** (Shapiro, 2001:295) as indicated in Figure 2.22. In this case the driving force for a company's manufacturing strategy is the company's need and desire to manufacture competitive products. Product competitiveness depends on a number of factors including cost, differentiation, agility, quality, cycle time, and new product development. Apart from new product development, other functional elements (not included in the logistics strategy formation framework) that also need attention are plant design and operations, quality management and supplier management.

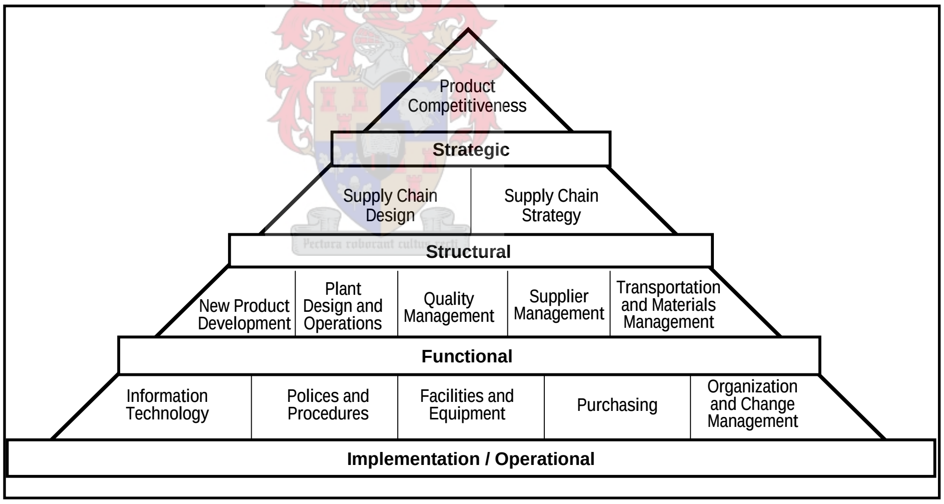


Figure 2.22 : Elements of a manufacturing company's supply chain strategy formation framework. [Source: Shapiro, 2001:295]

b) Supply chain network design

The Cardiff framework for supply chain design as explained by Naim & Towill (1994:82) provides a structured approach to analyzing the dynamic properties of supply chains as to highlight problems and hence to develop suitable solutions. The process for the framework is divided into two phases, as indicated in Figure 2.23:

Qualitative phase - Acquiring sufficient intuitive and conceptual knowledge to understand the structure and operation of a supply chain.

Quantitative phase - Development and analysis of mathematical and simulation models.

According to Ballou (1995:40) logistics network design relates to decisions regarding customer service, inventory policy, transportation modes and stocking points to be located and sized. The typical location decisions issues include location of retail outlets, processing plant/ports, sources, warehouses / break bulk points / consolidation points, and layout of activities within a plant or office.

To identify effective supply chain redesign strategies one should focus on the identification and management of the sources of uncertainties in supply chain decision-making processes (Van der Vorst & Beulens, 2002:427). By breaking down the walls between supply chain stages, as indicated in Figure 2.24 SCM provides the opportunity to reduce the decision-making uncertainties within the supply chain system. Some of the major supply chain uncertainties include (Van der Vorst & Beulens, 2002:413):

- Unclear objectives and corresponding performance indicators
- Lack of information about (or understanding of) the supply chain or its environment
- Lack of information processing capabilities
- Inability to accurately predict the impact of possible actions on supply chain behaviour
- Lack of effective control actions

Van der Vorst & Beulens (2002:414) also indicate that some of the main sources for supply chain uncertainties are:

- Inherent characteristics (demand, product, process, supply)
- Supply chain configuration (infrastructure, facilities, capacity)
- Supply chain control structures (Orders forecasting horizon [Order lead time, order sales period])
- Decision policy and complexity (parties involved, roles)
- Supply chain information system (data timelines, data accuracy and applicability)
- Supply chain organizational structure (authority / responsibility, human behaviour)

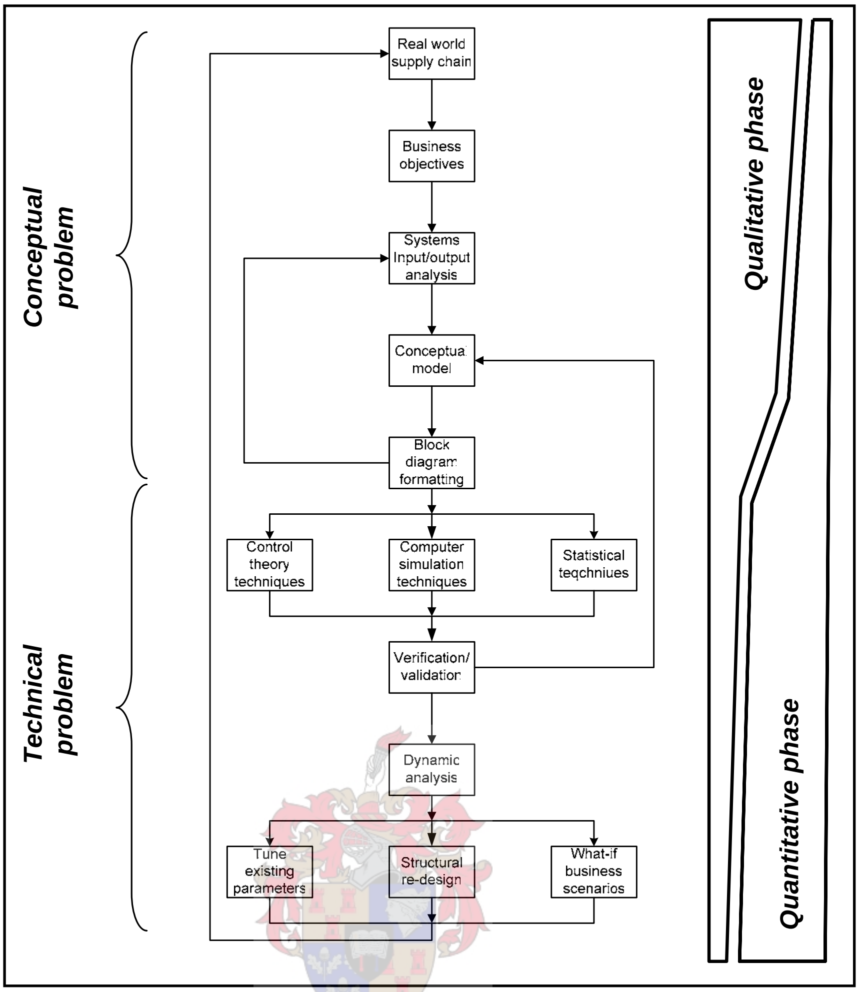


Figure 2.23 : The Cardiff framework for supply chain design
[Source: Naim & Towill, 1994:83]

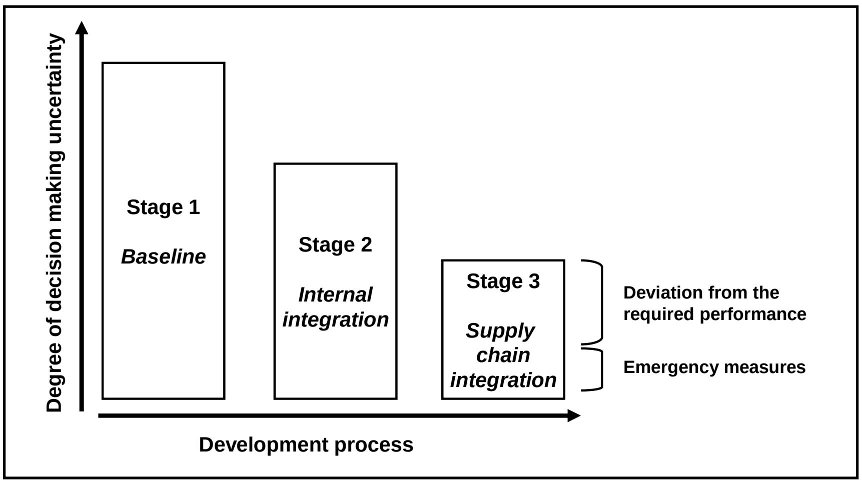


Figure 2.24 : SCM helps to reduce the decision-making uncertainties
[Source: Van der Vorst & Beulens, 2002:413]

Based on different business alternatives being considered, supply chain managers need to propose different enabling supply chains. The following are typical supply chain redesign strategies or elements to articulate the different scenarios (Van der Vorst & Beulens, 2002:414):

- Supply chain configuration (Structures, facilities, parties involved)
- Supply chain control structure (Set of decision functions [Multiple decision layers with different decision horizons] that governance the execution of operational activities)
- Supply chain information systems (Supports decision-making and/or are required to perform operations [EDI, ERP, APS, etc.])
- Supply chain organization and governance structures (Assigns tasks to organizations and persons in the supply chain [corresponding responsibilities and authority]; jointly define the chain objectives and performance indicators)

To adequately supply to geographically dispersed markets, a properly designed configuration of facilities is essential. This is particularly important in designing international supply chain configurations (Vos & Van den Berg, 1996:70). On the corporate level, decisions regarding the physical design of the value chain for specific product families need to be taken and implemented. As part of the supply chain configurations, typical locations decisions that need to be taken are:

- Construction of new plants
- Expansion of existing manufacturing capacity
- Acquisition of or joint venture with foreign firms
- Re-location of existing plants
- Re-location of manufacturing activities

The following however are potential barriers / restrictions to configuration choices (barriers and associated issues):

- Transportation barriers
    - *Both dissipation in the corporate strategic planning process*
- Time barriers
    - *perishability*
    - *high value added products*
    - *customer service requirements*
- Trade barriers
    - *tariff barriers*
    - *non-tariff barriers*
- Restructuring barriers
    - *financial barriers*
    - *cultural barriers*
- Country specific barriers
    - *view toward foreigners*

- *nature and extent of nationalism*
- *political ideology*

Chopra & Meindl (2001:52-54) states that as part of the supply chain design process, key structuring decisions must be made that relate to supply chain drivers. These are decisions that relate to:

- Inventory Decisions
  - *Cycle Inventories*
  - *Safety Inventories*
  - *Seasonal Inventories*
- Transportation Decisions
  - *Mode of Transportation*
  - *Route & Network Selection*
  - *In-house or outsource*
- Facilities Decisions
  - *Location*
  - *Capacity (flexibility v/s efficiency)*
  - *Manufacturing Methodology*
  - *Warehousing Methodology*
- Information Decisions
  - *Push v/s Pull*
  - *Co-ordination of Information Flow*
  - *Forecasting & Aggregate Planning*
  - *Enabling Technologies*

Inventory management plays a very important role, and decisions regarding inventory should be incorporated in strategic supply chain models (Shapiro, 2001:487). Key inventory planning phenomena to be captured are:

- Pipeline inventories
- Safety stock inventories
- Replenishment inventories

c) Logistics network design

With strategic logistics planning, management must challenge itself to identify a broad range of options (Shapiro, 2001:288). This planning discipline is based on scenario analysis. Strategic planning processes should be institutionalized so that they are repeated on an annual, or some other periodic, basis. The two main issues for strategic logistics planning are:

Network design: It is concerned with activities and functions needed to achieve the customer service goals and how different participants in the supply chain carry them out.

Network strategy: It is concerned with decisions about the logistics network. Some key decisions include the location and mission of facilities and strategies for using these facilities to serve customers.

In logistics systems design, a company is typically faced with two design situations (Kasilingam, 1998:20-21). The one is new logistics systems design and the other existing logistics systems re-design. For both these situations, the same logistics systems analysis phases apply, i.e.:

- Problem definition
- Data collection
- Problem analysis (Methods to be used)
    - Mathematical Methods
    - Heuristics Methods
    - Simulation Methods
- User testing and implementation

Strategic logistics planning cover three typical areas to be evaluated (Copacino & Rosenfield, 1992:163). These evaluation areas include: Leveraging logistics (*for competitive advantage & differentiation*), evaluating impacts of proposed corporate strategic plans (*participation in the strategic planning process*), and supporting the corporate strategic plan (*establish cost effective plans to support the corporate plan*).

The objective of logistics network decisions is to minimise system-wide costs, subjected to a variety of service level requirements. It is important in scenario analysis to always compare against baseline information (to test what-if scenarios). Other considerations are flexibility and robustness (Bramel & D. Simchi-Levis, 1997:255). Information and data play a critical role in logistics network design. From the vast range of data available (from data collection), one can approximate information in a number of ways to reduce the problem size. Data aggregation is one of the effective techniques that one can use for this purpose. The following are some key categories of information required for logistics network design:

- Transportation rates
- Mileage estimate
- Warehousing costs
- Warehousing capacities
- Potential warehouse locations
- Service level requirements
- Future demand

Detailed typical key information required:

- Location of customers, retailers, facilities and suppliers
- All products (volume, special transportation requirements)
- Annual demand
- Transportation rate by mode
- Warehousing cost (labour, inventory carrying cost, fixed ops cost)
- Shipment size and frequency for customer delivery
- Order processing cost
- Customer service requirements and goals

d) *Facility Location Planning*

Locating facilities in a logistics network is a major strategic planning problem due to major capital investments often needed to be made (Ballou, 1995:39). Logistics operational costs (Ranging from 8 to 30 percent of sales) are significantly affected by location decisions. Optimizing the location of facilities within an existing network can save between five and fifteen percent of logistics costs.

Kasilingam (1998:99) stated that facility planning include two major logistics decisions:

- Facility location, and
- Facility layout (Facility Layout has a major role to play in opportunities to minimise the total cost of material handling)

Dimensions/variants of location planning problems to be solved include the following (Ballou, 1995:40):

- Plant vs. warehouse location
- Static vs. dynamic time horizons
- Stochastic vs. deterministic data
- Single vs. multiple products
- Continuous vs. discrete analysis
- Spatial vs. temporal dimension
- Profit vs. cost optimization

e) *Decision support for long term supply chain/logistics decisions*

Decision support systems play a key role in logistics network configuration in decision-making. According to D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:18) the key logistics network configuration strategic decisions to be taken include:

- Number of warehouses
- Location of each warehouse
- Size of each warehouse

- Allocating space for products in each warehouse
- Which products customers will receive from each warehouse?
- Transportation decision are more tactical (modes, routes)

Modelling choices for location planning problems include the following (Ballou, 1995:45):

- Approximate (e.g. weighted checklist method)
- Simulation (time or events simulation, aggregate demand & cost data)
- Exact (Centroid, LP, Integer Programming)
- Heuristics

It is of vital importance to choose the right modelling technique for solving logistics network planning problems. Ballou (1995:50) provides the following as some criteria for choosing the right modelling technique:

- Can adequately represent the problem at hand
- Does not require excessive amount of time, costs and effort
- Can find a satisfactory solution within a reasonable amount of computational effort
- Can be executed on computer equipment that is readily available and inexpensive

Logistics Network Modelling deals with four major planning areas (Kasilingam, 1998:48):

- Customer service levels
- Location decision
- Inventory planning
- Transportation management

The components of a Logistics network model comprise the following (Kasilingam, 1998:49):

- Vendors (Suppliers)
- Upstream materials and downstream products
- Manufacturing plants
- Distribution centres
- Transportation services
- Customers

Most of the logistics network models are structured around objective function, constraints and variables (Kasilingam, 1998:52). Frazelle, (2002:15) provides an example of how to determine the optimal customer service policy given the objective is to minimise the total logistics costs (TLC). The TLC includes inventory carrying costs, response time costs (warehousing and transportation), and lost sales costs. The constraints are the availability of inventory and the response time requirements that make up the core of the customer service policy. Mathematically, one can write the following:

Minimise:

Total logistics costs = Inventory carrying costs + Response time costs
+ Lost sales cost

Constraints:

1. Inventory availability> Customer service inventory target
2. Response time < Customer service response time target

Data aggregation is used to reduce problem size (Ballou, 1995:42-45). Some of the key dimensions for aggregation are (some of these are also used for demand planning - more detail in paragraph 2.2.2.2 b)):

- Product aggregation
- Demand aggregation
- Transport rate curves
- Distance estimation
- Inventory consolidation curves

2.2.2.2 Medium-term supply chain decisions

Medium-term supply chain decisions relates to management control (tactical planning) (Miller, 2001:3). At this level the decisions focus on resource allocation and resource utilization. It also focuses on how to utilise the infrastructure and capacity as effectively as possible. The drive is the implementation of strategic decisions. Typical tactical logistics decisions are the following:

- Assignment of production capacity to product families, by plant (and often) by medium size time periods (e.g., quarters)
- Planned manufacturing capacity utilization rates, by plant and network wide
- Workforce requirements (regular and overtime levels)
- Plant, distribution centre, and sales region/country sourcing assignments
- Inter-facility (e.g., inter-distribution centre) shipment plans
- Inventory investment and deployment plans
- Transportation mode and carrier selections

Tactical planning decisions typically spans over a planning horizon of at least twelve months and sometimes up to eighteen or twenty-four months. These decisions typically do not carry as high a level of risk and uncertainty as is the case with strategic planning decisions (but it has a high impact on business). Strategic supply chain planning is concerned with maximization of net revenue (executed infrequently/ad-hoc) while tactical supply chain planning is concerned with product competitiveness (done repetitively and on routine basis) (Shapiro, 2001:311).

Tactical planning models are derived from strategic planning models by fixing resource acquisition and divestment options based on the optimal or preferred configurations determined by the strategic models and senior management. Tactical planning models are predominantly multi-period. Single period models can be linked by using inter-period inventory flows. The dynamic effects of the supply chain to be captured include:

- Planning inventories to accommodate seasonal demand patterns or to achieve smooth adjustments to unexpected ebbs and flows in demand
- Adjusting operating shifts per week and according to other labour resources as the result of changing market conditions
- Scheduling yearly plant maintenance to minimize avoidable costs across the supply chain
- Exercising vendor contracts on a monthly basis to reduce inventory holding costs while avoiding contractual penalty costs for taking insufficient volumes.

a) Sales and operations planning (S&OP)

Sales and operations planning (S&OP) forms a critical part of tactical supply chain planning (Miller, 2001:203). The American Production and Inventory Control Society (APICS) define sales and operations planning as follows:

"A process that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. The process must reconcile all supply, demand, and new-product plans at both the detail and aggregate level and tie to the business plan. It is the definitive statement of the company's plans for the near, to intermediate term covering a horizon sufficient to plan for resources and support the annual business planning process."

Figure 2.25 illustrates some of the components, inputs and outputs most commonly found in a firm's S&OP process.

Lapide from AMR (as interviewed by Murphy & Sherman, 1998:62) states that when integrating supply and demand planning, technology must provide more than just the mechanistic forecasting of demand. It must support marketing and sales in planning for demand creation programs such as price cuts, trade and customer promotions. According to Lapide (1998:5) companies are moving towards an integrated, synchronised planning model where supply plans are based on unconstrained demand forecasts. Supply plans are largely created assuming a given demand plan. This is typically achieved through a sales and operations planning (SOP) process with multifunctional teams meeting to develop a consensus-based operational plan. The process ensures that supply meets demand. The interrelationship between the supply and demand planning processes are clearly illustrated in Figure 2.26.

According to Asgekar (2004), the only enterprise process that balances the supply- and demand-side equation optimally is a S&OP process. A formal well-executed S&OP process is one of the key practices used by performance leaders (good indication of planning accuracy). S&OP is all about collaboration and consensus from the supply side (upstream, manufacturing and downstream supply) and demand side (the customer and marketing and sales). S&OP processes will also involve operations, sales, marketing, finance, and product development groups so that product transitions and phase-outs as well as financial implications such as revenue targets, profitability goals, and inventory investments could be planned. The biggest benefit from S&OP is that everyone in the enterprise understands and aligns to a common goal.

Demand *(Sales-Marketing -Forecasting)*	**Supply** *(Operations-Production Sourcing)*	**Business Plan** *(Total Firm)*
• ***Sales/marketing forecasts*** • ***Inventory analysis of customers*** • ***New product introductions*** • ***Product discontinuations*** • ***Advertising and promotion plans*** • ***Product return projections*** • ***Performance measure reviews*** • ***Sales, marketing and distribution cost projections*** • ***Sensitivity analysis***	• ***Production plans*** • ***Inventory plans*** • ***Customer service fill rate objectives*** • ***Capacity utilization projections*** • ***Capacity contingency plans*** • ***Performance measure reviews*** • ***Manufacturing and purchasing cost projections*** • ***Sensitivity analysis***	• ***Revenue projections*** • ***Total cost projections*** • ***Profit projections*** • ***Sensitivity analysis***

Figure 2.25 : Illustrative components of S&OP process.
[Source: Miller, 2001:204]

S&OP process definitions already started in the late 1980s. The current best practice definitions is quite different (Cecere et la., 2005:3). The process has shifted from a four-step process of balancing demand and supply in the early 1990s, to a more collaborative six-step planning process in early 2000, and now to a nine-step process followed by demand driven supply network (DDSN) oriented leaders in 2005. This new process steps (as indicated in Table 2.2) has become the standard practice for leaders attempting to become demand driven.

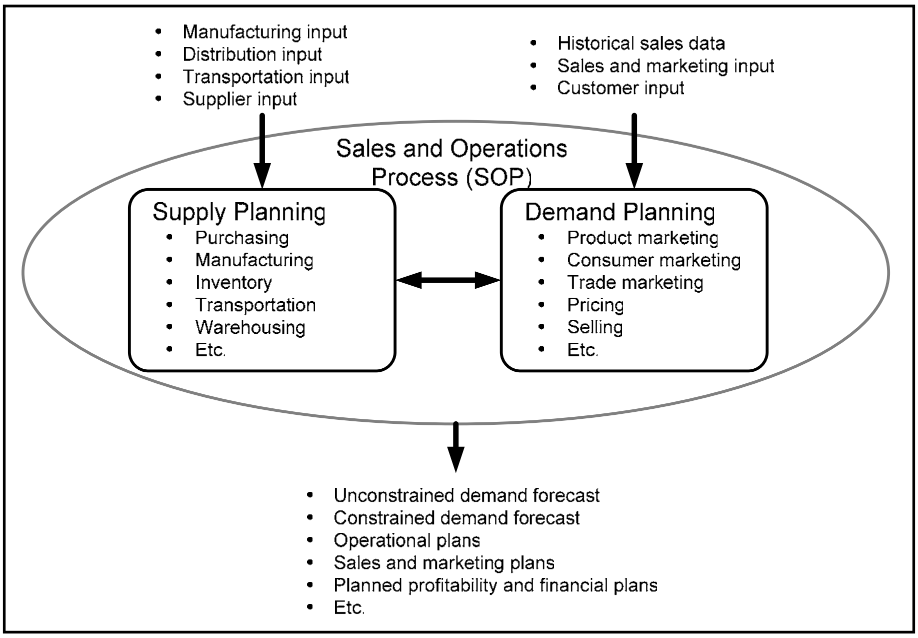


Figure 2.26 : Integrated supply and demand planning process model
[Source: Lapide, 1998:7]

Table 2.2 : Changes in S&OP process definition over time
[Source: Cecere *et la.*, 2005:4]

1990s	Early 2000	DDSN Leaders
Develop a demand forecast	Collect sales input	Collect sales and market input
Balance demand with supply	Develop a forecast	Develop a demand plan
Consensus meeting	Shape demand consensus refinement	Demand consensus refinement
Publish the plan	Develop a constrained supply plan	Shape demand based on what-if analysis on demand for supply
	Review and gain agreement through a consensus meeting	Develop a constrained plan by supply
	Publish the plan	What-if analysis by supply to determine trade-offs on the measurements and identify demand-shaping opportunities
		Review and gain agreement through a consensus meeting
		Publish the constrained plan
		Measure and communicate the plan

According to Lee (2005:1), S&OP is a continuous supply chain management process which balances supply with demand in accordance with the business strategy. Strong cross-functional teamwork is required in both demand and supply planning in order to optimize the whole instead of the individual parts. Several monthly sub-processes, as well as continuous monitoring of performance vs. plan are needed. It culminates in a monthly meeting at which the previous month's performance is reviewed and recommendations for alterations to future months' plans are presented.

S&OP is that set of business processes and technologies that enable an enterprise to effectively respond to demand and supply variability. It allows the enterprise to timely determine the right market and supply chain mix throughout the S&OP time horizon (Elbaum, 2005:i).

The diagram in Figure 2.27 gives a good indication of the supply chain planning business processes from demand to delivery. It also indicates the inter-relationship between demand planning, supply planning, production planning and distribution planning.

From the previous paragraphs, the fundamental decision in the S&OP process is what to make where, and when – in the future. The key planning processes playing a prominent role in medium term supply chain decisions are demand planning, inventory planning, supply planning (upstream and downstream), and operations / manufacturing planning.

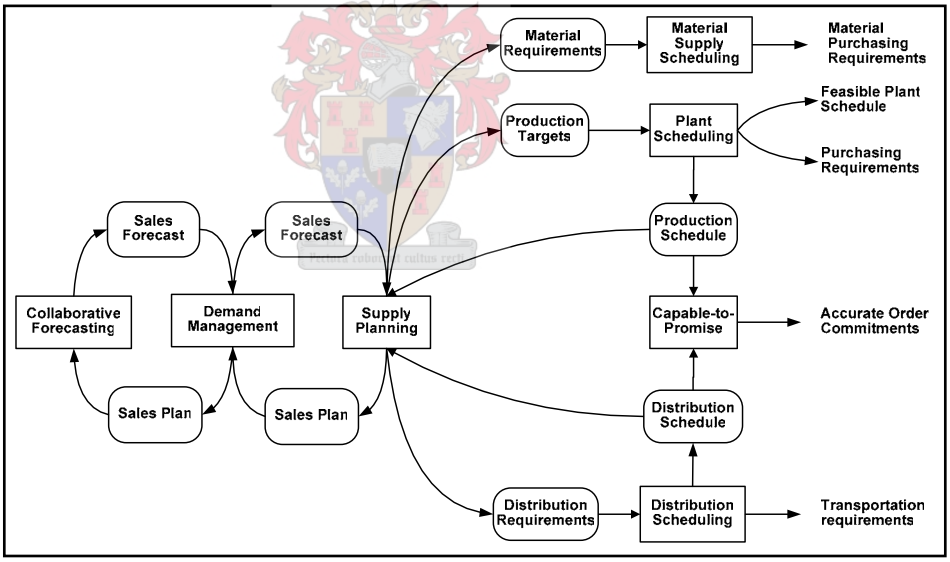


Figure 2.27 : Tactical SC planning business processes - demand to delivery [Source: Adapted from Aspen Technology, 2003:3]

b) Demand planning

Demand planning is widely accepted as the driver of supply chain planning. This forms the basis for companies looking to integrate strategy across functional and national divides (Smart, 1995:15).

The tactical use of historic demand data will give a company only a forecast of projected sales (Langabeer II, 2000:69-70). A strategic view of the same data (using advances demand planning approaches), on the other hand, leads management to alter the portfolio and produce investment strategies. Contrary to the conventional view, the past is not necessarily a sound indicator of future demand, particularly in highly competitive markets. In reality, it is not enough to merely use basic forecasts that average historic demand. A more strategic approach to demand management is to use all available intelligence and market data to analyze demand and create more accurate scenarios for the future.

To reach the most accurate forecast possible means that companies are increasingly looking to decrease the amount of noise in their forecasts by looking for the true source of demand - the end customer (Smart, 1995:15). Forecasting demand is critical because it reduces uncertainty at each stage of supply. In the past it was common for each department to set its own forecasts. The problem was that each area then accumulated safety stock as a buffer against the demands of the other areas and this was costly. Companies are now re-organizing their company structure to ensure that each different functional area work together, sharing a “one-number" forecast. Forecasting allows a company to look into the future and understand how external factors are likely to influence their business.

Demand planning is increasingly becoming part of integrated supply chain planning solutions (Smith, Mabe & Beech, 1998:126). The typical best practices applied in demand planning are:

- Integrated forecasting, planning and execution
- A cross-functional forecasting process
- Top-down, bottom-up and adjustment capability
- Pull-based demand signal
- Statistical techniques
- Performance monitoring and tracking

The typical demand planning process includes some of the following ingredients (Smith, Mabe & Beech, 1998:131):

- One of the keys to excellence in demand forecasting is collaboration
- Use of a cross-functional, consensus based process
- A typical sales and operations planning process has six main steps:
    - Generate baseline forecast
    - Translate to common terms
    - Review from various perspectives
    - Consensus meeting
    - Publish forecast
    - Measure actual performance against original forecast

The intent of demand planning is to aid in the integration of three dimensions (Smith, Mabe & Beech, 1998:133): Horizontal (between functional areas and along the supply chain stages) Vertical/hierarchical (integration of activities over strategic, tactical and operational planning horizons) and Geographical (spatial nature of a supply chain network; regional country units).

To support the S&OP requirements and the viewing of required data from a demand and supply perspective, it is important to define demand and supply hierarchies (Cecere *et al.*, 2005:4). These different views of data are required to support the processes of marketing and sales (demand) and operations (supply). Figure 2.28 illustrates the typical demand and supply perspectives and hierarchies.

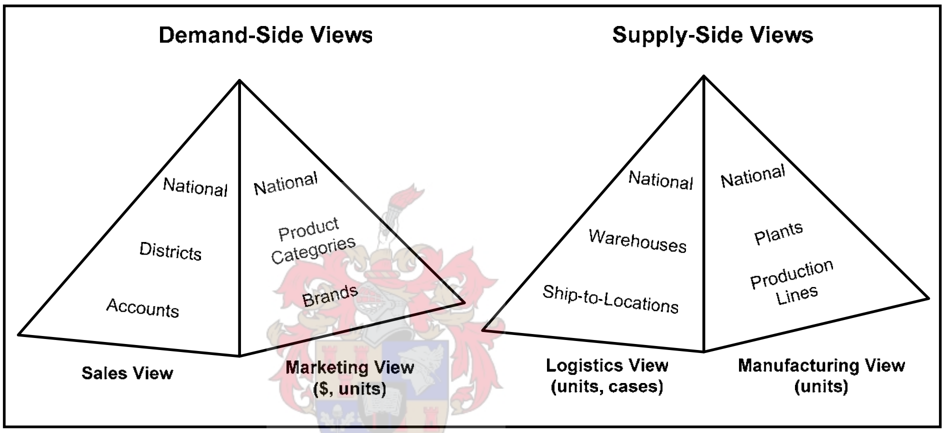


Figure 2.28 : Demand and supply hierarchies
[Source: Cecere *et la.*, 2005:10]

Small improvements in forecast accuracy can dramatically reduce inventory costs (Mitchell-Keller, 2005:34). Many techniques are available to address the different business needs within each company and throughout each trading network. These techniques include time-series analysis, judgment forecasting (expert estimates or management targets), advanced time-series analysis, data-driven events, critical causal index and life cycle forecasting and consumer behaviour forecasting. One tried and tested way of improving demand predictions is through collaborative planning. Trading partners throughout the supply chain work together to determine inventory and replenishment strategies and make efforts to align their sales forecasts accordingly. This collaborative initiative should lead to lower inventory throughout the supply chain, more inventory turns, fewer stock-outs, and higher profitability.

In screening and choosing demand planning technology, the following should be considered (Smith, Mabe & Beech, 1998:136):

- Available statistical models
- Software must support the process
- Software way of integration
- Cost (benefits) must be justified (also look at business dynamics)

There is a fine line between demand management and demand planning (Bolton, 1998:139). In essence demand management reduces demand volatility. A lot of demand volatility is often due to the organization's own self-induced policies and procedures. Demand management seeks to get the right customer demand profile into the demand planning process. This profile must be as smooth as possible. Its task is to identify, to reduce and eliminate causes of customer volatility. The following are indications of how volatility creates/increases complexity (Bolton, 1998:142):

- Increased supply chain uncertainty
- Increased reliance on accurate and timely information
- Increased risk of stock outs
- Increased customer lead time
- Increased reliance on efficient production planning capability
- Decreased ability to provide accurate information to manufacturing
- Increased risk of obsolescence

There are a number of root causes for demand volatility. Some examples are:

- Terms of trade
- Promotions and pricing
- Specific company policies
- Distribution (marketing) channel structures
- Minimum order quantity

Forecasting plays a critical role in supply chain management (Chopra & Meindl, 2001:68). It forms the basis for supply chain strategic and planning decisions. It is also used as basis for decisions in the push phase of supply chain (Production, Marketing, Finance, Personnel). Some of the key characteristics of forecasting are the following:

- Forecast is always wrong (use measure for forecast error)
- Long-term forecast is less accurate than short-term forecast
- Aggregate forecasts are more accurate than disaggregate forecasts

Chopra & Meindl (2001:68) provides some key forecasting factors to take into account:

- Past demand
- Planned advertising or marketing efforts
- Display position in catalogue
- State of the economy

- Planned price discounts
- Competitor actions

Langabeer II (2000:70) also indicates that demand can be viewed as a function of:

- Competition
- Organizational direction
- Portfolio differentiation
- Price elasticity
- Customer buying behaviour
- Seasonality
- Exogenous influences and causal factors
- Brand equity

c) Inventory planning

Due to lead times and cycle time, inventory is a key requirement to balance the supply chain (B.A. Ayers, 2002:658). Lead time is associated with a product or service delivered by the supply chain. It is imposed on the supply chain by the competitive environment (depicted by the customer service requirements). Cycle time is a property of processes in the supply chain. The minimum theoretical cycle time is the sum of individual process cycle times. When cycle time is greater than lead time, inventory is required.

A number of factors in the past years have caused both demand and supply variability to increase (Cecere, Sarnevitz & Preslan, 2005:1). The proliferation of items, channels and the increase in promoted goods, have led to an increase in demand variability. With greater dependence on offshore sourcing, supply variability has also escalated. Manufacturing capacity and inventory are two key shock absorbers for variability in the supply chain. The increase in global manufacturing capacity and the dependency on outsourced manufacturing, has led to a greater need for inventory to serve as a shock absorber. The role of inventory as a shock absorber plays a key role in Demand-Driven Supply Network (DDSN) strategies purely due to the increase in global manufacturing capacity and the dependency on outsourced manufacturing.

Inventory is a necessary evil for the proper functioning of the supply chain and is often a neglected factor (Kasilingam, 1998:75-80; Waller, 1999:294-295). The function of inventory is to meet uncertainty in production and supply, achieve economies of scale, provides protection against increase in purchase price, and balance out the seasonal fluctuations combined with limitations in supply. There are however major costs associated with inventory:

- Procurement and production cost
- Inventory carrying cost
    - Investment in Inventory
    - Warehousing
    - Holding Cost
- Transportation and in-transit inventory cost
- Inventory ordering cost
- Inventory stock-out cost
- Safety stock cost
- Quality cost

Related to inventory planning are the following typical distribution questions (Redmond, 1998:49):

- Where should we locate our manufacturing facilities?
- Where should we hold stock?
- Is load consolidation worthwhile?
- Which market places should be served from which warehouse?
- How much stock should we have?
- How can we shorten lead times and improve service levels?
- What should our distribution fleet look like?

Inventory Planning makes trade-offs amongst the logistics cost elements (Miller & Liberatore, 1996:24). It evaluates the trade-off amongst inventory carrying costs, inventory investment costs and transport costs. The five major quantitative cost factors are:

- Freight costs
- Inventory carrying costs of pipeline inventory
- Inventory carrying costs of a cycle stock at the receiving location
- Inventory carrying costs of the required safety stock at those receiving location
- Investment costs to produce the inventory to fill the pipeline

Inventory management decisions should be incorporated in tactical supply chain models (Shapiro, 2001:492): The following are key aspects to incorporate:

- Multi-period model
- Dynamic and time-dependant
- Capture beginning and ending inventories

d) Transportation/distribution planning

Transportation planning plays a critical role in supply chain planning (Kasilingam, 1998:158). The transportation system comprises facilities, equipment and people. These system components form the basis for transportation planning. Transportation economics is one of the key factors taken into account. The typical transportation economic elements are:

- Routes
- Terminals
- Vehicles
- Transportation cost
  - Fixed cost
  - Variable cost
  - Attributable cost
  - Non-attributable cost

Transportation models normally include the following decision variables (Kasilingam, 1998:166):

- Mode selection
- Route selection
- Fleet sizing
- Vehicle scheduling
- Shipment consolidation

The qualitative trade-off factors in choosing the right mode and carrier are typically the following (Miller & Liberatore, 1996:24):

- Customer service
- Tracking and tracing capability
- Billing/invoicing accuracy
- Electronic data interchange capability
- Potential to develop mutually beneficial long term partnerships
- Cargo capacity limitations
- Ability to provide service that does not damage goods while in transit
- Customs clearance capability
- Impact on the shipper's negotiation position/leverage on other shipping activities

e) Manufacturing operations planning

The integration of the production function also plays a key role in supply chain planning. The production function is composed of many activities including planning, scheduling and real time-process control (Bodington & Shobrys, 1996:56). Planning (strategic or tactical) averages operations over a given period, and determines the feedstock purchases and the required plant loading to meet demand commitments. Scheduling selects the proper process sequence, production run sizes and inventory levels. Scheduling doesn't average operations over time, but follows operations continuously over a relatively short period. Process controls provide the real-time process management. Actual production performance depends on how accurate the planning and scheduling predictions can be achieved in the plant via process control systems.

The term 'planning' covers all those activities required for desired objectives to be met. In business, the planning process generally has its roots in the strategic, or long-range, plans which are then broken down into a more detailed operating plan (Waller, 1999:329-350). A strategic plan has a nominal time horizon of about five years, though it might be longer or shorter depending on the industry. On the other hand, the horizon of the operations plan is about a year; although for some firms it may be up to 18 months. The objective of the operating plan is to enumerate in detail all the activities necessary in order to produce end-products, or to provide the required services for a customer in a timely manner.

An operations plan itself may comprise short term and medium term components, i.e.:

A ***medium-range plan*** would cover the period between three months and 12 or 18 months. Some of the activities would include.

- Sales planning
- Hiring, or termination, of employees
- Budgets (usually budgets are prepared for the year)
- Selecting new subcontractors or suppliers
- Selecting, and installing, new machines and equipment (this may be part of the long-range plan for large expensive capital equipment)
- Production plans.

A ***short range plan*** would cover less than three months, maybe one week, or even one day. The activities might include:

- Scheduling production programmes
- Establishing work assignments
- Organising deliveries of raw materials
- Organising shipments of finished goods
- Hiring, or termination of employees' services (where flexibility exists)

Rigorous attention to operations planning is critical for the smooth functioning of the supply chain. Poor scheduling in the reception of raw materials, in production programmes or in the delivery of finished goods can all lead to delays and dissatisfied customers.

The starting point for production planning is the ***aggregate plan***. The aggregate plan is the development of an estimate of future needs of end products. This estimate, derived with input from marketing, may be firm orders from clients, anticipated orders promised but not yet booked, or pure forecasts. When this estimate is established, all the end products are totalled or aggregated into a demand for the production facility. For production to convert this into capacity requirements, the aggregate demand is translated into resource requirements of material quantities, labour hours and machine hours using appropriate standards.

Aggregate planning in the manufacturing or service sector involves deciding on how resources will be used to meet the forecast or actual client demand cost-effectively within the constraints of the capacity of the facility. The capacity of an organization is governed by the physical space (buildings and land), the labour force, financial resources, materials, and machines. There are a number of ways capacity can be adjusted to meet demand:

- Hiring and termination of the permanent workforce's services
- Overtime
- Part-time workers
- Temporary workers
- An extra shift
- Weekend work
- Machines
- Purchased materials
- Adjusting inventory levels
- Demands on backorder
- Subcontractors

Demand can also be modified to accommodate capacities:

- Reduction in product price
- Taxation and fees
- Advertising
- Cash payments
- Creating a new demand

The choices of planning in a production operation include:

- Level production (when a plan is prepared such that the production rate is uniform over time),
- Synchronizing the production with the aggregate demand, and
- a hybrid of level and synchronized production.

The Master Production Schedule (MPS) is a key planning tool, with a time horizon in weeks or months (depending on the firm), indicating what end items need to be completed. The purpose of the rough-cut capacity plan is to see where adjustments can be made to balance the MPS (see Figure 2.29 for an example).

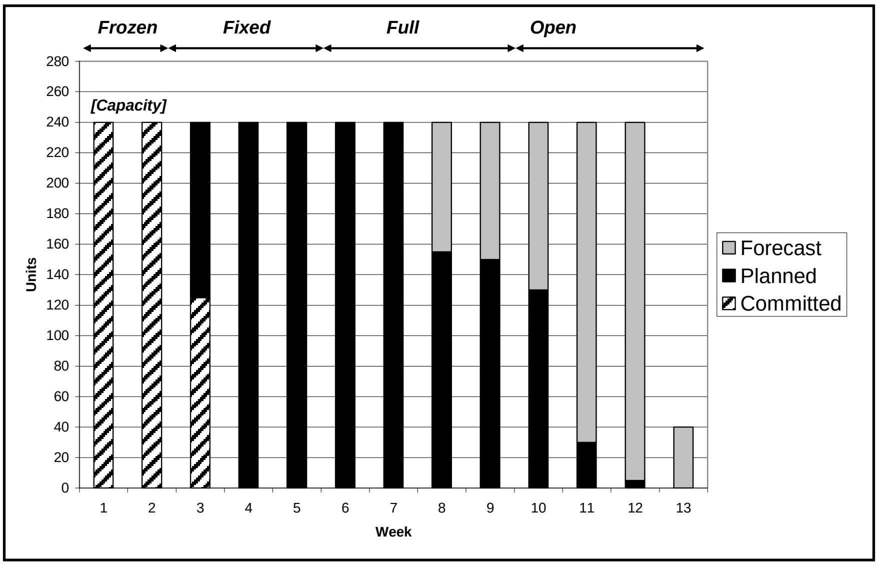


Figure 2.29 : Master production schedule: capacity balanced.
[Source: Waller, 1999:350]

The following key functional components are required to integrate the production function (Bodington & Shobrys, 1996:56):

- Process information systems (central to data collection and analysis of real time process performance)
- Data communications and networks (Usually three network levels are in a plan; local control network [on each process control system]; local area network [for information and data management within each process]; wide area network [combining information from local area networks and data transferring to and from the plant])
- Databases and information management (although data storage might be distributed, the database should appear as a single entity to users with a standardized interface for all applications)
- Data reconciliation (ensures that all data makes sense and is adjusted to comply with natural laws)
- Advanced process control (an important part of supply chain integration since they operate processes in a predicted manner)
- Scheduling (Modern scheduling systems improve both manufacturing processes and inventory management)
- Planning (Requires new database-oriented computer systems; These databases are easy to integrate with other functions and allow sophisticated techniques such as nonlinear or mixed integer programming; nonlinear optimization is used because of its improved process modelling; supply chain integration requires that planning and scheduling predictions closely match the reality of process operations)

- Organizational issues (Companies that are integrating their supply chain generally half to change the organization to support the new integrated functional operations. The impetus for change and the drive to an integrated system must be provided by top management)

2.2.2.3 Short-term supply chain decisions

This type of decisions focuses on operational control (operational planning and scheduling) (Miller, 2001:5-6). Operations must carry out the resource allocation and utilisation decisions made at the tactical level in the daily and weekly activities. Schedulers and operators execute its daily operations using the resources made available by the tactical planning process. The typical operations logistics decisions include the following:

- Daily and weekly production scheduling at the item level including item sequencing decisions
- Short term inventory balancing and reconciliation
- Customer order processing and scheduling
- Warehouse operations scheduling
- Labour scheduling for manufacturing and warehouse operations
- Vehicle scheduling
- Carrier selection for individual loads
- Logistics support for individual promotions (e.g., special direct store delivery promotions)

Operational supply chain planning relates to short-term decision problems facing supply chain managers who execute the company's business (Shapiro, 2001:429). Such problems involve the timing and sequencing of decisions (scheduling problems). Operational problems can best be analyzed by the "unified optimization methodology", which combines rigorous models and methods with problem-specific and general-purpose heuristics.

Typical characteristics of operational planning problems are (Shapiro, 2001:431):

- Planning over a short-term horizon during which demand and receipts are reasonably well known
- Focused decision-making within a single facility or a geographical region
- Coordination of a number of time-dependent decisions

Operational planning problems also cover the following domains:

- Production planning and scheduling environments:
  - o Discrete parts manufacturing
  - o Process manufacturing
  - o Job-shop scheduling
  - o Hybrid manufacturing (mix of above)

- Vehicle routing and scheduling
- Human resources scheduling

Operational planning requires of modelling systems to be repetitively employed, in a time-critical manner, and it must support decisions that are immediately carried out. (Shapiro, 2001: 441). For an operations modelling system to fulfil its purpose, it must be fully integrated with other analytical and transactional systems maintained. Typical inputs are orders, inventory, cost and capacity data. The order fulfilment system might be a MRP, DRP, or some other system that translates the released plan into detailed instructions for manufacturing and/or distributing.

a) Operations scheduling

This relates to all required operations in the supply chain required for the inventory flow of material, intermediate products and final products. These operations typically include production, warehousing, and transportation.

According to Marylou Fox (as quoted by Andel, 1996:31) the solution for production is not only scheduling. The problem with production is that they don't have a good handle on demand because the production schedule changes too frequently. In those situations people might be drawn to a better scheduling solution.

Operations scheduling is the function that involves the preparation of a timetable for work that needs doing to meet client need dates, or for activities to achieve some desired objective (Waller, 1999:386-390). Operations scheduling covers those activities that are normally repetitive in nature and have a relatively short-term time frame of hours, days, weeks or perhaps a few months. Gantt chart (bar chart) provide managers with an easily understood summary of what work is scheduled for certain time periods, how much of the scheduled work is completed according to plan and what function performed the work (see Figure 2.30 for example). Some typical sequencing rules are:

- First come, first served
- Earliest due date
- Shortest processing time
- Longest processing time
- Last arrived, first processed
- Least slack time
- Critical ratio
- Least changeover cost

There are also non-quantifiable sequencing rules. Some of these typical rules are as follows:

- Client that shouts the loudest
- Best client
- Emergency situations

Some of the most preferred sequence methods are based on:

- Respecting delivery dates
- First come, first served
- Shortest processing time
- Longest processing time
- Changeover cost

Waller (1999:409) states that optimized production technology (OPT) are typically used for timing and sequencing of decisions (scheduling problems), and is also called management by the theory of constraints (TOC). OPT is based on a set of nine related rules, which principally revolve around the concept of bottlenecks. These applications are predominantly focused on system throughput.

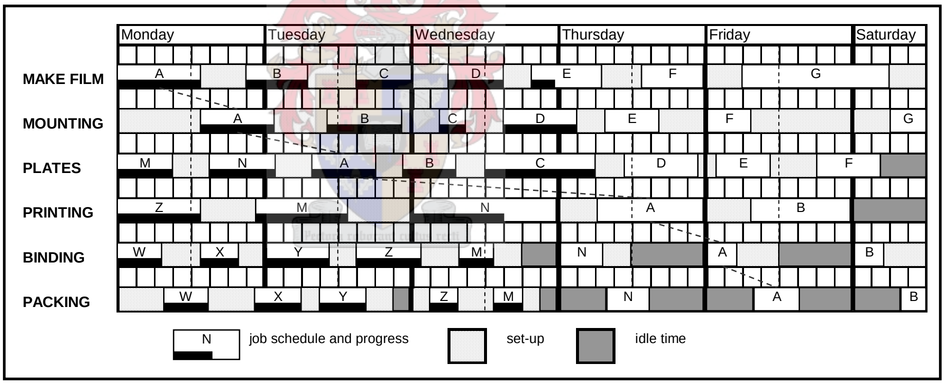


Figure 2.30 : Example of a printing operation schedule
[Source: Waller, 1999:388]

b) *Inventory management*

Recently, attention has focused on creating business processes that reduce or eliminate inventories, mainly by reducing or eliminating uncertainties that make inventories necessary (Shapiro 2001:477 - 478). Better communication and coordination between activities across a company's functions and between the company and its vendors and customers can greatly reduce uncertainties. Specific measures to reduce inventories include the following:

- Improving the accuracy of forecasts by developing better forecasting models and by promoting better communication between supply chain managers, and marketing and sales personnel

- Sharing supply chain information with vendors, third-party transportation providers and other suppliers
- Consolidating number of locations where products are held, and reducing product variety
- Postponing product customization to downstream stages of the supply chain

According to Shapiro (2001:477) there exist a number of reasons to hold inventory. The following are a few:

- To create buffers against the uncertainties of supply and demand
- To take advantage of lower purchasing and transportation costs associated with high volume
- To take advantage of economies of scale associated with manufacturing products in batches
- To build up reserves for seasonal demands or promotional sales
- To accommodate products flowing from one location to another
- To exploit speculative opportunities for buying and selling commodities and other products

In the supply chain, one of the key variables that have to be managed is inventory (Waller, 1999:288-290). The inventory includes a vast spectrum of material that is being transferred, stored, consumed, produced, packaged or sold in one way or another during a firm's normal course of business. The following are the major types of inventory:

- Raw materials
- Purchased parts
- Spare parts
- Small tools
- Consumable supplies
- Packaging material
- Work in progress
- Waste products
- Finished goods
- Goods in transit

Inventory can also be classified based on its dependency. ***Independent inventory*** includes those items that are not dependent on other parts. This means that they are the ultimate finished products destined for the final consumer (automobiles, cans of beer, washing machines, etc.). Demand for them depends solely on the requirements and demand of the consumer. Managing these inventory items requires forecast information based on consumer needs. ***Dependent inventory*** includes items that are usually feedstock, assemblies or parts used in the manufacture of the final consumer product. For example, in the manufacturing of a bicycle, there are one frame, one saddle, one pair of handle bars and two wheels. For each wheel there are 36 spokes. This martial represents a typical bill of material used in material requirements planning.

Inventory management and forecasting are planning activities that go hand-in-hand. Both play critical roles in the management of a firm's supply chain (Miller, 2001:181). Inventory decisions are taken on strategic, tactical and operational time frames:

- Strategic (what is the optimal level of inventory investment?)
- Tactical (deployment of inventory)
- Operational (inventory targets; deliver specific customer service fill rates)

Executives will appreciate the importance of effective inventory management once the financial impact of increased inventory turns is translated into their impact on key financial indicators. (e.g. ROI and other benefits: working capital reduction, increased profitability, increased customer satisfaction, improved asset return) (Trent, 2002:29-30). The three Vs model of inventory management (volume, value, velocity) is an effective method to focus on key inventory drivers. Various ways to manage inventory investment better are:

- Improve inventory record integrity
- Improve product forecasting
- Create a planning system and structure
- Pursue a lean supply chain
- Standardize and simplify design
- Leverage company-wide procurement

Hedging against the uncertainty in demand (and associated inventory levels) during a delivery period (related to lead time) of specific goods or products are the essence of the inventory theory (Shapiro, 2001:482). Figure 2.31 typically indicates the relationship between some of the well known inventory management parameters such as replenishment quantity, lead time and safety stock. Inventory stock-outs of consumer products may lead to customer dissatisfaction or lost sales. Costly equipment downtime can also result because of inventory stock-outs of critical parts for a machine tool, mainframe computer, or commercial aircraft. Managerial judgment must be used to decide how much to spend on safety stock to avoid, but not eliminate, these costs or to ensure that stock-outs occur only with a sufficiently low probability.

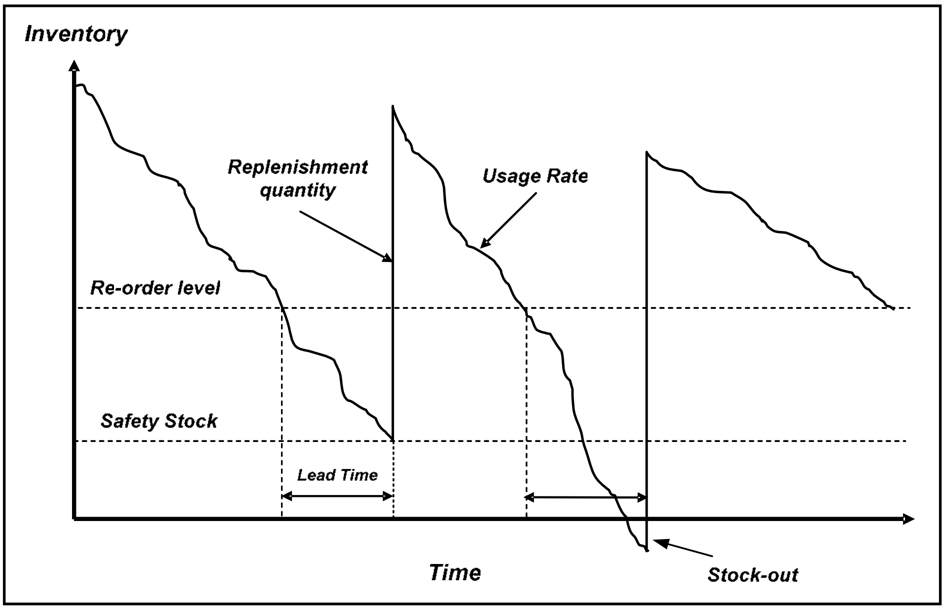


Figure 2.31 : Inventory profile subject to uncertain demand
[Source: Shapiro, 2001:482]

For inventory management, the 80/20 rule has manifested itself in the form of ABC classifications. The criteria for establishing ABC rankings are most common around the following measures:

- Sales value (i.e. total dollar sales)
- Total unit sales
- Total inventory investment value (at cost)
- Frequency of sales, purchase or shipment
- Total profit contribution, and
- Total inventory storage space (e.g., cube) or pallet locations occupied

A typical ABC policy used for forecasting around certain inventories is (indicated in Figure 2.32):

- "A" items will be monitored closely and adjusted as appropriate on a regular basis. The top 20% of inventory could represent up to 80% of total sales.
- "B" items will be monitored less closely and adjusted on a less frequent interval than forecasts for A items. The mid 30% of inventory could represent up to 15% of total sales.
- "C" items will receive occasional review and simple forecast methods will be employed to establish forecasts for these items. The last 50% of inventory could represent as little as 5% of total sales.

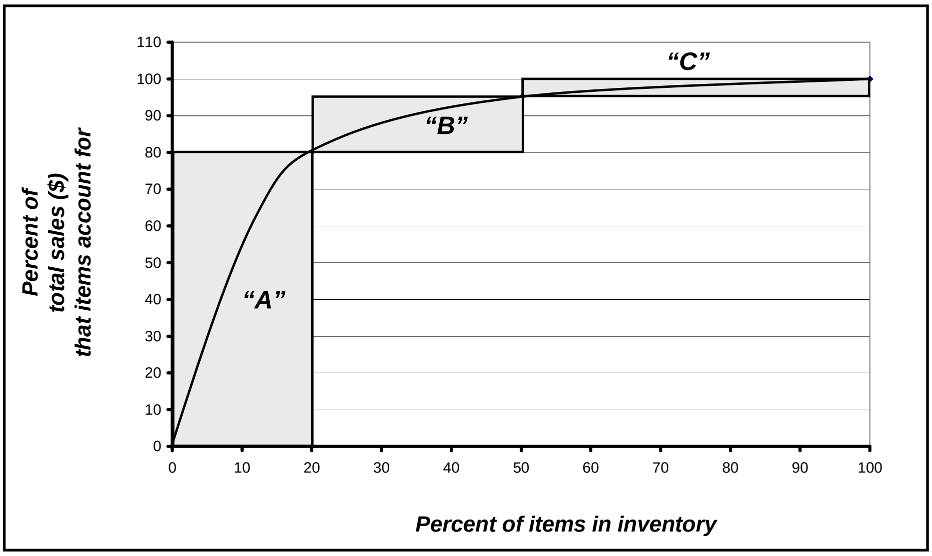


Figure 2.32 : ABC classification of finished goods items.
[Source: Miller, 2001:185]

Miller (2001:185) also indicates the importance of different dimensions (in addition to "product") that firms frequently apply in using hierarchical methods to forecast. These dimensions include:

- Product (e.g. product family, major product line, division product line)
- Geographic (e.g. countries, states.)
- Sales organization (e.g. regions, districts, territories)
- Sales channels (e.g. mass merchandisers, wholesalers)
- Company organization (e.g. company, business unit, sub-unit,)
- Planning horizon/time period (e.g. years, quarters, months)
- Network locations (e.g. plants, DC's)
- Customers (e.g. customer, customer location)

2.2.3 Coordination, collaboration and integration

Collaboration is focused on improving the way people work together to carry out processes rather than on the process activities themselves (Keen, 1997:107). Teamwork and trust are emphasized and depends on communication and cooperation. Collaboration is about people, not work flows. It is an appropriate strategy to apply to processes or sets of processes that depend on judgment. In many manufacturing firms, the company is organized around its own operational priorities rather than its customers' needs. Processes should be transformed by beginning with the customer's requirements. A collaborative orientation forms the basis of business processes. Rather than tracking the flow of materials or data, business processes chart the coordination of action between people (and sometimes machines) involved in an activity.

Coordination on the other hand means working together to get a job done. Collaboration means working together to accomplish much more than you can by working alone. A climate of trust and cooperation is needed for true collaboration. Michael Schrage points out (as referenced by Keen, 1997:111) that just providing tools for coordination and communication does not create the climate of trust and cooperation needed for true collaboration. The network is the infrastructure for information sharing, but it only serves that purpose if people are willing to share information (The Trust Factor). A network is just machinery; a team-based, collaborative culture turns the network into a “worknet”.

Coordination, integration and collaboration are important building blocks for supply chain planning (Rohde, 2000:183-186). Coordination is important for consistent plans across the different planning levels, and for each entity of the supply chain. One of the means of integration in the supply chain is via information technology. Related to supply chain planning, key technologies that aid in the integration of advanced planning and scheduling (APS) are OLTP (e.g. ERP, Legacy systems) and data warehouse. Collaboration can be achieved via master planning and the central exchange of relevant information. Alert monitoring (Filtering), vendor managed inventory and eBusiness (B2B, B2C via EDI & XML) are examples of technologies that can enable collaboration.

2.2.3.1 Coordination

Logistical coordination constitutes a combination of corporate planning and operational matters (Bowersox, 1974:100). This is one step forward from either pure physical distribution or material management. The planning functions consist of forecasting, production scheduling, and materials planning. The operational aspect of logistical coordination is to a large extent inventory replenishment.

Lack of coordination in the supply chain is primarily the result of conflicting objective, or distorted information related to the supply chain (Chopra & Meindl, 2001:360). Typical effects of poor coordination are:

- Manufacturing cost (Increases)
- Inventory cost (Increases)
- Replenishment lead time (Increases)
- Transportation cost (Increases)
- Labour cost for shipping & receiving (Increase)
- Level of product availability (Deceases)
- Relationship across the supply chain (Deceases)

Chopra & Meindl (2001:363) also indicate the following as major obstacles to coordination:

- Incentives (isolated)
- Information Processing (distorted)
- Operational (manner & size of orders)
- Pricing (policies)
- Behavioural (organisation learning)

Related to the above, fortunately there are a number of management levers that can be used to achieve coordination (Chopra & Meindl, 2001:368):

- Align goals and incentives
- Improve info accuracy
- Improve operational performance
- Designing price strategies to stabilize orders
- Building partnerships on trust

Coordination can also be achieved in practice. This can be done by quantifying the "bullwhip effect", get top management commitment for coordination, devote resources for coordination, and focus on communication with the other supply chain stages.

2.2.3.2 *Collaboration*

With the goals of reducing inefficiencies in supply chains (which result in excess inventories and unproductive activities and assets) and increasing responsiveness to consumer demand, companies increasingly consider collaborating with trading partners as a key enabling best practice (Keskinocak & Tayur, 2001:85).

Collaboration requires supply chain managers at customer and supplier companies to talk more and share previous unshared information (Forger, 2001:56). Collaboration is all about building new mutually beneficial business processes that benefit the entire supply chain, not just one company or segment. Collaboration is a much broader partnership than simply talking or sharing forecasts.

The principles of collaboration relate to (Bruce & Ireland, 2000:84):

- Mutual focus on the end-customer
- A customer driven value chain
- Mutual visibility and management of decisions
- Open business relationships that share information, data and communications

Collaborative planning is essentially to synchronize supply chain planning across multiple plants and to support such inter-company efforts (best practices) as just-in-time, quick response, efficient consumer response, vendor-managed inventory and continuous forecasting and replenishment (Murphy & Sherman, 1998:64).

As collaboration begins to displace the largely antagonistic relationships among members of the supply chain community, the impact on industries, markets, companies, and business processes will be profound. Service will eclipse products, demand will drive production, prices will match market conditions, tens of thousands of e-marketplaces will emerge, and industry portals will become obsolete (Taylor & Terhune, 2000:42).

The internet also facilitates collaboration among parts of a supply chain, and promises to make that dream of virtual integration a reality by providing global optimal solutions in a decentralised world (Keskinocak & Tayur, 2001:71). To exploit these new avenues to improve their profitability, companies need both decision support tools, which provide evaluation of alternatives using OR/MS models, and managerial insights based on models from economics that allow practitioners to think strategically.

The collaboration processes between players in a supply chain have received much attention, and the benefits are becoming clearer (Langley Jr., 2004:14). Recent studies identified seven essential principles that support successful collaboration.

- Real and recognized benefits to all members
- Dynamic creation, measurement, and evolution of collaborative partnerships
- Full collaboration among supply chain participants
- Flexibility and security
- Collaboration across all stages of business process integration
- Open integration with other services
- Collaboration around essential logistics flows

a) Collaborative Planning Forecasting and Replenishment (CPFR)

The Collaborative Planning Forecasting and Replenishment (CPFR) model was developed by a subcommittee of the Voluntary Inter-industry Commerce Standards (VICS) group (Loshe & Ranch, 2001:57).

The nine-step CPFR Model illustrated in Figure 2.33, incorporate the roadmap to achieve the following (Loshe & Ranch, 2001:58, McCarthy & Golicic, 2002:434, Ireland, 2005:20):

Step 1 Front-End agreement

- Agree to confidentiality and dispute resolutions
- Develop scorecard to track supply chain performance measures
- Establish incentives

Step 2 Joint Business Plan

- Project team develops plans for promotions, inventory policy changes, new product introductions, store openings and closings

Steps 3 – 5 Sales forecast collaboration

- Trading partners share demand forecasts and identify exceptions. Resolutions are collaborated on causal factors to a single forecast number.

Steps 6 – 8 Order forecast collaboration

- Trading partners share replenishment plans, identifying and resolving exceptions.

Step 9 Order generation/delivery execution

- Results data is shared and forecast accuracy problems are reviewed. Performance measures are accessed.

Although companies increasingly move towards sharing information through such initiatives as CPFR, it remains to be seen how much internal information companies will share with their supply chain partners or third-party independent intermediaries (Keskinocak & Tayur, 2001:76).

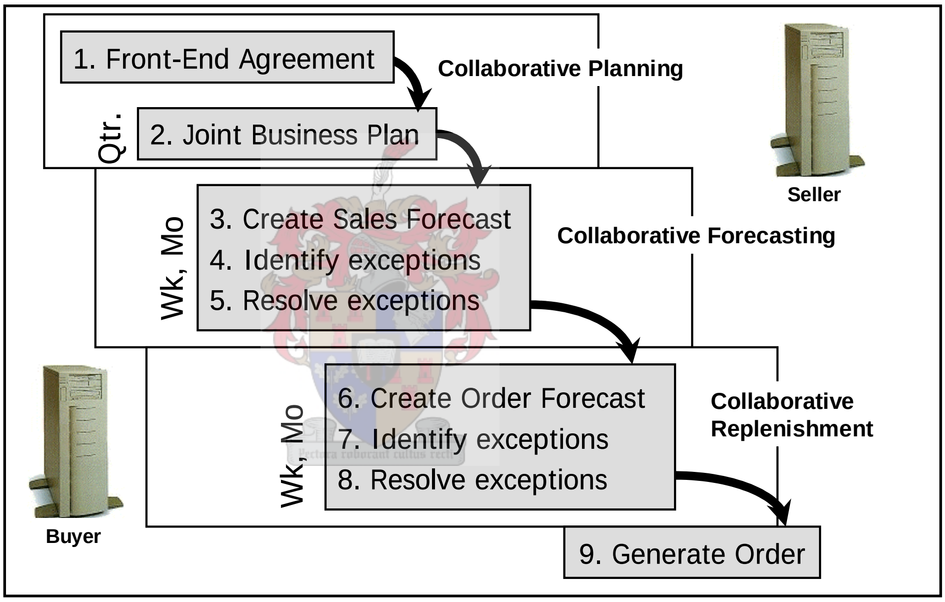


Figure 2.33 : The CPFR Process

[Source: www.CPFR.org]

b) Collaborative forecasting

According to McCarthy & Golicic (2002:434), collaborative forecasting involves reliance on supply chain partners to provide accurate, detailed and timely demand information. They also propose an alternative approach (collaborative forecasting) to the CPFR that would require considerably less investment of time and personnel. This collaborative forecasting approach promises to provide benefits related to increase responsiveness, increased product availability, and optimised inventory and associated costs (all adding to increased revenue and earnings) (McCarthy & Golicic (2002:446). Adapting a collaborative forecasting (CF) model would require committing to the following:

- committing to an internal process audit
- Senior management recognition of competitive advantage
- Resources committed to train boundary spanning personnel in CF methods
- Initial target "A" level customers with subsequent targeting of "B" level customers
- Institution of regular scheduled forecasting meetings between trading partners
- Alternative method of ongoing timely information exchange
- Creation of a single shared projection of demand

c) *Steps for achieving supply chain collaboration*

According to Tompson (as quoted by Quinn, 1998:39), companies can achieve supply chain collaboration through **two major steps**. **The first** is to get its own house in order. Functional integration must occur within the organization before integration can occur throughout the entire supply chain. The major intra-function integration that needs to happen is that of the logistics related functions (inbound and outbound transportation, distribution, warehousing, and fleet management). The other functions that need to be integrated within an enterprise are supply management (sourcing, vendor selection, and purchasing), manufacturing (production planning, scheduling, packaging), marketing, and the application of information technology.

Arntzen (as quoted by Quinn, 1998:39) also indicates that in most companies the power lies within manufacturing or marketing. A lot of attempts by logistics professionals to integrate the supply chain cross-functionally hit a wall because they do not have the support of these key functional areas. The internal walls invariably are the toughest to scale. Top management must give their full and visible support to dismantle these barriers.

After functional integration, **the next step** in the design process is to integrate the internal organization with the external partners (suppliers, customers, and logistic service providers) (Quinn, 1998:40).

Manrodt & Fitzgerald (2001:67) provide seven propositions for successful collaboration:

- As companies move towards collaborative strategies, logistics and supply chain executives must increasingly take a process view of their organizations
- Not all processes are created equal. The importance of each process should be based on a company's corporate strategy
- Before collaborative logistics can be effective, coordination must be improved (the process integration with single customer or supplier)
- Collaborative logistics, currently at an immature level, is moving towards more intelligent communities

- New tools will enable and facilitates increased level of integration, coordination and collaboration
- The key to integration, coordination and corporate collaboration is the visibility of key supply chain activities
- The future lies beyond collaboration in synchronization

d) *Cross-enterprise collaboration*

Bowersox, Closs & Theodore (2003:18-19) state that the essence of cross-enterprise supply chain collaboration is to share information, jointly develop strategic plans and synchronize operations. Two or more firms voluntarily agree to integrate human, financial, and technical resources in an effort to create a new, more efficient, effective, or relevant business model. Cross-enterprise collaboration is an organizational model that seeks the benefit of vertical integration without the burden of financial ownership.

Companies have started to put technology in place to “link-up” and share information with one another. The next phase of sharing information is a more complex and committed form of collaboration. It entails companies sharing formerly proprietary information with other companies that are members of collaborative business communities (CBC) (Taylor & Terhune, 2000:36-37). One of the key values of the CBC approach is that the members share a common infrastructure. This allows them to implement a collaborative operations planning (COP) process. CBC capitalise on three key advantages; visibility, velocity and the variability.

There is however a risk for cross-enterprise collaboration implementations to fail (Bowersox, Closs & Theodore, 2003:20). Some common reasons are:

- Failure to establish the business case and sustainable value proposition up front
- Failure to establish policies and guidelines
- Failure to develop and implement long term reward- and risk-sharing agreements
- Failure to modify internal command, and control organizational structures and performance measures to facilitate cross-enterprise collaboration

It is important to note what cross-enterprise collaboration is NOT (Bowersox, Closs & Theodore, 2003:20):

- Interaction between supply chain partners while the basic governance model remains command-and-control
- Buying and selling interaction
- Acknowledgement of interdependency between two business organizations; emergence of a supply chain relationship; emergence of contracting and outsourcing
- Functional or process outsourcing

Bowersox, Closs & Theodore (2003:26) present a supply chain collaboration framework (See Figure 2.34) that identifies the processes, competencies, and capabilities that are characteristic of successful supply chain collaboration. ***Processes*** included are leadership, planning and control, and integrated operations. The strategic ***Competencies*** must be sufficient to drive competitive advantage for the extended initiative. ***Capabilities*** define skills and knowledge cultivated over time that enables the firm's assets to be selectively deployed. Cross-enterprise collaboration requires the variety of processes, competencies, and capabilities.

A sample of what is required under each of the major processes presented by Bowersox, Closs & Theodore (2003:21) is:

Leadership Process

- Competency: *Relational integration*
  - Capabilities:
    - ⇒ Role specificity
    - ⇒ Guidelines
    - ⇒ Information sharing
    - ⇒ Gain/risk sharing

Planning and control process

- Competency: *measurements*
  - Capabilities:
    - ⇒ Functional assessments
    - ⇒ Activity based- and total-cost methodology
    - ⇒ Comprehensive performance measures
    - ⇒ Financial impact
- Competency: *technology and planning*
  - Capabilities:
    - ⇒ Information management
    - ⇒ Internal communication
    - ⇒ Connectivity
    - ⇒ Collaborative forecasting and planning

Integrated operations process

- Competency: *material/service supplier integration*
  - Capabilities:
    - ⇒ Strategic alignment
    - ⇒ Operational fusion
    - ⇒ Financial linkage
    - ⇒ Supplier management

- Competency: *internal integration*
  - Capabilities:
    - ⇒ Cross functional unification
    - ⇒ Standardization
    - ⇒ Simplification
    - ⇒ Compliance
    - ⇒ Structural adaptation
- Competency: *customer integration*
  - Capabilities:
    - ⇒ Segmental focus
    - ⇒ Relevance
    - ⇒ Responsiveness
    - ⇒ Flexibility

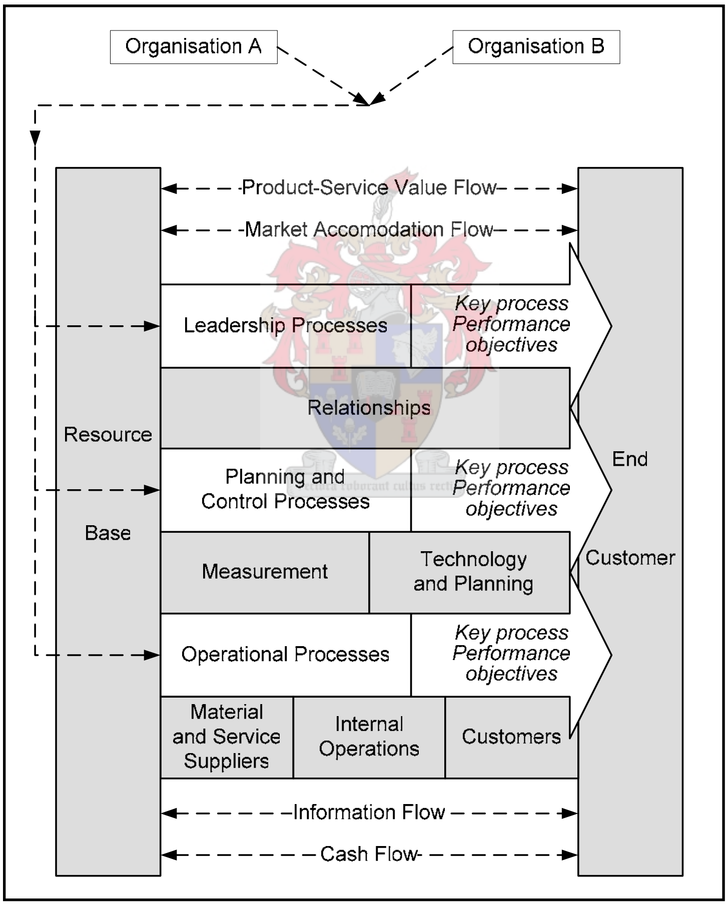


Figure 2.34 : Cross-enterprise collaboration framework

[Source: Bowersox, Closs & Theodore, 2003:26]

e) Collaboration levels

Collaboration can exist at a number of levels between organisations (Bowersox, Closs & Theodore, 2003:22). The most common and easily implemented form of collaboration is ***Operational*** and information sharing.

(e.g. advanced shipping notification). ***Tactical*** collaboration involves the joint modification of traditional processes to enhance the way in which essential functions are performed (e.g. CPFR). The ***Strategic*** integration is the most complex. It is the model that drives the extended enterprise dream.

As indicated in Figure 2.35, collaboration can also be viewed at different levels (Burnes, New & Young, 1995:8). The three levels are transactional, process, strategic. Above these levels is Business Strategy. Collaboration could be at a number of different levels, ranging from transaction integration at the functional level of the two businesses through to development of a joint supply chain strategy. Integration at business strategy level implies a joint venture, embracing all aspects of the business.

2.2.3.3 Integration

Supply chain management also refers to integrated planning (Shapiro, 2001:7). Integrated planning should be approached from the following three dimensions:

Functional integration of purchasing, manufacturing, transportation, and warehousing activities.

Spatial integration of these activities across a supply chain's geographically dispersed vendors, facilities, and markets.

Inter-temporal (hierarchical) integration of these activities over strategic, tactical and operational planning horizons. Decisions in these planning horizons has the following focus:

⇒ Strategic planning involves resource acquisition decisions (long-term)

⇒ Tactical planning involves resource allocation decisions (medium-term)

⇒ Operational planning involves execution decisions (short-term)

Another aspect of inter-temporal planning is the need to optimize a product's supply chain over its life cycle through the stages of design, introduction, growth, maturity, and retirement. Like most areas of strategic planning, life-cycle planning requires integration of supply chain and demand management. Lee (2000:32) also defines three dimensions of supply chain integration. These are information, coordination and organizational linkage.

a) Functional integration

Traditionally, integration has been involved in this sharing of information and materials between a company's separate functional silos. With technology becoming much more affordable, companies are increasingly linking up and integration is now also about sharing information between the partners in a supply chain (Gattorna & Hanlock, 1999:6).

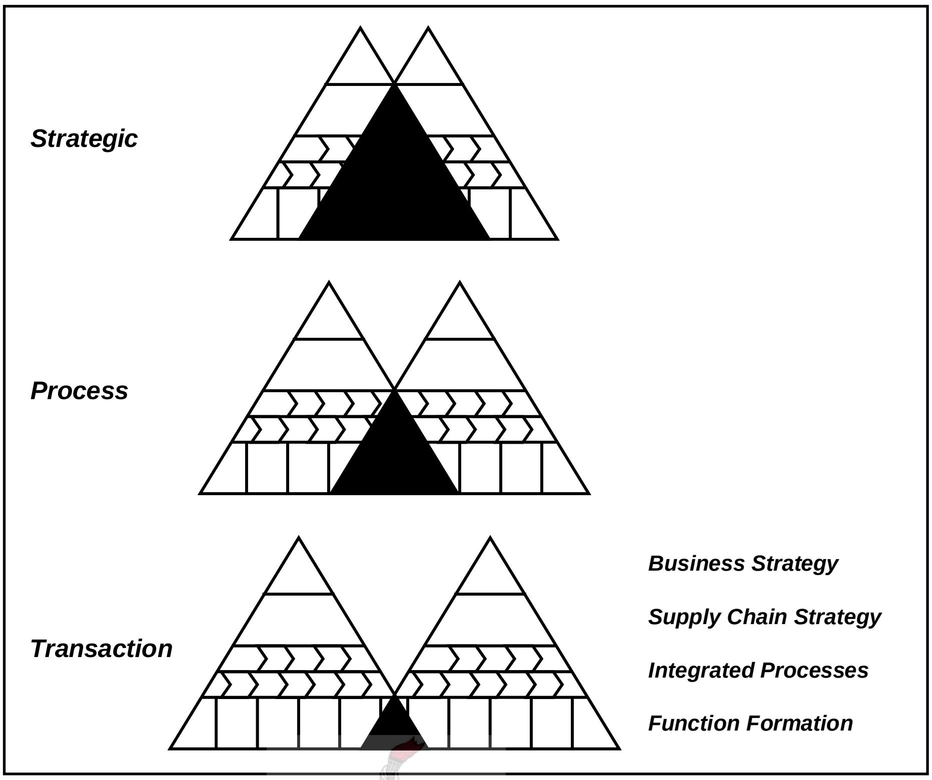


Figure 2.35 : Collaboration at different levels
[Source: Burnes, New & Young, 1995:9]

Logistics is no longer the mere support function it once was (Ribbers, 1994:26). Integrated logistics goes a step further by requiring a firm to focus on its entire value chain. This includes the design and coordination of its physical network; use of suppliers and other third parties; information technology systems; the way staff are organized and trained to think in integrated terms. The real driving force behind integrated logistics is service and value to the customer.

b) Spatial integration of the supply chain stages

It is not enough to integrate one's own organization. The greatest successes come from achieving integration across company boundaries (AT Kearney, 1997:8). However, one of the problems of achieving true supply chain integration is that the supply chain seldom comes under unified control (Bender, 2000:10). A supply chain is a complex network of dispersed geographical facilities and organizations with different, conflicting objectives. The challenge lies with integrating the flow and transformation of raw materials into products from suppliers through production and distribution facilities to the ultimate consumer.

Mehta & Sundaram (2002:532) defined three different supply chain management approaches. These are independent, semi-integrated, and integrated approaches. They were used to model and test the performance of supply chain with the different degrees of integration. The integrated supply chain approach presents a system, which involves integration of all the decision-making processes across the supply chain. Increased collaboration across this supply chain resulted in improved performance of the supply chain (Mehta & Sundaram, 2002:549). In general, optimizing each process of the supply chain in isolation from other processes does not guarantee optimization of the whole supply chain. Considering the advancement in technology, manufacturers should try to achieve optimality in the supply chain by integrating that decision-making processes across the supply chain under a single system.

Supply chain integration implies process integration (Christopher, 1998a:231). This means integration both of upstream and downstream in the value chain. It can be achieved through collaborative networks (relationships), joint product development, common systems, and shared information. The extended enterprise is one way of reaching value chain integration. Supply base rationalization, supplier development programs, early supplier involvement in design, integrated information systems and centralization of inventory are some of the levers available for integration. In managing the supply chain as a network, some of the significant issues and challenges include:

- Collective strategy development
- Win-win thinking
- Open communication.

c) *Hierarchical integration*

Three discrete levels of management control - strategic, tactical and operational - are often employed in the successful model for the international chain (Houlihan, 1992:158). The primary focus of these management hierarchies are:

- Strategic; objectives and policies
- Tactical; plans and forecasts
- Operational; schedules and controls

The overall structure is shown schematically in Figure 2.36. This management dimension to integration is the key to effective organizational development. It precludes the need to talk of centralized or decentralized logistics functions, as exclusive structures permits the vital flexibility of centralizing the strategic, decentralizing the operational, where practical, and tuning the tactical decision-making to the organizational preferences of the particular company.

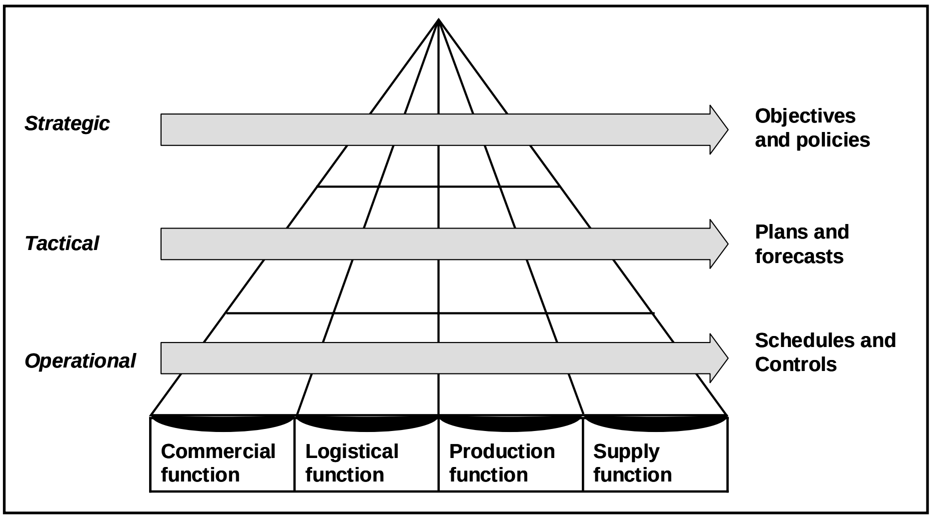


Figure 2.36 : Integration of organization and systems functions
[Source: Houlihan, 1992:158]

d) *Information integration*

For true supply chain integration and optimal supply chain management, all the participants in the chain must not only be linked physically; they must also be tied to the other members of the supply chain electronically (AT Kearney, 1997:5).

Using information and collaboration effectively to better match supply and demand can lead to dramatic improvements in supply chain performance (D. Simchi-Levi, 2000:75). This is a move away from pure sequential optimization and closer to concurrent optimization.

Platts (2002:26) proposes an information technology integration framework with the following key ingredients:

- Systems must be able to interface to each other quickly
- Business processes can be abstracted and used to navigate users
- Information technology can be configured as the business change
- Formation technology is extensible and scalable.
- Development of executive dashboards

In most cases it is easier to achieve technical integration of system areas than it is to integrate across functional boundaries (Franz, 1995:D2-5). Two levels of information integration are applicable:

1st level: Movement of information within the organization

2nd level: This is the coordination of processes or workflow with a single supplier, customer, or logistics service provider.

With the integration of organization and systems functions, the systems and information flows need a degree of horizontal integration (Houlihan, 1992:157). This requires:

- Management of data capture and flow across the functional boundaries without delay and distortion
- Linking systems for purchasing, production and inventory control, distribution, customer order entry and service
- Shared ownership of information and a high degree of visibility across all functions of plans, allocations, inventories, and customer as well as replenishment orders

In supply chain coordination and integration, horizontal and vertical information flows are important enablers for decision-making (Fleischmann, Meyr & Wagner, 2000:67).

2.2.4 Hierarchical planning

The principle of aggregation and use of aggregate planning in a supply chain is one of the key building blocks for hierarchical planning. Planning is done on a higher aggregate level (e.g. not on a SKU level). These planning processes serve the purpose of determining levels of capacity, production, subcontracting, inventory, stock outs, and even price over a specific time period (Chopra & Meindl, 2001:101-105). The objective of aggregate planning is to satisfy demand in a way that maximizes profit for the firm. Aggregate planning makes trade-offs amongst capacity, inventory, backlog/lost sales. The planner could use some, or a mixture, of the following strategies:

- **Chase strategy,** using capacity as the lever
- **Time flexibility from workforce or capacity strategy,** using utilization as the lever
- **Level strategy,** using inventory as the lever (a buffer for smoothing operations)

Hierarchical Production Planning (HPP) has existed both in theory and practice for several decades and is another approach and philosophy towards the organization, planning and scheduling of production activities (Miller, 2001:1). This was originally developed as a planning and scheduling approach primarily for production activities. HPP has evolved to encompass a broad range of supply chain management activities. The rationale for HPP is partly a result of the managerial decisions classification into (a) strategic planning, (b) management control (tactical planning), and (c) operational control (operational planning and scheduling). These decisions differ in terms of (to name only a few):

- Length of planning horizon
- Level of detail required of planning decision support data
- Risks and costs of the decisions
- Long term impact of the decisions

It is very difficult to design one decision support model to address the complex hierarchy of decisions which must be made (solvability). The broad dimensions of production planning decisions virtually necessitate that multiple layers of management participate in the decision-making process.

Miller (2001:8-9) also states that decisions made at the strategic level place constraints on the tactical level and ultimately on the operational level, while decisions made at the tactical level constrain the operational level. Decisions made at the operational and tactical levels should provide feedback to evaluate the impact of decisions made at the tactical and strategic levels, respectively. The litmus test for evaluating a hierarchical planning system consists of determining whether a particular system has well established feedback and linkage mechanisms built into a closed loop, top-down and bottom-up system. This suggests that a hierarchical production planning system must consist of a number of linked models (algorithmically or decision support systems) which provide inputs and/or outputs to each other. These decomposed sub-problems must also be integrated.

There are almost a countless number of methods and algorithms used to perform operational, short run planning and scheduling. Miller (2001:64) indicates that even in relatively similar production environments (e.g., all manufacturers in a specific industry), one can usually find innumerable different scheduling methodologies in use at different firms, and oftentimes, even at a single firm.

HPP systems plan for "independent demands" while MRP systems plan for "dependent demands" (i.e., independent demand for finished goods drives the dependant demand for materials and components) (Miller, 2001:90-91). HPP and MRP systems focus on different planning levels and activities at the plant. These systems share the common attribute that they are both top-down planning systems with bottom-up feedback capabilities built into them. One of the many differences between HPP and MRP systems is that MRP focuses strictly at the operational planning level, while HPP addresses the strategic, tactical and operational planning levels. HPP and MRP also differ in that traditional HPP systems address finished goods end items and higher levels of product aggregations (e.g., product families), while MRP systems plan at the WIP and materials level. The bill of materials (BOM) lies at the heart of MRP. The BOM provides critical information on both the sequences and quantities required to complete one unit of a finished end item. A MRP system however does not evaluate the feasibility of producing the calculated net requirements in terms of the available capacity. Capacity requirements planning (CRP) performs a detailed analysis of the labour and machine requirements necessary to produce a net requirements schedule generated by a MRP calculation.

2.2.5 MRP, DRP and APS systems

MRP, DRP and APS Systems are all related to various stages in the advancement of supply chain planning. The approach of these systems will be screened in the next few paragraphs but more detail on the related decision support systems will be discussed in paragraph 3.1.5.

Material Requirements Planning (MRP) was the first attempt at capacity planning (Martin, 2001:63). These systems however posed the following serious limitations related to supply chain planning:

- They only focused inside the four walls of the factory
- MRP focused on, and reduced the constraint of not having enough material
- MRP II focused on both material constraints and production capacity constraints
- MRP and MRP II only focused on constraints that affects production
- They have largely overlooked constraints that affect deployment and delivery of goods from the factory to the store and ultimately to the customer.

MRP has evolved over time (Waller, 1999:359). The first was MRP I. This is a mathematical modelling tool for determining the needs of dependant components, such as raw material, parts and subassemblies in a manufacturing or warehousing / distribution environment.

The relevant inputs to MRP I are:

- Master Production Schedule (MPS)
- Product structure on bill of materials
- Inventory file (a complete record of the quantity of each material held in inventory)

The output of MRP I is the purchasing requirements for products obtained from outside and production requirements for those materials produced internally.

The basic MRP I system evolved considerably into so-called MRP II systems, or Manufacturing Resource Planning (also refer to Table 2.3), and beyond to business applications software systems that manage a company's entire business (Waller, 1999:376). These are referred to as Business Resource Planning (BRP) or Enterprise Resource Planning (ERP) systems. Feedback loops make it possible to adjust, or propose modifications to, earlier plans if resources are insufficient.

Distribution requirements planning (DRP) is the planning process in the supply chain to help ensure that finished goods destined for clients reach the right location, on the right date and in the right quantity (Waller, 1999:505). The supply chain covering the DRP may be from the manufacturer, through the various distribution centres, to the retailer, or it may just be from the distribution centres to the retailers in a service firm. The distribution requirements plan might be a pull or a push system.

Pull System: A pull system is when the outlet at the lowest end of the distribution network, usually the retailer, initiates the order. The retailer pulls the products through the distribution, or supply chain, network.

Push system: In the push system, the supplier at the beginning of the network, usually the manufacturer, produces the finished products according to its own master production schedule (MPS). This MPS would have been established according to estimates of client's demands and then modified to suit the company's resources available at the manufacturing site. Material is pushed through the distribution channel when the products are ready.

Bonner (2001:22) indicate that **advanced planning and scheduling (APS)** systems provide a powerful tool to achieve the cooperation and coordination of business activities by generating and modifying realistic plans that can serve as the frame of reference for all functions (i.e. management, finance, sales, production, distribution, purchasing). As indicated in Figure 2.37, APS is a move away from local optimization in the direction of global optimal planning by pulling all parties (contributing to the supply chain) in the same direction.

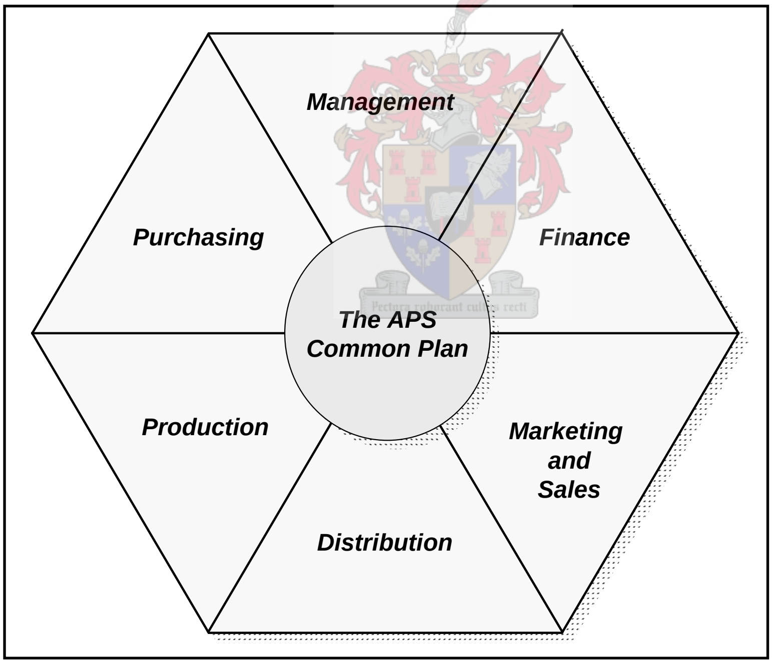


Figure 2.37 : APS - The integration entity
[Source: Bonner, 2001:22]

2.2.6 MRP II + JIT + TQM + TOC + Six Sigma

A number of management movements have developed over time to advance businesses in becoming more focused (Demming & Petrini, 1992:10). Some of these management movements include MRP II, JIT, TQM, and TOC. The key features of these management movements are indicated in Table 2.3.

Table 2.3 : Features of management movements
[Source: Demming & Petrini, 1992:11]

Approach	Primary Focus	Major Concepts	Major Techniques
MRPII *(Manufacturing Resource Planning)*	Integration of planning and control processes	1. Planning based management 2. Independent/dependent demands 3. Standard planning and control functions	1. Gross-to-net calculations 2. Offset by lead time 3. Capacity planning and load profiles 4. Dispatch lists 5. Input/output control 6. Work orders and shop packets
JIT *(Just in Time)*	1. Elimination of waste 2. Continuous improvement through many small steps (kaizen)	1. Respect for people. Empowerment. Teamwork. Reciprocal obligations and rewards 2. Inventory is the "root of all evil" 3. Flexibility not inventory - multi-skilled flexible workers - protective machine capacity	1. Eliminate inventory to expose problems 2. Group technology, manufacturing cells and sequential flows 3. Uniform plant loading, mixed model scheduling, stabilized schedules 4. Small lot sizes, kanban, backflushing 5. SMDE: Single minute exchange of dies 6. SPC and TQC 7. Total productive maintenance
TQM *(Total Quality Management)*	1. Customer satisfaction 2. Continuous improvement	1. Everybody is responsible for quality 2. manage the process, not the product 3. Quality at the source: - product and process design - role of workers - role of suppliers	1. SPC: Statistical Process Control 2. Stop production authority (jidoka) 3. Mistake-proofing (poka-yoke) 4. Cause and effect analysis; fishbone diagrams 5. Pareto analysis
TOC *(Theory of Constraints)*	1. Defines the goal 2. Identify constraints 3. Continuous improvement by focus on constraints	1. Throughput world thinking 2. The OPT principles 3. Socratic implementation	1. Drum, buffer, rope scheduling 2. The five focus steps 3. Effect-cause-effect diagrams 4. Cloud diagrams

According to Demming & Petrini (1992:10) **MRP II** provides the framework for integrating strategic, tactical and operational decisions. **JIT & TQM** provide the orientation and techniques to simplify and improve both shop floor and office operations (Predominantly a continuous improvement focus). The TOC move provided focus on the goal of the organization and the constraints that limit attainment of these goals. TOC also will provide analysis and implementation tools to break these constraints. Together these separate movements will provide a unique approach to the dynamic, multidimensional world faced by each manager.

A fundamental premise of the **Theory of Constraints (TOC)** is that the flow through every system is constrained by something. The key to success is in proper management of that constraint and its relationship to the rest of the system. The theory of constraint approach is to balance flow, rather than capacity (Simons & Moore, 1992:15). The Five step TOC process includes the following:

- ***Step 1:*** Identify the system constraint(s). (physical – machines, workers, etc.; procedural – policies, operational instructions, technical data, etc.)
- ***Step 2:*** Decide how to exploit the system constraint(s)
- ***Step 3:*** Subordinate all other decisions to the effective use of the constraint

- ***Step 4:*** Elevate the system constraints
- ***Step 5:*** If the constraints identified previously have been broken, return to step one

Once identified, the system's constraint is used as a drum in the sense that it beats the pace of the flow rate of the entire system (Simons & Moore, 1992:17). This is the concept of Drum-Buffer-Rope. Buffers are limited accumulations of work in process created at relative few key locations in the system (as indicated in Figure 2.38). Buffers will be located immediately prior to the constraint and prior to every point in the system flow where the output of non-constraints is merged with output which has been processed through a constraint. The idea of a rope is used to communicate the beating of the drum to the input of the organization. This communication link serves to assure that the system does not induce more work than it is capable of converting to outputs. The ropes will assure that system inputs are released only when needed (supporting the pull vs. push concept).

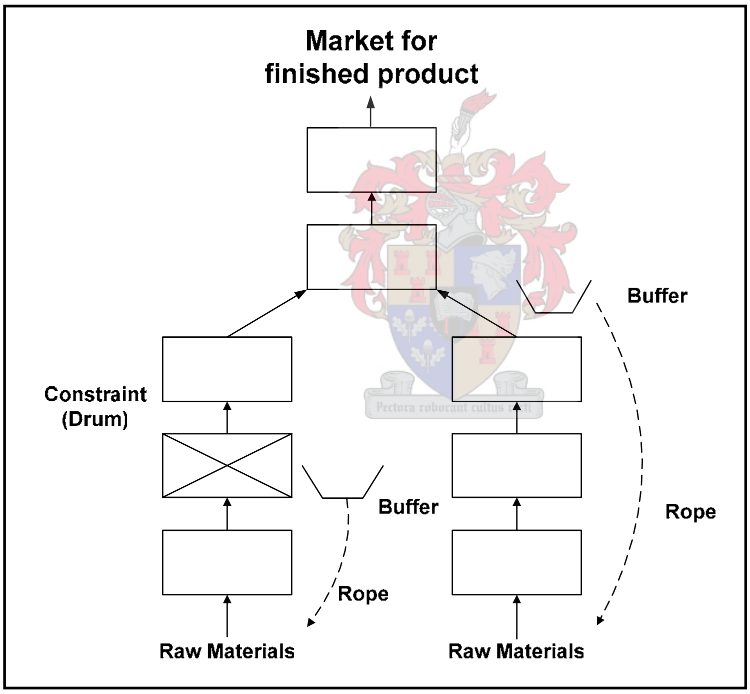


Figure 2.38 : A simple drum-buffer-rope system
[Source: Simons & Moore, 1992:17]

Six Sigma is another management movement aimed at business process improvement. It is a high-performance, data-driven approach to analyzing and eliminating root causes of business problems (Dudley, 2003:5). Six Sigma achieves dramatic improvement in business performance by understanding customer requirements and then eliminating the "defects" from existing processes, products, services, or plants. "Six Sigma" is a statistical term that equates to 3.4 defects per one million items or transaction. Six Sigma has the greatest impact when it is applied across core business processes. A core business process is a set of interrelated, cross-functional processes that have a profound impact on customer satisfaction - either positive or negative. As indicated in Figure 2.39 the objective of Six Sigma is to reduce variation and move product or service outputs permanently inside customer requirements (Curve A to B). Six Sigma thus aims to not only focus on the average value of a performance measure but also it's variation.

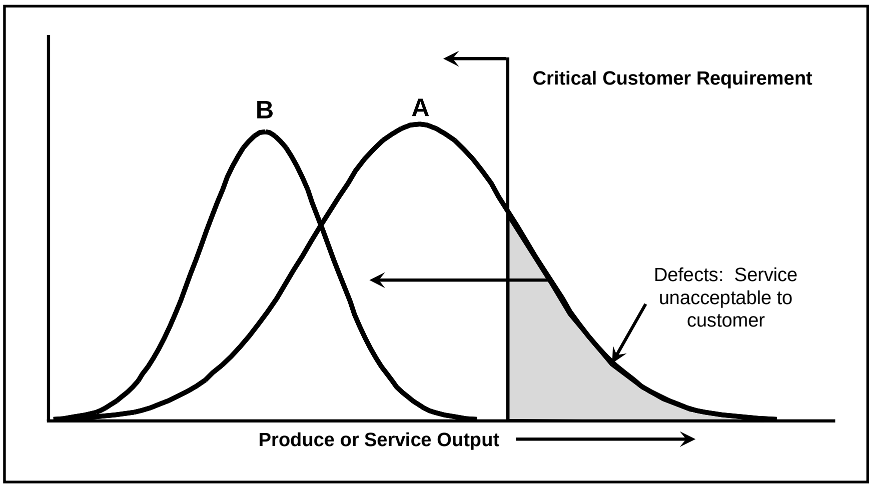


Figure 2.39 : Six Sigma improvement focus
[Source: Simons & Moore, 1992:17]

2.3 Operations Research (OR) and Management Science (MS) application for decision support

The discipline of management science is devoted to the studying and developing of procedures to help the process of decision-making (Cook & Russell, 1985:3). OR and MS is a multi-discipline field comprising elements of mathematics, economics, computers and engineering. Cook & Russell (1985:6) also indicate that the nature of management science has a fundamental characteristic; the scientific or systematic approach to decision-making. Various types of models can be developed (Cook & Russell, 1985:10). The major categories of models are:

- Iconic (physical representation of object - e.g. airplane model)
- Analogue (e.g. statistical representation of numerical data)
- Mathematical (represent reality by means of mathematical equations)

2.3.1 Supply chain modelling orientation

Supply chain modelling includes several management disciplines (Shapiro, 2001:12). These include:

- Strategy formation and the theory of the firm
- Logistics, production, and inventory management
- Management accounting
- Demand forecasting and marketing science
- Operations research

Optimization is a key ingredient in logistics master planning methodologies (Frazelle, 2002:15). For this, optimization techniques from the OR/MS disciplines are important ingredients to the different models that are incorporated in decision support systems.

2.3.2 Supply chain models and modelling systems

Supply chain models and modelling systems fall into two broad categories (Shapiro, 2001:10-12, Haydock, 2003). These are Descriptive and Normative models. They are distinguished by:

- Descriptive models
    - Forecasting models
    - Cost relationships
    - Resource utilization relationships
    - Simulation models
- Normative models
    - Optimization models
    - Mathematical programming models

For a long-time, simulation models have been applied to supply chain problems. This popularity exists mainly due to the fact that simulation methods are more intuitive to understand (compare to optimization models). Simulation models, which are defined as descriptive models, permit managers or analysts to study the dynamic behaviour of supply chain systems (Shapiro, 2001:463). The following are two broad categories of simulation models:

- Deterministic Simulation (describe system behaviour with no random effects)
- Stochastic Simulation (describe system behaviour with random effects)

According to Shapiro (2001:385) mathematical programming models for analysing supply chain strategy can extend their scope and level as indicated in Figure 2.40. In terms of level, these models can extend from a single period deterministic to multi-period deterministic and eventually to multiple period stochastic focus. The scope can also extend from an initial focus on minimizing cost over supply chain resources to maximizing net revenues over supply chain and marketing resources to ultimately take on the challenge of competitive equilibrium.

Accurate descriptive models are necessary but not sufficient for realising effective decision-making. Optimization models require descriptive data and models as inputs. These models form the basis for analytical IT application and move towards integrated supply chain planning.

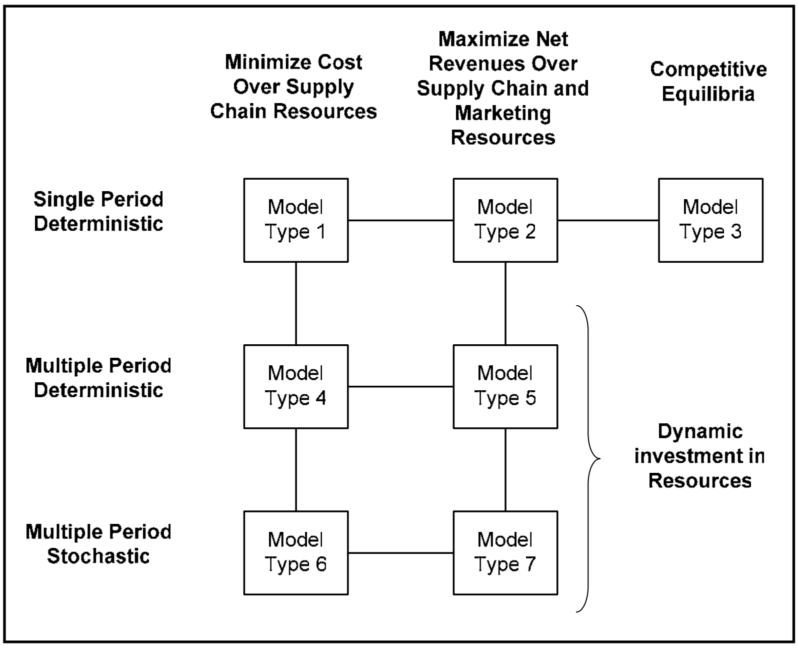


Figure 2.40 : Mathematical programming models for analysing strategy.
[Source: Shapiro, 2001:385]

According to Hagerty, Cecere & Souza (2005:1) a new type of decision support platform is needed that can integrate analytics (for measurement) and optimization. With the birth of Supply Chain Planning (SCP) systems 15 years ago, companies are only now starting to see analytics and optimization converge into a common platform. In the meantime, leading entities built their own measurement systems to complement their optimization installations (basing them on available Business Intelligence (BI) tools). Table 2.4 provides a bit more insight into the different categories of applications ranging from pure BI tools to pure optimization tools.

Unfortunately, because most managers are not modelling experts, they can easily be taken in by systems that translate input data into supply chain plans using ad hoc, mediocre models and methods. The opportunity loss incurred by applying a mediocre modelling system is not simply one of mathematical or scientific purity. Although a mediocre system may identify plans that improve a company's supply chain operations, a superior system will often identify much better plans, as measured by improvements to the company's bottom line (Shapiro, 2001:41-45). Analytical IT applications associated with the supply chain domain can be grouped into several types of optimization modelling systems (Refer to Table 2.5 for characteristics of these systems):

- Strategic optimization modelling systems
- Tactical optimization modelling systems
- Demand forecasting and order management systems
- Production planning optimization modelling systems

- Logistics optimization modelling systems
- Production scheduling optimization modelling systems
- Distribution scheduling optimization modelling systems

Transactional IT centres around Enterprise Resource Planning System (ERP), Materials Requirement Planning System (MRP) and Distribution Requirements Planning System (DRP).

Table 2.4 : Supply chain analytic application categories
[Source: Hagerty, Cecere & Souza, 2005:9]

Category	**Attributes**
I. Pure Analytics Tools	Software to report, analize, and display data. Can be pointed at any source of data. No specific supply chain intelligence built into tool. Displays whatever the company wants, either in reports, cubes, and/or dashboards/scorecards.
II. Analytics Tool with a Light Data Model	Same characteristics of "Pure Tool," but with available data models to support specific analytic functions. Light data model indicates some intellectual property is delivered with the product, but it is not comprehensive, and is considered a starting point for further development.
III. Heavy Data Model with Tool and Reporting Capability	Same characteristics of "Pure Tool," but with more sophisticated data models geared toward supply chain management.
IV. Heavy Data Model with predefined applications, extensible data model	This is the tipping point to where this software is fielded more as an application rather than tool. Data model is fixed to very specific analytic scenarios and, in some cases, toward specific industry issues. Visualization is customized from current application versus created by using a tool. Data model can be extended and enhanced based on customer need.
V. Decision Support Optimization Tool with a predefined application, non-extensible data model	Supply chain products that combine optimization and analytic applications together. Systems to report and analyze supply chain performance data from the strategic through to the transactional time horizons. Designed for business community.
VI. Optimization Engine	Decision support optimization tools with limited reporting. Designed as a support tool for the supply chain planner responsible for demand, supply, or logistics.

Table 2.5 : Features of analytical and transactional systems
[Source: Tayur, et al. 1999 (as referenced by Shapiro, 2001:47)]

Modelling Systems	Planning Horizon	Model Structure	Objective Function	Frequency of Analysis	Planning Time	Run Time
Strategic Optimization Modelling Systems	1-5 Years	Yearly snapshots	Maximize net revenues or return on assets	Once a year	1-2 months	10-60 minutes
Tactical Optimization Modelling Systems	12 Months	3 months, 3 quarters	Minimize total cost of meeting forecasted demand or maximize net revenue by varying product mix	Once a month	1 week	60-120 minutes
Production Planning Optimization Modelling Systems	13 weeks	4 weeks, 2 months	Minimize avoidable production and inventory costs	Once a week	1 day	10-30 minutes
Logistics Optimization Modelling Systems	13 weeks	4 weeks, 2 months	Minimize avoidable logistics costs	Once a week	1 dlay	10-30 minutes
Production Scheduling Optimization Modelling Systems	7-28 days	7 - 28 days	Minimize myopic production costs	Once a day	30 minutes	10 minutes
Distribution Scheduling Optimization Modelling Systems	7-28 days	7 - 28 days	Minimize myopic distribution costs	Once a day	30 minutes	10 minutes
Materials Requirement Planning Systems	7-28 days	7 - 28 days	Not applicable	Once a week	1-3 hours	60 minutes
Distribution Requirements Planning Systems	7-28 days	7 - 28 days	Not applicable	Once a week	1-3 hours	60 minutes
Demand Forecasting and Order Management Systems	1 week - 5 years	Varied	Not applicable	Varied	Varied	10 seconds - 10 minutes
Enterprise Resource Planning Systems			Not applicable	Real time or continuous	Real time or continuous	Not applicable

2.3.3 Modelling application and techniques for supply chain decisions

Certain types of models are better suited for application in the different decision phases in a supply chain. These decision phases relate to long term decisions, medium term decisions, and short term decisions. According to Suleski (1998:34) the consensus among relevant participants surveyed (from academic, manufacturing, consulting, and software vendor) indicated that at the **strategic level**, optimization most frequently employs mathematical programming, especially linear and integer programming. At the **tactical level**, combinations of linear programming, heuristics, simulation, genetic algorithms, and other methods are most frequently used. At the **operational level**, heuristics is most common. These participants also agreed that the method employed to solve any particular problem was much less important than understanding and properly framing the business problem. When the problem is understood, the granularity of data needed to solve it and the ease of acquiring and using this data plays an important role in determining which method will be most applicable.

Pienaar (2005:88) developed an extensive list of the key competencies and OR Techniques that prospective logisticians should master for their quantitative (model building) toolkit (see Table 2.6).

Table 2.6 : Key competencies and OR techniques
[Source: Pienaar, 2005:88]

Competencies	**OR techniques**
Forecasting	Exponential smoothing
	Linear recreation analysis and the least-squares methods
	Markov analysis
Analysis with simulation	Discrete-event simulation
	Random number and Monte Carlo simulation
	Simulations of this continuous random variability
Make rational decisions	Utility theory
	Feasibility analysis
	Decision tree
	Marginal analysis
	Multi-criteria decision analysis
	Linear programming
Location of facilities	Network models
	Location in perpendicular coordinates
	Linear programming
Determine routes for vehicles	Heuristic models
	Transportation modelling
	Assignment
	Transhipments
	Integer programming
Control inventory levels	Deterministic models
	Probabilistic models
	Linear programming
	Integer programming
	Dynamic programming
	Nonlinear programming
Scheduling (machines, projects, vehicles, and crews)	Machines: Algorithms
	Projects: CPM and PERT
	Vehicles: Heuristics, integer programming
	Crew: Heuristics, integer programming
Apply queuing theory	Birth-death process
	Poisson arrivals
	Exponential and Eerlang service times
	Queue networks
	Chi square test

The following are typical analytic tools used for strategic planning (Copacino & Rosenfield, 1992:170):

- Logistics cost analysis (also known as functional cost analysis). Typically used to analyse logistics costs by:
  - channel of distribution
  - product
  - type of customer
  - geographic market or
  - logistics function
- Decision support models:
  - what-if models
  - optimization models
- Traditional manufacturing strategy tools:
  - learning curve
  - life cycle costing
  - product/process matrix
- Grid framework (balance of two key service dimensions):
  - breadth of the product line (narrow or broad)
  - location of the inventories (centralized or decentralized)
- Cost-service trade-off curve:
  - structure of demand / product variety
  - transport economics
  - structure of value add stream

Optimization models for strategic logistics planning also centre around logistics network models (Shapiro, 2001:289). Facilities, transportation and inventory are the core focus for logistics network models. The following expands on the key issues:

- ***Facilities*** and their functional operations.
  - Which existing facilities should be left open or expanded?
  - Which existing facilities should be shut down?
  - Which new facilities should be opened with how much throughput capacity?
  - What is the mission of each facility (e.g., which products does it handle and/or store in inventory)
  - What equipment (e.g., flow-through sorters, conveyors, refrigerated storage areas) is needed at each facility to support its mission?
  - Which facility or facilities will serve each customer or market?
  - Which suppliers will replenish each facility?
- Three ***transportation*** sub-models
  - Inbound transportation sub-model
  - Inter-facility transportation sub-model
  - Outbound transportation sub-model
- Materials / ***inventory*** management
  - Relates to activities that cut across the entire supply chain

Logistics network modelling solution techniques, that are also suited for strategic decision support, are mathematical optimization techniques (exact and heuristics) and simulation models (D. Simchi-Levi, Kamisnsky & E. Simchi-Levi, 2000:30).

Inventory theory models can typically be categorised into deterministic models, probabilistic models, and ABC Classification techniques (Shapiro, 2001:477).

From the paragraphs above, it is obvious that numerous analytical techniques are available for decision support in the supply chain. The following paragraphs summarize the major modelling techniques.

2.3.3.1 Linear Programming

Shapiro, (2001:64) indicate that Linear Programming (LP) models, and methods for optimizing them, play a central role in all types of supply chain applications. The models and methods were originally devised to optimize the allocation of scarce resources to economic activities in a complex system. Logistics network models (including transportation models) are also well suited for the application of linear programming.

Linear programming can also be enhanced to cater for multiple objective optimization models (Shapiro, 2001:101). Goal programming and weighted objective function optimization are some examples.

An extension of linear and mixed integer programming, called stochastic programming, is an attractive option for strategic planning because it allows the decision maker to explicitly analyze uncertainties and control risks. The underlying idea is to simultaneously consider multiple scenarios of an uncertain future, each with an associated probability of occurrence (Shapiro, 2001:104).

Waller (1999:657) also indicates that linear programming is a powerful quantitative tool for decision-making, which can be used to optimise decisions both at the operating and strategic levels. It determines the values of variables that would achieve a particular objective such as to: maximise revenues, maximise profits, minimise costs and maximise market share. The objective is however restricted by resource availability, legal codes and specifications.

The application of linear programming is typically in the following areas (Waller, 1999:658):

- Product mix
- Transportation
- Production plan
- Assignment

2.3.3.2 Mixed Integer Programming

Mixed Integer Programming (MIP) models are generalisations of linear programming models in which some variables, called integer variables, are often strained to take on only non-negative integer values. MIP is used to capture/model a variety of strategic supply chain options (Shapiro, 2001:125). These include fixed costs, economies of scale, and production changeovers. It also provides for multiple choice and other non-numeric constraints.

The typical application of mixed integer programming is for distribution centre location models and supply chain network optimization models (Shapiro, 2001:133-139).

2.3.3.3 Heuristics

Heuristic methods are myopic search methods that attempt to quickly find a good solution to decision problems (Shapiro, 2001:179). They may be problem specific or general purpose. Problem specific heuristics use rules of thumb about a given decision problem in trying to determine a sound, feasible solution. They are not guaranteed to find an optimal solution or even a feasible solution to the problem. General-purpose heuristics are methods for intelligently searching the space of feasible solutions; they may be combined with problem-specific heuristics to improve their effectiveness. Heuristics are ad hoc search methods customized to a specific decision problem based on rules gleaned by humans about the problem.

Heuristics do have an important role to play, but their effectiveness is primarily in analyzing certain types of homogeneous sub-models embedded in larger, heterogeneous models.

2.3.3.4 Genetic algorithm

The term Genetic Algorithm (GA) denotes an analogy to selective breeding of plants or animals that seek to create offspring with improved characteristics by controlling the way in which parents' chromosomes are combined. The connection to a combinatorial optimization problem is to think of solutions to it as comprising chromosomes (Shapiro, 2001:185). A genetic algorithm attempts to improve on a pair of solutions (the parents) by a crossover or exchange of chromosomes that, it is hoped, creates a new and improved solution (the offspring).

Genetic algorithms are powerful and robust in difficult environments where the solution space is usually large, discontinuous, complex, and poorly understood (Lopez-González & Rodríguez, 2000:686). They are not guaranteed to find a total optimal solution to the problem, but they are generally good at finding acceptable solutions to problems quickly.

According to Klein (2000a:344) the genetic algorithm provides sound application in scheduling and routing problems. The genetic algorithm application has recently become increasingly popular as a means of solving such problems heuristically.

2.3.3.5 *Constraint programming*

Klein (2000b:353) explains that Constraint Programming (CP) represents a relatively new technique for computing feasible (and possible optimal) solutions to combinational decision problems like those typically arising in scheduling and routing. The basic idea of constraint programming consists of providing an integrated framework for formulating and solving decision problems based on a single programming language. In contrast to classical operations research techniques such as mixed integer programming, the user of constraint programming does not only specify the decision problem to be solved, but also determines how the search for a corresponding feasible solution should be performed. Constraint programming differs from classical optimization programs by not considering an objective function.

Constraint programming does not rely on mathematical optimization for solving decision problems, but rather on constraint satisfaction problems which, basically, consist of variables, domains as well as constraints.

The constraint satisfaction problem aims at finding feasible solutions to a real world problem rather than an optimal one. Optimality can be attempted by representing an objective function within particular constraints of the constraint satisfaction problem and solving several constraint problems consecutively.

By analyzing each of the constraints, possible inconsistencies resulting from modification are discovered and subsequently resolved by removing inconsistent values from the domains of the remaining variables participating in the affected constraints. This is usually referred to as domain reduction.

2.3.3.6 *Forecasting*

Forecasting is the trigger that sets the supply chain in motion (Waller, 1999:219-220). The starting point for all operating activities begins by forecasting, or estimating, the demand for finished goods or services. Forecasts, or estimates, can be made over any time horizon. A ***short-range*** forecast is one for a time span of a few weeks, up to about three months. It would include forecasting such items as: purchase transactions; cash requirements; work scheduling; workforce levels; job assignments; production levels. A ***medium-range*** forecast is one that covers between about three months up to one year. In this case it would include such items as: sales plans; production plans; capacity plans; operating cash budgets;

management levels; subcontractor needs. A ***long-range*** forecast is of about one to five years and would include: capital expansion plans; new investment; new product development; facility location; research and development programmes; strategic plans; implementing new technology: acquisitions.

Waller (1999:222) indicates that a number of economic indicators can be used to assist in describing past, current and future macroeconomic conditions. These can be leading or lagging indicators. The factors that can be used for forecasting include the following:

- Macroeconomic Factors: *(interest rates, exchange rates, unemployment level, demographic trends, government regulations, political climate, labour unrest, elasticity of demand)*
- Microeconomic Factors: *(competition, reputation for quality, price, design, delivery times, disasters)*

Chopra & Meindl (2001:72) states that a sound approach to demand forecasting includes:

- Understand the objective for forecasting
- Integrate demand planning and forecasting
- Identify the major factors influencing demand forecasting
- Understand and identify customer segments
- Determine the most appropriate forecasting technique
- Establish performance and error measures for the forecast

A set of time series data forms the basis for forecasting techniques. A time series is historical data, representing a specific activity that has been collected over a regular period of time (Waller, 1999:229). A number of components in a data series may indicate a trend, season variation, business cycle activity, irregular occurrences, or random variations. Modelling techniques that are typically used in forecasting includes averaging, exponential smoothing and linear regression.

The observed demand consists of systematic components (level, trend, seasonality) and random components. Chopra & Meindl (2001:71) indicate that forecasting can typically be classified into qualitative, time series, causal and simulation methods.

Time series forecasting methods are either static or adaptive (Chopra & Meindl, 2001:75). The static method assumes that the estimates of level, trend and seasonality within the systematic components do not vary as new demand is observed. The adaptive methods estimation of level, trend and seasonality are updated after each demand observation. The static method typically comprises the estimation of level, trend and seasonal factors. The adaptive methods comprise: moving average; simple exponential smoothing; trend corrected exponential smoothing (Holt's model); trend- and seasonal corrected exponential smoothing (Winter's model).

As stated earlier, most demands have a random component. The random component manifests itself in the form of a forecast error. A good forecasting method should capture the systematic components of demand but not the random component. Measures for demand forecast error normally include: mean square error (MSE); mean absolute deviation (MAD); mean absolute percentage error (MAPE); tracking signal (TS) (Chopra & Meindl, 2001:86).

2.3.3.7 Artificial intelligence

Artificial intelligence is an aspect of information technology and can broadly be viewed as the use of computers to mimic or copy aspects of human intelligence, such as learning languages, making decisions and performing physical actions (Chopra & Meindl, 2001:183). Robots are related to artificial intelligence where a robot is programmed to accomplish specific coordinated manual tasks. Expert systems, neural networks, and fuzzy logic are the three elements of artificial intelligence which has application in the design of processes.

2.3.3.8 Simulation

The basic concept of simulation constitutes the abstraction of a complex system in preferably a computerized model and the use of the model to evaluate various scenarios (Meyer, 1995:D5-1). The most important factor that warrants the use of simulation models are complex interaction between system components, variability of such components and variability in certain parameters over time. Simulation can typically be used in designing and re-designing a logistics channel for the following:

- Preliminary evaluation of the channel
- Resource balancing
- Physical layout or configuration of the channel
- Management configurations

Rogers (1997:84) indicate that simulation is ideally suited for analyzing systems with multiple sources of variation and interdependencies.

When modelling off-sites for chemical plants (facilities lying outside a primary production plant) and logistics, interactive and visual stochastic simulation can be used to test for supply chain event dynamics and feasibility (testing for adequate capacity) (Falcorn, 1994:40).

2.3.3.9 Geographical information systems

A Geographic Information System (GIS) is a system for the management, analysis, and display of geographic information. Geographic information is represented by a series of geographic datasets that model geography using simple, generic data structures. GIS includes a set of comprehensive tools for working with the geographic data (ESRI, 2004:2).

A GIS is a unique kind of database of the world—a geographic database (geodatabase). It is an "information system for geography." Fundamentally, a GIS is based on a structured database that describes the world in geographic terms. Each GIS dataset (layer of data) provides a geographic representation of some aspect of the world (e.g. roads, rivers, lakes, magisterial districts, etc). A GIS allows a user to bring all types of data together based on the geographic and location component of the data. But unlike a static paper map, GIS can display many layers of information that is useful to the user. Relationships between the data become more apparent and data becomes more valuable.

Geographical Information Systems (GIS) coupled with Operations Research (OR) techniques for decision support are still in its infancy, but it surely has great potential in logistical planning, routing, marketing applications, and location analysis (Camm et al., 1997:141). Problem solving can be improved through operations research and information technology by merging integer programming, network optimization models, and GIS. The use of a GIS as the medium for user interaction greatly facilitated user acceptance of these analytical techniques.

2.4 Summary of literature study related to chain planning processes and operations research application

For companies to compete in the future, they need to understand the strategic importance of a process orientation towards their business. A business process orientation emphasizes processes (as opposed to hierarchies) with a special emphasis on outcomes. Business processes typically have a specific starting and ending point that are composed of a series of linked, continuous, managed activities and typically transcends cross functional boundaries within or between companies and contributes to an overall outcome.

With the term "supply chain" emerging on the business scene only about a decade ago, it spoke of a process management concept and sparked a hope that senior management would finally see value in investing in a well-orchestrated supply chain. Increasingly, supply chain management is being recognized as the management of key business processes across the network of organizations that comprise the supply chain. World class supply chain management focuses on combining doing the right things (planning) and doing things right (execution). Supply chain process management is the glue that binds together the different focuses of planning and execution. Planning is viewed as one of the key supply chain processes.

With the supply chain management momentum moving forward, there is a need to first integrate the separate processes within the organization, then to integrate the processes externally into the organization in an attempt to more closely connect the organization with its customers and suppliers. Most of the barriers to integrate an organisation through supply chain management are organizational, not technical. Past research into human- and organizational decision-making has shown that timeless issues of ignorance, superstition, conflict, and self-seeking behaviour are still around. For supply chain business processes to work properly, a firm needs to restructure its conventional vertical oriented organizations and balance it with a horizontal market facing businesses.

The typical planning tasks along the supply chain deal with:

Long-term planning tasks. Product program and strategic sales planning; Physical distribution structure; Plant location and production system; Materials program and supplier selection; Co-operations

Mid-term planning tasks Mid-term sales planning; Distribution plan; Master production scheduling and capacity planning; Personnel plan; Material requirements planning; Contracts

Short-term planning tasks. Short-term sales plan; Warehouse replenishment and transport planning; Lot-sizing and machine scheduling, Shop floor control; Short term personnel planning; Ordering materials

The challenge of integrated and advanced supply chain planning really lies with process integration. The greatest challenge is to ensure that the supply chain parts cooperate with each other and stay focused on a single objective. Advanced planning has to cross not only the functional silos within your enterprise, but also the corporate barriers across the supply chain. The concept of time phased planning and the resulting capacity plans enable users to identify future constraints with adequate time to pursue alternatives. To manage constraints across a supply chain, companies must match the supply and demand of capital, people, equipment, and space across every node in the supply chain from suppliers to the end customer. The principle of aggregation and use of aggregate planning in a supply chain is one of the key building blocks for hierarchical planning. Planning is done on a higher aggregate level (e.g. not on a SKU level). These planning processes serve the purpose to determine levels of capacity, production, subcontracting, inventory, stock outs, and even price over a specific time period. The objective of aggregate planning is to satisfy demand in a way that maximizes profit for the firm. Aggregate planning makes trade-offs amongst capacity, inventory, and backlog/lost sales.

Coordination, integration and collaboration are important building blocks for supply chain planning. Coordination is important for consistent plans across the different planning levels, and for each entity of the supply chain. Collaboration is all about building new mutually beneficial business processes that benefit the entire supply chain. Integrated planning should be approached with a functional, spatial and inter-temporal (hierarchical) integration orientation.

In the adoption of advanced supply chain planning, it is advisable to move the decision-making through three advancement stages. Initially the focus must be on information visibility. All the required information for the applicable supply chain planning processes must be accessible. The next stage allows for enabling "what-if" tools for planners to test the implications of a specific scenario or course of action. Only when planners have adopted these stages of sophistication can one start to automate some supply chain decision-making processes with appropriate optimization algorithms.

The discipline of management science and operations research is devoted to the studying and developing of procedures to help the process of decision-making (following a systematic approach). Supply chain models that are built using operations research techniques include multi-disciplinary fields comprising elements of mathematics, economics, computers and engineering. Supply chain modelling also includes several management disciplines. These include: strategy formation; logistics; production and inventory management; management accounting; demand forecasting and marketing science, and operations research.

Chapter 3: Decision Support Systems (DSS) and roadmaps for interventions

Chapter 3 examines the relevant literature found regarding Decision Support Systems (DSS) and roadmaps for executing improvement interventions. Advanced supply chain planning requires the appropriate enabling information technology. The mayor types of DSS are portrayed and positioned. Because supply chain and logistics performance (measured by appropriate performance measures) play such a vital role in building sound business cases, a number of paragraphs are devoted to literature findings in this regard. Roadmaps and strategies for interventions are also screened including the major issues of managing supply chain projects, business case development, organization development and change management.

3.1 Supply chain planning and enabling decision support systems

According to Gattorna & Hanlock (1999:10) firms are becoming more process-focused. This is particularly the case in the supply chain areas of demand planning, capacity and resource planning, network optimization and e-commerce. To enable these requirements technologically, firms are demanding more dynamic systems for their supply chains. Supply chain planning systems therefore provide the critical link between supply chain strategy and supply chain operations. It is of vital importance to understand that in managing a company or supply chain, focus is required on both processing transactions and supporting decisions (Bender, 2000:60).

Companies typically invest heavily in technology for their information processes when attempting to build an integrated supply chain (Dershin, 2000:74). They also pay attention to the physical processes like manufacturing and transportation but yet they often overlook the third element of the supply chain DNA; the business processes so necessary to achieving the full benefit of integration. Companies that tried to implement advanced systems without considering the complimentary business processes will never achieve full supply chain integration.

Although information technology (IT) systems can play a key enabling role for supply chain planning, some prerequisites are required. As George Colony for Forrester Research indicated (quoted by Schlegel, & Smith, 2005:22): "Deploying technology without changing process and organization will create little impact—and it often brings negative consequences. Naked technology wipes out productivity improvements, hurts return on investment, and dulls the bright edge of well-conceived strategies."

Significant changes in decision support systems and IT have occurred over recent decades (D. Simchi-Levi, 2000:77). Information is now made readily available and computer power increased significantly. Over time, different categories of IT systems emerged. Transactional IT systems and analytical IT systems differ fundamentally in form and function (Shapiro, 2001:37). Table 3.1 compare and indicate the differences between the two domains in a number of dimensions. Supply chain planning typically resorts in the analytical IT system categories.

Different levels in the organization play a different role regarding control. Figure 3.1 typically indicates four levels of control involved in logistical administration. Adjacent to each level, reference is made to a corresponding rank within a corporation (Bowersox, 1974:441 & 444). On the left hand side of the chart, a data pyramid is developed to reflect the selectivity of information considered at each level of control. Each level is concerned with system monitoring as well as exception reporting. However, as information flows from the direction level to the policy level, the content of subject matter increases in importance to the welfare of the total corporation. These levels of control and information flows have the following purpose:

Policy revision: Relates to a basic change in logistical objectives. Once again, the areas of system design and administration merge when questions of policy are confronted.

Decision: It is concerned with modifications in the operational plan. In essence, situations have materialized at the direction and variation levels that require a reappraisal of the original operational plan.

Variation: It is concerned with accumulation of information which indicates that all is not going according to plan.

Direction: Information flow and control are concerned with execution of the operational plan.

Table 3.1 : Comparison of transactional and analytical IT.
[Source: Shapiro, 2001:37]

Dimension	Transactional IT	Analytical IT
Time Frame Addressed	Past and present	Future
Purpose	Communications	Forecasting and decision making
Business Scope	Myopic	Hierarchical
Nature of Databases	Raw and lightly transformed objective data	Moderately raw and heavily transformed data that is both objective and judgmental
Response Time for Queries	Real-time	Real-time and batch processing
Implications for Business Process Redesign	Substitute for or eliminate inefficient human effort	Coordinate overlapping managerial decisions

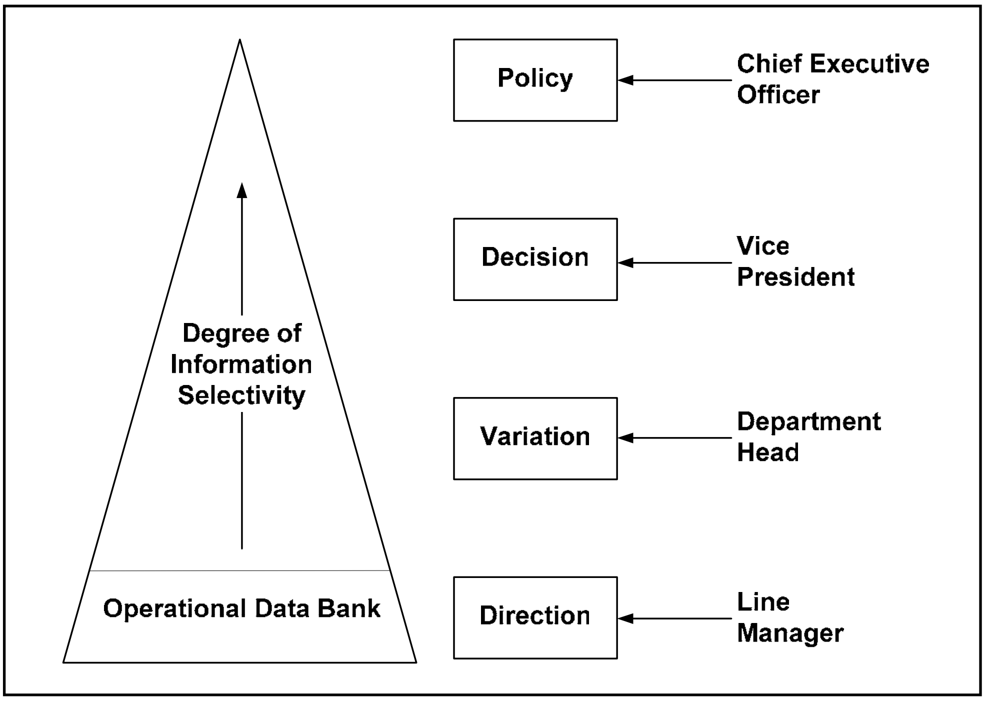


Figure 3.1 : Levels of control and information flow.

[Source: Bowersox, 1974:444]

According to Beavers (2002:43) information technology solutions sets typically have a horizontal and vertical integration focus. These sets include:

Horizontal solutions sets:

- Customer relationship management (CRM)
- Supply chain planning (SCP)
- Electronic procurement system (EPS)
- Supply chain integration (SCI)
- Logistics management system (LMS)

Vertical solutions sets:

- Enterprise resource planning system (ERP)
- Supply chain execution system (SCE)
- Manufacturing execution system (MES)
- Warehouse management system (WMS)
- Factory automation system (FAS)
- Factory floor control system (FCS)
- Computerized maintenance management system (CMMS)
- Product data management (PDM)

3.1.1 Information technology (IT) related evolution

A relatively new breed of software (Supply chain management suites) is the result of advances in computer technology and a growing recognition of the importance of supply chain efficiency to business success. These suites are designed to provide optimised solutions to problems and decision support for a full range of supply chain planning and execution activities (Murphy & Sherman, 1998:58).

John Bermudez from AMR (as referenced by Murphy & Sherman, 1998:60) stated that supply chain planning software is more revolutionary than evolutionary. The key to understanding advanced planning and scheduling (APS) is to recognize that it is a truly new technology. (Not a re-hash of 30 years old MRP programs). APS technology is changing the way manufacturers plan today. During the optimization process APS often look for the best plan by making multiple passes through the planning data. In contrast material requirement planning (MRP) programs make a single pass through the data. It assumes infinite plant capacity and material availability, as well as simple time-phase production and purchase orders based on customer due dates (often resulting in a sub-optimal plan).

Chopra & Meindl (2001:339-350) explains that IT systems (as the information enabler) can be segmented according to the stages in the supply chain where they focus and the phases in decision making for which they are used (Refer to Figure 3.3 for this horizontal and vertical distinction). IT applications in the supply chain domain have evolved from the past to the present with the addition of the following systems:

Past: Legacy systems (Initially)

Present (transactional): Enterprise resource planning (ERP) systems developed as an excellent system to monitor transactions, but lacked superior analytical capability. These ERP systems typically have the following modules:

- Finance (to track financial information: revenue and cost)
- Logistics (transportation, inventory management, warehouse management)
- Manufacturing (track the flow of product through the manufacturing process)
- Order fulfilment (monitors the order fulfilment cycle)
- Human resources (handles human resources tasks and information)
- Supplier management (monitors supplier performance)

Present (analytical): Analytical Applications have developed to provide the following capabilities:

- Planning Capabilities
    - Procurement & Content cataloguing applications
    - Advanced planning and scheduling (APS)
    - Transportation Planning & Content Systems
    - Demand Planning and Revenue Management
    - Customer Relationship Management (CRM) & Sales Force Automation (SFA)
    - Supply Chain Management (SCM)
- Execution Capabilities
    - Inventory Management Systems (IMS)
    - Manufacturing Execution Systems (MES)
    - Transportation Execution
    - Warehouse Management System (WMS)

The supply chain IT map for enterprise resource planning (ERP) and analytical applications (as indicated in Figure 3.2 and Figure 3.3) shows the differences in focus between these two domains. ***ERP*** systems provide an integrated view of the operational information across the functions within a company with the potential to go across other companies in the supply chain. This could then provide the required transparency of relevant transactional information to all supply chain partners. The

analytical applications place a major emphasis on linking the strategic and tactical planning processes across the supply chain and support the decisions in this environment.

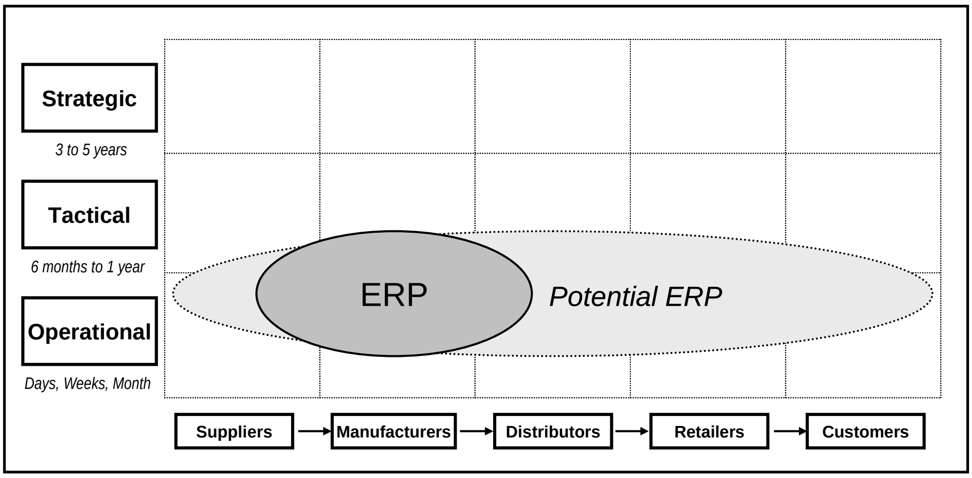


Figure 3.2 : Supply chain IT map – ERP systems.
[Source: Chopra, 2001:345]

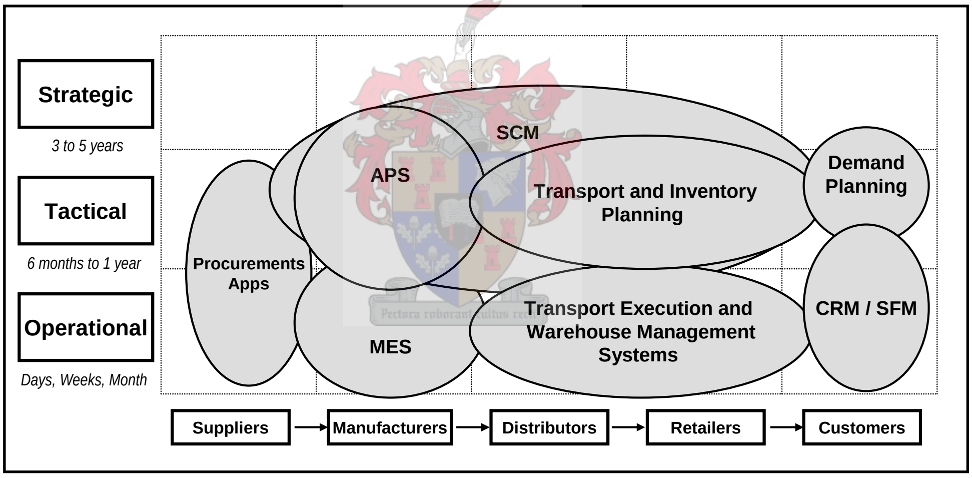


Figure 3.3 : Supply chain IT map – analytical applications.
[Source: Chopra, 2001:349]

While interest in, and adoption of, older tools and technologies (e.g., MRP and DRP) continues to decrease, acquisition and adoption of new functionality and technology is on the rise (Peterson, 1999:3). The applications that have reached product maturity and are ready for the pragmatic market are demand planning, manufacturing scheduling and single-site capable to promise. Multi-plant planning, commonly referred to as supply chain planning, has reached maturity in certain industries.

According to Shepherd & Scott (2004:4) the most important application investment area would include customer management and supply chain management. These are the major priorities for application investment (refer to Figure 3.4). The changes in customer interaction and management of the global supply chain are the primary drivers for application investment. Traditional areas like Enterprise Resource Planning (ERP) and performance management are still important, but less compelling from a revenue-generation or cost-advantage perspective. Many organizations are prioritizing investments that respond to anticipated customer requirements for better connectivity and information-based services such as Vendor-Managed Inventory (VMI), automatic replenishment, or category management. Applications are no longer viewed simply as an operations efficiency tool, but also as a competitive differentiator. Corporations are beginning to differentiate themselves through value-added services attached to their products. These services are often information-based. The investment in supply chain applications is often driven by a combination of increased customer expectations and low-cost sourcing opportunities. The customer management applications tend to be a mix of better connectivity and collaboration, along with a much more proactive effort to understand and influence customer demand.

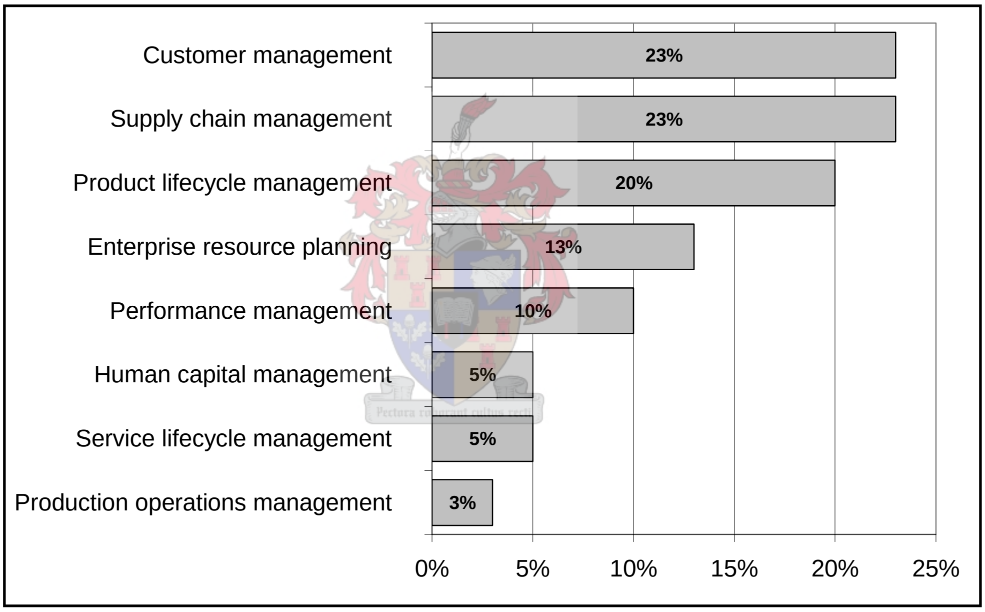


Figure 3.4 : Most important application investment area in the next 12 months
[Source: Shepherd & Scott, 2004:4]

The limitations of many replenishment systems are that they primarily focus on execution, rather than on execution and planning (Martin, 2001:64). These systems also tend to be departmentally focused. There is however different approaches required at each level of the supply chain. Fundamental changes to replenishment systems are required. Time phased planning systems that enables planning and execution on the same system throughout the supply chain should provide access to a single set of numbers (i.e. “Sing from the same hymnbook”).

3.1.1.1 *Stages of IT Evolution*

As businesses review their approaches to supply chain optimization and begin to understand the tools available, there will likely be a shift in focus toward implementing advanced planning and scheduling (APS) systems that will further leverage the ERPs and LPs already in place (Kafoglis, 1999:50). What is important is that the opportunity exists to shift from financial transaction processing to supply chain planning, as well as to achieve true enterprise-wide business integration rather than optimizing each silo of information along the supply chain.

Four levels of supply chain management system development and components are required to make the system's architecture complete (Dave, Roger & Leep, 1997:28). Table 3.2 provides a framework for the different components of these systems. The different levels and focuses typically use the decision hierarchy from strategic and tactical to operations and execution.

Table 3.2 : Supply chain system architecture components
[Source: Dave, Roger & Leep, 1997:28]

Level	Focus	Systems	Components / Modules
Level I	Primarily strategic	Demand plan and design systems	Forecasting Network optimization model
Level II	Rough-cut tactical planning	Operations planning systems	Master Production Schedule [MPS] Material requirements planning [MRP] Distribution requirements planning [DRP]
Level III	Operations scheduling	Scheduling and management systems	Finite capacity scheduling [FCS] Inventory deployment [MRP II] Warehouse management systems [WMS] Transportation management systems [TMS] Performance evaluations systems [PES]
Level IV	Execution processing	Transaction processing systems	Financial accounts On-line transaction processing systems [OLTP] for Buy, Receive, Process, Commit, Distribute

In 2005, Computer Sciences Corporation (CSC) and Supply Chain Management Review conducted the 3rd annual "Global Survey of Supply Chain Progress" (Porier & Quinn, 2006). As basis for the survey they use the philosophy that a business enterprise moves through **five levels or stages of evolution** on its way to advance in supply chain management (as illustrated in Figure 3.5). The framework ranges from enterprise integration (level 1) to full network connectivity (level 5). At **levels 1 and 2,** supply chain optimization efforts are limited to within the four walls of the company. **Level 3** denotes the beginning of external collaboration, which is typically accompanied by process improvements. **Levels 4 and 5** denote true connectivity among the supply chain partners.

According to the 2005 results, a high percentage of companies have moved through the third level and are purposely working to collaborate with external supply chain partners. Almost 50 percent of the respondents indicated that their progress is beyond level 2. The most frequently pursued initiative is strategic sourcing of direct materials, followed by sales and operations planning (S&OP). Strategic sourcing of indirect materials, strategic inventory planning, and advanced planning and scheduling make up the top five. For years, the Supply-Chain Council, through its Supply-Chain Operations Reference (SCOR) model, has emphasized the importance of the "plan" step in its model. Looking at the top five initiatives, it's evident that the planning process is starting to get the attention that the Supply-Chain Council and others believe it deserves.

Manugistics (as referenced by D. Simchi-Levi, Kamisnsky & E. Simchi-Levi, 2000:243) indicates that a key integration issue revolve around a supply chain's stages of development and focus. The following is an indication of the stages of development and the focus at that stage:

Stage one: the fundamentals; focus on quality and cost

Stage two: cross functional teams; serve our customers

Stage three: integrated enterprise; drive business efficiency

Stage four: extended supply chain; creating market value

Stage five: supply chain communities; be a market leader

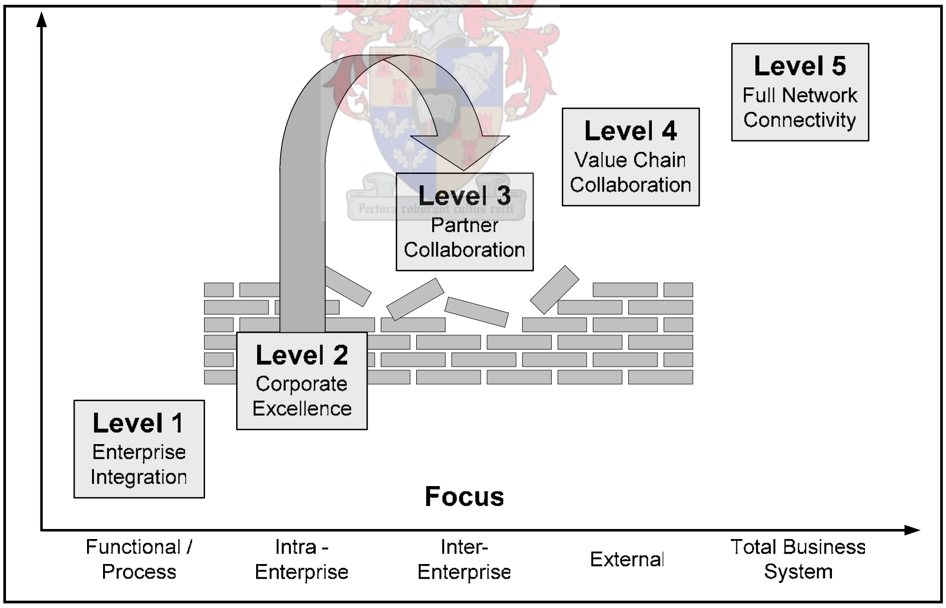


Figure 3.5 : Five levels of supply chain evolution.
[Source: Porier & Quinn, 2006]

By adopting an enterprise commerce management (ECM) approach, companies can turn supply chains into "venture chains" (Parker, 2001:19). As indicated in Figure 3.6, the following three layers of system development are positioned:

- Information services layer must form the corporate ***system of record***.
- Interaction services form a company's ***system of process***
- Collaboration services deliver the ***system of venture***

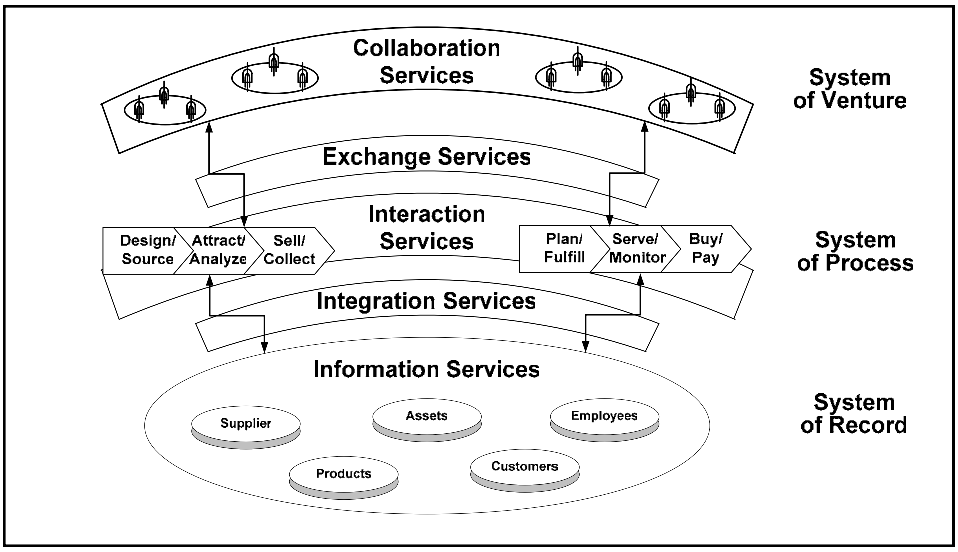


Figure 3.6 : ECM blueprint - the IT infrastructure.
[Source: Parker, 2001:21]

The interaction layer (as indicated in Figure 3.6) defines the business rules and typically provides enterprise-wide, corporate shared services. This layer incorporates all the global process management applications, including the following process sets (their interaction is as indicated in Figure 3.7):

- Supply chain management (SCM)
- Product life cycle management (PLM)
- Customer relationship management (CRM)
- Procurement
- Enterprise management

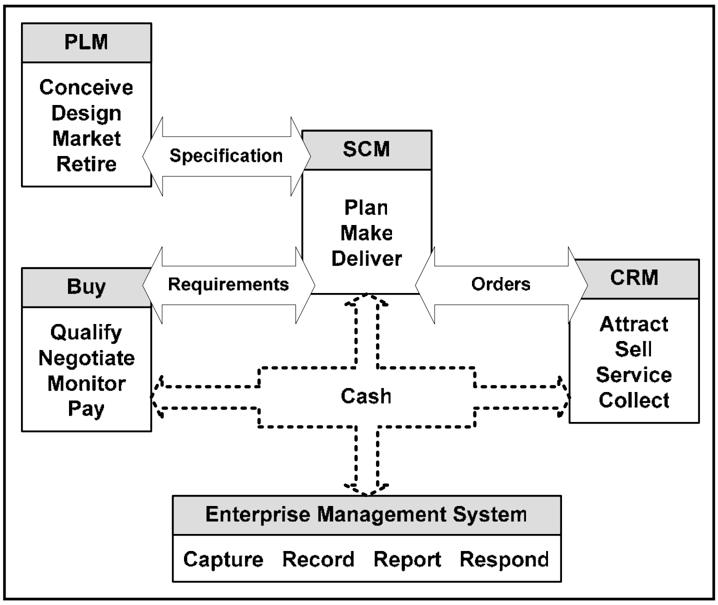


Figure 3.7 : Global Process Management.
[Source: Parker, 2001:21]

3.1.1.2 Technology risk

O'Laughlin (as quoted by Andel, 1996:31) indicates that there is a substantial difference in the risk of transactional vs. decision support systems. Managing the risks in change from one technology to another is particularly important with transactional process software, because it's controlling your business as opposed to the decision support tools with which you interact on an asynchronous basis.

The ability to process information is as important as the ability to process materials. Both of these make an important contribution to the success of a modern manufacturing company (Rowlands, 1996:10). Not having the correct and timely information available for decision making can place a company at risk.

3.1.2 Nature and components of Decision Support Systems (DSS)

The nature of the information system is tied not only to the decision, but to the organizational level at which this decision is made and the functional area of the firm in which it is made (LeMay & Wallace, 1989:3). The following provide the context for each decision phase related to scope, structure and information requirements:

- ***Strategic decision level:*** Choices about what the whole enterprise should have as its goal; Scope is large, structure low, and information needed is predominantly external, future and extremely diverse.
- ***Tactical decision level:*** Decisions are alternately financial and activity measured, semi structured and periodic; Opportunity to integrate operational functions with each other at this level; Knowledge of the characteristics of operational activities is most critical.
- ***Operational decision level:*** Repetitive, well structured, and quantitative decisions that can easily be programmed into rules written mathematically; Scope is narrow within a department or activity and information internal and current/historical.

DSS are typically focused on planning processes and reach across functional silos (Andel, 1996:30). The problem with point solutions and legacy systems is that they create data silos throughout a company.

The interaction between information systems and decision modelling, and the progressive transformation of data into information and knowledge, is a key process underlying any decision support system (DSS) for strategic, tactical or operational planning (Koutsoukis et al., 2000:640).

DSS brings the manager closer to the computer, analytical tools, and databases (LeMay & Wallace, 1989:2&3). Management information systems should help managers in their primary obligation to plan, organize and control. Management information systems provide the data relevant to the problem. Decision support and expert systems anticipate user algorithms and heuristics and extend the manager's speed and scope without affecting management responsibility at a decision making level.

By repeatedly instantiating models by data, metadata, and information, and analysing the results, knowledge is created (Koutsoukis et al., 2000:642). Knowledge and information are used to aid decision making. Data, information and knowledge are three major components of the “information value chain” as indicated in Figure 3.8.

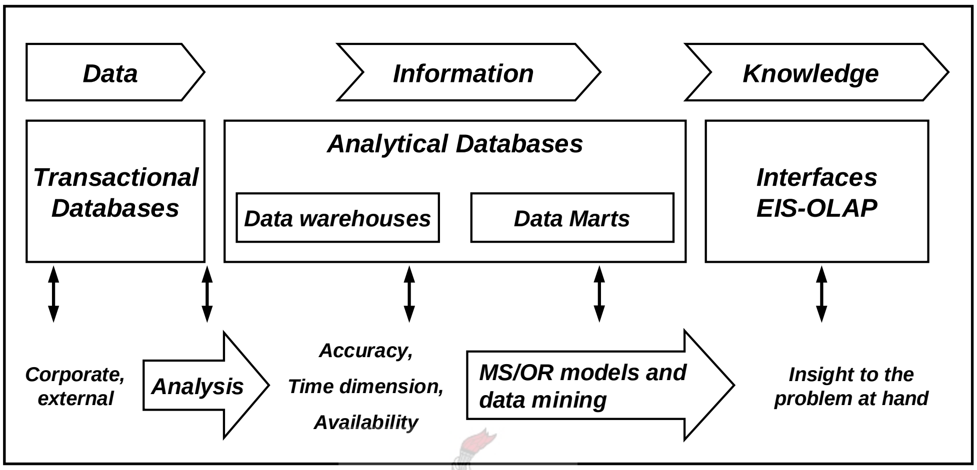


Figure 3.8 : The information value chain
[Source: Koutsoukis et al., 2000:642]

Koutsoukis et al. (2000:657) indicate that the three major software components of any DSS relate to the graphical user interface (GUI), database system, modelling tool and a solver (optimiser). Figure 3.9 outlines the key properties of DDS software architecture:

- Functions
- DSS Process
- Software tools and components
- Some level of user interaction

D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:253) also indicate that the major DSS components include:

- Input databases/parameters
- Analytical tools (queries, statistical analysis, data mining, online analytical processing (OLAP) tools, calculators, simulation, artificial intelligence, mathematical models and algorithms [exact algorithm/heuristics])
- Presentation mechanisms (reports, charts, spreadsheet tables, animations, specialized graphic formats [floor plan], Geographic Information Systems (GIS), and Gant charts)

Analytical IT comprises supply chain decision databases plus (from corporate databases) the modelling systems and programs (Shapiro, 2001:30-31). It also needs processes to extract, aggregate, extrapolate and transform transactional data into input data required by modelling systems to support decision making.

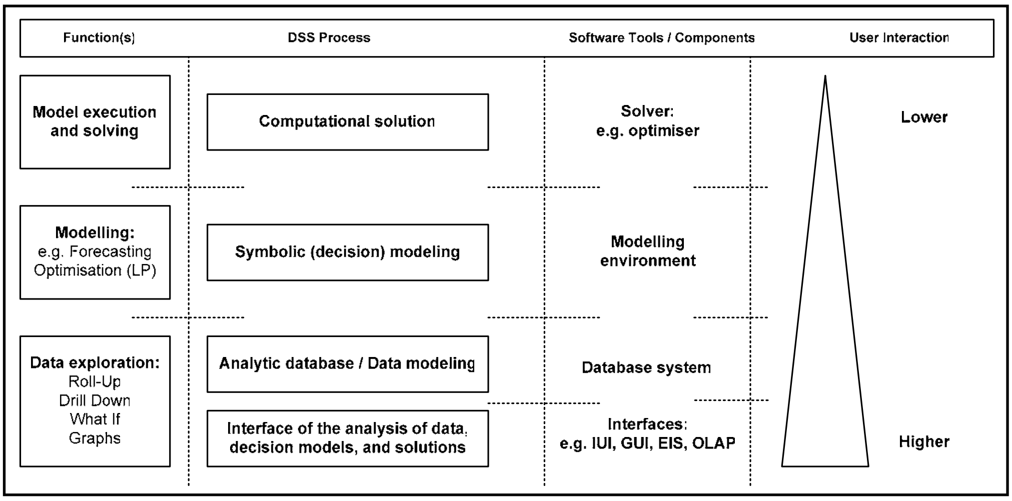


Figure 3.9 : DSS functions, processes, uses interaction and tools
[Source: Koutsoukis et al., 2000:657]

Shapiro (2001:151) indicates that strategic and tactical supply chain planning problems share common features across many companies and industries. However, operational problems arising in production, transportation, and other areas of SCM vary significantly from industry to industry and even company to company. The design of supply chain decision support systems typically includes the following components:

- Modelling gestalt
- Model generator
- SC decision database (Model input file sets)
    - Sets of structural data
    - Sets of numerical data
- Model output file sets.

Shapiro (2001:154) also indicates that key components of a DSS are:

- Analytical engine
- Database management system
- User interfaces
- Data transformation programs. (e.g. a geographical information system)

The optimization software used in a DSS should include the required optimisers/algorithms (Shapiro (2001158-163). Efficient linear programming algorithms are normally based on the simplex method, and the interior point method. Efficient mixed integer programming algorithms uses the branch-and-bound method. Spreadsheet optimization software are typically limited to models that are small and simple but are good for rapid developing and exercising a “proof-of-concept”.

Stock & Lambert (1987:537) defined decision support systems as “integrated systems of subsystems with the purpose of providing information to aid decision makers in making choices”. The typical subsystems include: decision relevant models;

interactive hardware and software; databases; data management system; graphical and other sophisticated displays; user friendly modelling language. A DSS is comprised of three distinct components: data acquisition, data processing and data presentation. Modelling is the process of developing a symbolic representation of real total systems.

A wide range of model types exists. These typically include visual, verbal/narrative, iconic, mathematical, conceptual, and computer models.

Models are typically used for diagnostics and tactical/strategic planning. The DSS model users are normally decision makers and technical experts (Koutsoukis et al., 2000:643). The technical experts range from database experts, modelling experts, and solver experts to domain experts.

3.1.3 Decision support systems for supply chain management

Richmond et al. (1998:510) indicated the major categories of **supply chain management tools:**

- Supply chain configuration tools (strategic, networks)
- Demand planning tools (to predict future demand)
- Supply planning tools (to match supply and demand)
- Transportation planning and management tools (Transportation selection, sequencing and tracking)
- Warehouse management tools (Transactional, managerial activities between the four walls)
- ERP tools (The single data model, transactional backbone)

The major supply chain management tools can also be viewed from three perspectives (Richmond et al. 2000:509):

- Transactional systems (for day to day operations)
- Tactical and operational planning systems (Weekly and monthly operations planning)
- Strategic tools (design and re-design supply chain infrastructures)

Visibility tools for decision support systems provide three features (Simchi-Levi, 2000:78). ***Firstly*** it provides users with information on the performance measures, both global measures across the supply chain and facility specific performance measures; ***secondly*** it enables users to identify and act when a certain measure of performance is violated, and ***finally*** it provides for planning based on global supply chain data.

Information technology is an important enabler of effective supply chain management (D. Simchi-Levi, Kamisnsky & E. Simchi-Levi, 2000:221). This is largely due to the abundance of information now available for sophisticated analysis, innovative opportunities coming from the internet, and supply chain processes spanning functional areas requiring integration. The goals of supply chain information technology should be the collection of information, provide access to any relevant data (from a single point of contact), and analyze, plan activities, and make trade-offs based on information from the entire supply chain. The means through which information technology can support supply chain management is:

- Standardization (for systems to work together)
- Information technology infrastructure (basic components needed; the interface devices, networks/communication, databases, system architecture)
- E-commerce (must be achievable and cost effective;, levels; one way communication; database access; data exchange, and sharing processes (e.g. SCOR & CPFR))

Evolutionary phases that typically categorises the **advancement** from batch systems to dynamic **supply chain planning** are (Peterson, 1999:4):

Phase I: Time-phased reorder point in the form of MRP and DRP— focus on batch-oriented or manual exception handling and expediting.

Phase II: Point solutions in the form of memory resident applications for factory and distribution planning and scheduling.

Phase III: SCP: For Business-to-business (B2B), Integrated planning of distribution, multi-plant for a single enterprise.

Phase IV: Reshaping business models through use of SCP for collaborative commerce and as backbone of dynamic trading communities.

D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:240&264) indicates that the supply chain management system components (that need support systems) typically include: logistics network design, production location assignments/facility deployment, demand planning, capacity or supply planning, inventory deployment, sales and marketing regions assignments, distribution resource planning (DRP), material requirements planning (MRP), inventory management, fleet planning, lead time quotation, production scheduling, workforce scheduling, and procurement/purchasing.

According to D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:246), other issues to consider are related to implementing ERP and DSS systems, and making a choice between best of breed vs. a single vendor ERP systems (with APS capabilities).

Appropriate decision support systems depend on the nature of the problem, planning horizon and the type of decision to be made (D. Simchi-Levi, Kamisnsky & E. Simchi-Levi (2000:251). DSS are used to address the various problems of strategic (logistics network design), tactical (product assignment) and operational (productions scheduling, truck routing) issues. The size and complexity of problems makes DSS an essential component for effective decision-making. Advanced planning and scheduling (APS) systems typically cover demand planning, supply planning and manufacturing planning and scheduling.

3.1.4 Major types of enabling decision support systems

To effectively apply IT in managing a supply chain, a company must distinguish between the form and function of Transactional IT and Analytical IT (Shapiro, 2001:3). There is a clear distinction in the role that data, models, and modelling systems play in helping companies improve the management of their supply chains. Analytical IT systems typically focus on: analyze their corporate databases; identify plans; redesign; and operating more efficiently (optimization models).

3.1.4.1 Enterprise Resource Planning (ERP) Systems

ERP systems (e.g. supplied by Oracle, Baan, J.D. Edwards and SAP) provide a backbone for data storage and transaction tracking, help to standardise data formats, and to create the required discipline for collecting and updating data (Keskinocak & Tayur, 2001:86). Shapiro, (2001:29) also indicate that these transactional databases govern standardisation across the company and facilitate integration of supply chain activities.

Although ERP systems provide solid transactional information, they are largely focused on the internal operations of an organization. This internal focus is insufficient to meet the more complex supply chain planning needs of organizations wishing to integrate with their partners along the supply chain. In addition to what the ERP systems provide, the supply chain needs a tool to guide functional activities and have the capacity to access knowledge to assist with decision-making (Gattorna & Hanlock, 1999:10).

Advance planning and scheduling (APS) systems does not substitute but supplement existing ERP systems. APS now takes over the planning tasks while an ERP system is still required as a transaction and execution system (Stadtler, 2000:16).

A number of companies selling ERP systems have added modelling modules (Shapiro, 2001:4). SAP has an add-on APO, Baan added CAPS and J.D. Edwards acquired Numetrix.

3.1.4.2 Advanced Planning and Scheduling (APS) systems

Unlike traditional Enterprise Resource Planning (ERP) the new Advanced Planning and Scheduling systems (APS) tries to find feasible, optimal/near optimal plans across the supply chain as a whole, while potential bottlenecks are considered explicitly (Stadtler & Kilger, 2000:2). Thus far APS is best suited for supply chains with centralized control, i.e. exercised by a focal company. (Stadtler & Kilger, 2000:318).

The key APS characteristics are that it drives an integral plan (of the entire supply chain), is based on true optimization (using optimization planning methods/heuristics) and follow hierarchical planning approach (Fleischmann, Meyr & Wagner, 2000:60). Meyr, Wagner & Rohde (2000:76) indicate that the typical APS modules include:

- Strategic network planning
- Demand planning
- Demand fulfilment and ATP
- Master planning
- Production planning and scheduling
- Distribution planning
- Transport planning
- Material requirements planning

APS systems are also used for demand fulfilment processes to improve on-time delivery by generating reliable quotes, assuring feasible quotes and scanning for more profitable orders (C. Kilger & Schneeweiss 2000:135).

APS planning modules that are typically covered by technology providers (PWC (1999a:105) are:

- Network planning
- Sales and operations planning
- Demand planning and communication
- Available to promise and capable to promise
- Distribution planning
- Manufacturing planning and scheduling
- Deployment planning
- Warehouse management
- Transportation planning and scheduling

AMR (as referenced by Murphy & Sherman, 1998: 60) states such critical and diverse functions as the following to fall under the APS umbrella:

- Supply chain network design
- Demand planning and forecasting
- Sales and operations planning
- Inventory planning
- Available to promise
- Manufacturing planning
- Distribution and transportation planning
- Production scheduling

- Shipment scheduling
- Inter company collaboration

The common thread between new users and early adopters of APS is that both are most likely to start by implementing manufacturing planning or the most significant subset, constrained master scheduling. This is purely because most of the pain, due to a poor performing supply chain, is being experienced by production ("bullwhip effect"/law of industrial dynamics)

Banker & Snitkin (2003:43) states that any company striving for operational excellence must have a model for continuous improvement. One such proven model is known as the DMAIC model, which relates to define, measure, analyse, improve and control. Figure 3.10 depicts the synergistic relationships among the model's components.

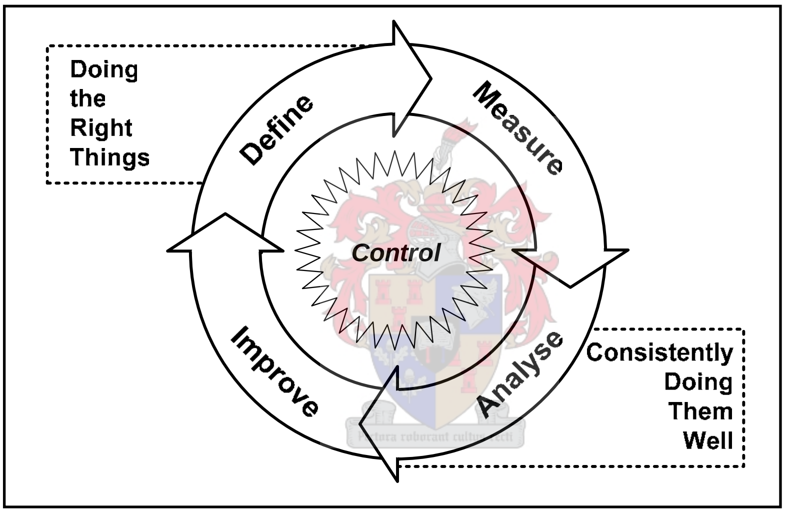


Figure 3.10 : The DMAIC Model
[Source: Banker & Snitkin, 2003:44]

Supply chain planning and execution suites largely focus on this DMAIC model's improvement and control components (Banker & Snitkin, 2003:47). The issues and solution for supply chain excellence is as indicated in Table 3.3. The solutions typically address each of the characteristics/issues to be improved in a supply chain. Although these software solutions can be individually implemented, they are also interdependent.

The applicability of APS planning modules for the different industries also varies. Table 3.4 indicates the most applicable advanced planning and scheduling (APS) functionality/modules per industry type (PWC, 1999a:108).

Table 3.3 : Operations excellence solution map.
[Banker & Snitkin, 2003:47]

Supply chain Issue	Typical software solution
Average performance *(Reflects the systems steady state behaviour)*	Production planning and scheduling Distribution planning Transportation planning Supply chain planning
Variability *(Generally reflects the lack of reliable business processes)*	Manufacturing execution Warehouse management Transportation management Order management
Responsiveness *(Handling change or unexpected events)*	Supply chain exchanges
Improvement	Supply chain process management Supply chain design Supply chain simulation

Table 3.4 : Application of APS modules
[Source: PWC, 1999a:108]

APS functionality	Batch manufacturing	Electronic assembly	Pharmaceutical	Process (Continuous)	Process (Batch)	Customer packets good	Wholesaling and distribution	Retailing
Network planning	L	L	H	H	M	M	M	M
Sales and operations planning	M	H	M	M	H	H	M	L
Demand planning and communication	L	M	M	M	M	H	H	H
Available to promise and capable to promise	M	M	M	H	H	M	L	L
Distribution planning	L	M	M	L	L	H	H	M
Manufacturing planning and scheduling	H	H	L	M	M	L	L	L
Deployment planning	L	M	H	M	M	H	M	L
Warehouse management	L	M	M	L	L	H	H	M
Transportation planning and scheduling	L	M	L	L	L	H	H	M
Key: Importance: L = Low M = Medium H = High								

3.1.4.3 Spreadsheets used as a planning system

Interestingly, spreadsheets (e.g. Excel) is the most common tool for supply chain planning. Planners successfully use it for forecasting, capacity allocation, collaboration, and even for limited finite scheduling (Supply Chain Consultants, 2003a). There is no doubt that spreadsheets are unparalleled as a personal productivity tool. However, supply chain planning is a collaborative exercise that requires data integration, communication, and the application of appropriate technology.

Some issues with spreadsheets-based tools are:

- Spreadsheets don't often have the latest data because the data updates from corporate systems are not automated or systemized
- Setting up a collaborative environment can be difficult because merging spreadsheets can break down into a manual process
- A number of complex spreadsheets are needed to represent the business problem, and these eventually collapse under their own weight
- Many of the business rules embedded in the spreadsheets are lost when a planner leaves his or her job
- Excel lacks the required optimization, simulation and/or statistical tools needed to model the business. To get around this, complex rules of thumb are embedded in the worksheet; unfortunately, these may not be relevant as business conditions change
- Formats change and considerable manual effort is required to resynchronize the spreadsheets when spreadsheets are passed from one person to another.

Supply chain planning is all about making planners more productive. This is done by giving planners good data, making sure that they are working on the right issues, and providing them with the necessary tools.

However, technology is no longer the driver in deciding whether to address initiatives in the supply chain. The critical issues are the ones that have always decided the success of sustainable improvements: organizational learning, improved processes and communication, and commitment to change.

3.1.5 Other related enabling technology

The major categories of supply chain management software are (Quinn, 1998:42):

- Advance planning software (Typically APS)
- Demand management and forecasting software
- Enterprise resource planning applications with the supply chain functionality
- Warehouse management software (WMS)
- Transportation management systems (TMS)
- Electronic commerce (internet, intranet, EDI, etc.)

Logistics data warehousing, data mining, and decision support systems are often an after-thought in the design and development of Logistics Information Systems (LIS's) (Frazelle, 2002:282). Execution systems are normally the main focus of logistics software providers and IT projects in most organizations. The focus is on automating or institutionalising logistics transactions. Unfortunately, very little thought or analysis is applied to the effectiveness or efficiency of the transactions that are being automated. The irony is that system paybacks accrue primarily from new efficiencies gained in improving, not automating tasks. The opportunities for improvement are found in data mining and the application of decision support systems.

3.1.5.1 *Data warehousing*

The problem with data is the overabundance of transactional records/data and the question of what all this data imply (Shapiro, 2001:23). Managers also do not know what the data in the company's transactional databases imply about how to integrate their activities with the supply chain activities of other managers in the company, and with those of the company's vendors and customers.

A first step in making sense of data is a data model. A data model is the method of describing the key pieces of data that must flow through a network in order to complete a business process (Hill Jr., 2000:62). Important integration issues for data are the data transfer formats/the presentation problem (ASCII, EDI, HTML, XML, etc.), the version and standard used. A common understanding of the business processes between two functions or two companies is also a prerequisite in order to send meaningful information back and forth, and to do business.

The earlier movers and evidence of data warehousing was the creation of executive information systems (EIS) with selected statistical data (Rowlands, 1996:11). Data warehousing's purpose is the storing of large amounts of related data about a business in what amounts to a central repository. Key data is captured frequently from its original source and consolidated on the parallel processing system. The aim is to capture functional data and use it for information and planning purposes.

The data for data warehousing comes from operations systems and external sources. This data needs to be extracted, cleaned, transformed and loaded into a data store. Data warehousing is the foundation for organization reporting systems, decisions support systems, executive information systems and data mining (Watson, Ariyachandra & Matyska, 2002:518).

A data warehouse is thus a subject-oriented (business entities focused), integrated (data is stored in a consistent format), time variant (data is associated with a point in time), non-volatile (data doesn't change once it gets into the warehouse) collection of data in support of management's decision making process.

3.1.5.2 *The internet*

The internet dramatically increases the velocity of information, which dramatically shortens the cycle time of supply chain processes across the board (Mulani, 2001:27).

Shapiro (2001:34) indicates that the potential of e-commerce could have a great impact on SCM. There are however a number of barriers to overcome:

(a) Multiple companies operating a virtual SC. These companies must have standardized definitions and meanings of data

(b) A virtual supply chain assumes a level of inter-company coordination that is often not achieved today among business units of the same company.

(c) Faster communication of data does not automatically lead to better decision making. A company also needs optimization modelling systems to support decision making.

3.1.6 Supply chain decision databases and information required (for supply chain planning)

According to Shapiro (2001:225) easy access to transactional data does not automatically lead to effective SCM. More than 80% of the data in transactional databases are irrelevant to decision making. Data aggregations and other analysis are needed to transform the remaining 20% of data into useful information.

Supply chain decision database should be organized according to SC structural elements (Shapiro, 2001:227). These typically include:

- Facilities
- Transportation networks
- Suppliers
- Customer demands
- Global and policy data
- Output Data (results from solutions created)

Three typical dimensions for data aggregations include SKUs (product) into product families, customers into markets, and supplier into supplier groups (Shapiro, 2001:228). The key data dimensions and categories for a supply chain decision database are the following (Shapiro, 2001:232-270):

- ***Facility data:***
    - o Types of facility
        - ▪ Manufacturing plant. Raw materials, parts, or components are physically transformed/assembled into intermediate or finished products (E.g. Process/discrete manufacturing plants)
        - ▪ Distribution centre. Products are handled but not physically transformed. (E.g. Warehouse/packaging plant)
    - o Recipes, Processes, Resources, and Costs
        - ▪ Cost classification:
            - – *Product costs.* Direct recipe costs associated with manufacturing or handling product
            - – *Process costs.* Direct costs associated with physical processes used in manufacturing and distributing products
            - – *Facility resource costs.* Indirect costs associated with resources consumed by multiple processes

        - *Facility overhead costs.* Indirect costs associated with maintaining the facility
    - Inventory
- ***Transportation network data:***
    - Inbound transportation network
    - Inter-facility transportation network
    - Outbound transportation network
    - Transportation Costs and Capacities (Flow costs and Transportation resource costs)
    - Modal Choice and Shipment Sizes
- ***Supplier data:***
    - Vendor Costs and Constraints
        - Volume Discounts
        - Reliability
        - Exchange agreements
- ***Customer data:***
        - Location
        - Demand profile and Volume required
        - Market segments and Service level requirements
        - Product Selling price
- ***Management accounting data:***
    - Causal cost relationships of direct and indirect costs
        - Cost drivers for direct cost relationships
        - Cost drivers for indirect cost relationships (activity-based costing)
    - Transfer, product, and customer costs
        - International transfer prices
        - Domestic transfer prices
        - Market-based transfer prices
- ***Global and policy data:***
    - Global resource constraints
    - Policy constraints

Throughout the process of securing data, information differentiations would require the following screening (LeMay & Wallace, 1989:6):

- Separates important from unimportant
- Separates normal from abnormal
- Separates information from noise
- Separates courses from coincidence (accident)

3.1.7 System integration

For two separate applications to share data in a seamless, “plug and play” fashion, they must share a common data model (Hill Jr., 2000:62). Systems typically require middleware (Adapters, Application Programming Interfaces (API), Enterprise Application Integrator (EAI), etc.) to assist with integration.

With the introduction of standards (e.g. EDI) data exchange has become routine (Andel, 1996:36). Today, there is no reason you should have to buy an inferior module from a vendor who provides a holistic approach to software implementation when you can buy a superior piece of that solution from another vendor.

The best rationale for system integration and enterprise-wide computing is the control of resources within processes, procedures, and tasks. This control allows built-in efficiencies that leave little room for waste and could thus contribute to measurable performance improvements (Ndede Amadi, 2004:197).

3.2 Supply chain and logistics performance

Although the prime focus of this dissertation is not on performance measures and indicators, it plays an important role in the justification of improvement interventions, as well as the quantification and sustaining of benefits.

Defining and measuring supply chain performance can be quite difficult (PRTM, 2005). On higher management levels, supply chain operations are expected to contribute to a company's financial performance. Accordingly, supply chain performance measures have three important objectives. ***Firstly***, they must translate financial objectives and targets into effective measures of operational performance. ***Secondly***, they must do the opposite—translate operational performance into more accurate predictions of future earnings or sales. ***Finally***, they must drive behaviour within the supply chain organization that supports the overall business strategy. The right set of performance measures is a sound indication of how well each core supply chain process is performing, highlight where there's room for improvement, assist in diagnosing problems and supports decisions on where to focus improvement efforts. Performance measures can also be a powerful management tool for indicating to people what's expected of them and to track progress.

Higgins & Hack (2004:4) indicate that although significant collective progress has been made in relation to supply chain performance measurement, many organizations still struggle with fundamental but complex issues. There are four major challenges:

- linking measures to strategy, budget, and compensation;
- finding the critical few meaningful measures that truly determine organizational health;
- balancing financial and other measures as well as blending leading and lagging indicators; and
- ensuring the organization is integrated and focused on strategy and goals in such a way that measurement drives desired behaviour.

Hofman (2006) also indicates that a network of the right performance measures portfolio (with performance measures that are at a level of detail that's neither too high nor too low) will allow the different areas of a company to manage its operations and clearly see the impact of an event in one part of the business on all other parts.

3.2.1 What constitutes supply chain excellence?

A truly optimized supply chain typically reveals the following (Johnson, Marsh & Tyndall, 1999:88):

- Customers are "delighted" with products and services
- Total supply chain costs and cycle times (to buy, make, move and sell the product) are at lowest and fastest possible levels
- The supply chain is contributing to profitable sales growth
- Worldwide effective tax rates are at lowest possible level
- Capital efficiency (working and fixed) is at lowest possible level
- The supply chain is able to respond to changes faster than its competitors

Successful supply chains manage the flows of product, information and funds to provide a high level of product availability to the customer while keeping the cost low (Chopra & Meindl, 2001:22).

On the other hand, one should also understand what constitutes poor supply chain performance. Bragg (2004:5&7) provides the following ten questions that focus on symptoms of poor Supply chain performance:

- Are sales, marketing, production, logistics, and suppliers working from the same demand forecast?
- Have you eliminated all re-keying of data?
- Do your delivery lead-times reflect available capacity?
- Are all your production plans mathematically 'optimised'?
- Is your part numbering consistent across every system?
- Do your key performance measures measure total SC performance?
- Do you know how much product your key customers consumed today?
- Have you consolidated and controlled transportation procurement, planning, and execution processes, and technology?
- If a process breaks, does the responsible manager discover the problem that day?
- Does your pricing dynamically depend on capacity utilisation, competitors' actions, and the individual customer?

Successful organizations are marked by good planning, execution, and decision making in terms of corrective action and adjustments to strategic efforts. These actions stem from a strong measurement system (Higgins & Hack, 2004:8).

Practices that assure success require supply chains to tie into a company's competitive strategy, operating model, and performance objectives (Lapide, 2005:29-30). These practices themselves must also fit together. Excellent supply chain has the following four characteristics:

- Support, enhance, and be an integral part of a company's competitive business strategy
- Leverage a distinctive supply chain operating model to sustain a competitive edge
- Execute well against a balanced set of competitive operational performance objectives (That is, one in which all customer-facing and internal Key Performance Indicators or KPIs are aligned to achieve the competitive positioning desired—e.g., to support a lowest cost, highest quality, or fastest delivery strategy)
- Focus on a limited number of tailored business practices that reinforce each other to support the operating model and best achieve the operational objectives (For example, a few truly innovative practices—such as customer segmentation and demand shaping —that are surgically-focused on achieving KPI targets)

3.2.1.1 Measuring principles

According to Hofman (2004:1-5), effective performance measurement remains a challenge. There are an abundance of possible performance measures to choose from that can be used for measuring the operational performance of a supply chain. The key is to focus on the few critical performance measures that really matter and to understand the interdependencies among theses performance measures. Simply indiscriminately adding performance measures into the pot is not the answer. A multilevel approach that allows increasing granularity of focus is needed. The hierarchy of supply chain performance measures, as illustrated in Figure 3.11, distinguishes between the following three tiers to put the right focus on the various levels:

***Top tier*:** Supply chain health assessment.

(*Typically performance measures:* Demand forecast accuracy (DFA), perfect order fulfilment, and supply chain management (SCM) total cost)

Mid-level: Supply chain diagnostic.

(*Typically performance measures:* Overall customer responsiveness and cash-to-cash performance measures)

Ground level: Supply chain operational effectiveness.

(Basis for root cause analysis and identifying corrective action)

(*Typically performance measures:* percentage of supplier receipts that passed quality, on-time standards, the raw material inventories, purchasing operating costs, and direct material costs)

The two fundamental principles of supply chain management are to define/measure and then drive performance improvement (Bolstorff & Rosenbaum, 2003:xvii).The work related to a SCOR implementation project also indicate the following:

"If you can define your supply chain, then you can measure it,"

> *"Once you've measured it, you'll find the opportunities are so big that you won't need any more motivation. You'll want to drive continuous improvement in your supply chain."*

Frazelle (2002:38) stated that *"people behave based on the way they are measured"*. This reiterates the well-known principle of *"What gets measured gets improved"*.

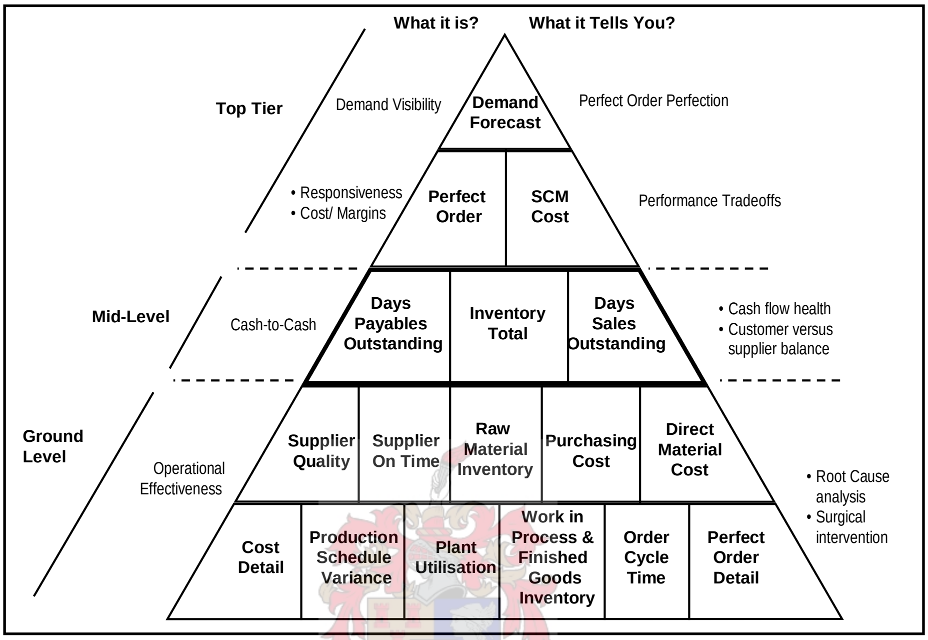


Figure 3.11 : Hierarchy of supply chain performance measures (metrics)
[Source: Hofman, 2004:5]

According to Bowersox (1974:32) to facilitate logistical performance (transportation, inventory, warehousing, material movement, and communication) coordination must occur on three levels:

- within the over-all logistical system;
- within the enterprise in consideration of marketing, manufacturing, and finance; and
- within the competitive environment faced by the total enterprise.

In supply chain management the emphasis is on how well a group of companies perform in terms of creating value for the customer (Brewer & Speh, 2001:48). Both the function-wide performance measures and the specific activity-focused measures are important in tracking and controlling how well the system is performing and how effective managers are in executing their key functional responsibilities. The performance measurement philosophy needs to change in 3 ways:

- Companies in the supply chain must work collaboratively
- In the supply chain environment, both companies and individual managers must be motivated to work in collaboration with supply chain partners. The performance measurement process must be structured to provide incentives for collaborative behaviour.

- Each company in the supply chain, regardless of how far upstream it may be, needs to focus on the satisfaction and ultimate cost of serving the final customer.

Companies should measure the performance of the supply chain and the corporation as a whole and assure top-down, bottom-up alignment (Krenek, 1997:100, Higgins & Hack, 2004:43). This typically means that ***executives*** should focus on strategic objective and their associated critical success factors (CSFs) and measures. ***Middle management*** should focus on process and functional objectives. ***Lower management*** should focus on contributor objectives and their associated CSFs and measures (refer to Figure 3.12).

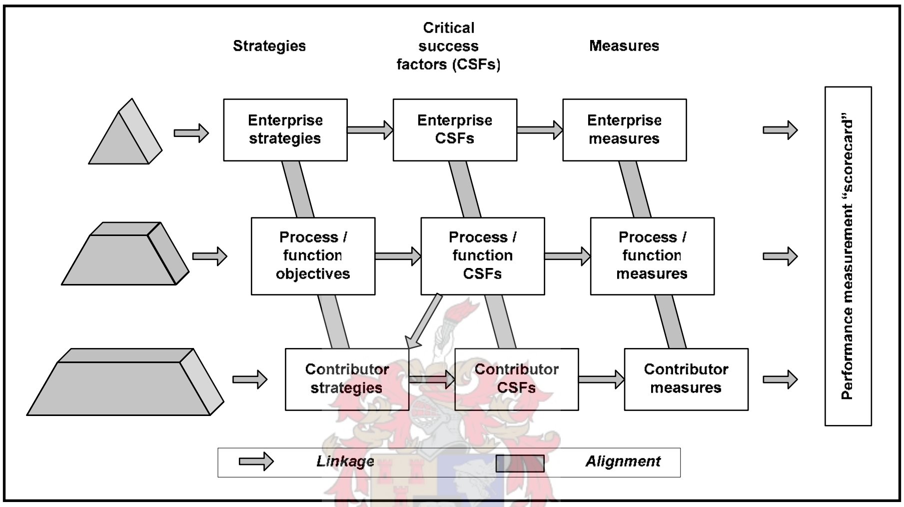


Figure 3.12 : Performance measurement process
[Source: Krenek, 1997:100]

PRTM (2005) provide the following performance management principles:

- o Set aggressive but achievable targets—and tie them to actions.
- o Ensure the selected performance measures are both balanced and comprehensive.
- o Implement a robust infrastructure for ongoing data collection and performance monitoring.

A good measurement strategy outlines a vision of a company's ultimate destination from a measurement perspective (Hofman, Hagerty & Stiffler, 2005). This includes a plan to get there, the necessary change management activities, and the enabling technology to make it repeatable. A measurement strategy encompasses three simple steps to performance improvement:

- o Why? Identify goals
- o What? Define performance measures hierarchy
- o How? Implement and sustain for repeatability

3.2.1.2 Drivers and enablers of performance

The driver of supply chain performance is to balance efficiency and responsiveness continually (Chopra & Meindl, 2001:50). The following elements of a supply chain can be manipulated to evaluate the trade-off:

- ***Inventory*** (more inventory lead to better responsiveness but lower efficiency)
- ***Transportation*** (lower cost modes are more efficient; faster modes are more responsive but less cost efficient)
- ***Facilities*** (the cost of number, size, location of facilities v/s responsiveness)
- ***Information*** (better information can lead to better decisions, making the supply chain more efficient)

According to O'Marah & Hofman (2004:4) "enablers" impact business performance and is typically measured by supply chain performance "indicators". Some of these enablers are shown in Figure 3.13 and fall in the three broad categories of application technology, best practices and e-business capabilities. Enablers are applied to a supply chain's operational environment and result in Operational Performance. Any company should also realise that a specific performance indicator does not stand on its own (there is a cause and effect relationship). There are interrelationship between the various indicators and enablers that ultimately drives supply chain excellence.

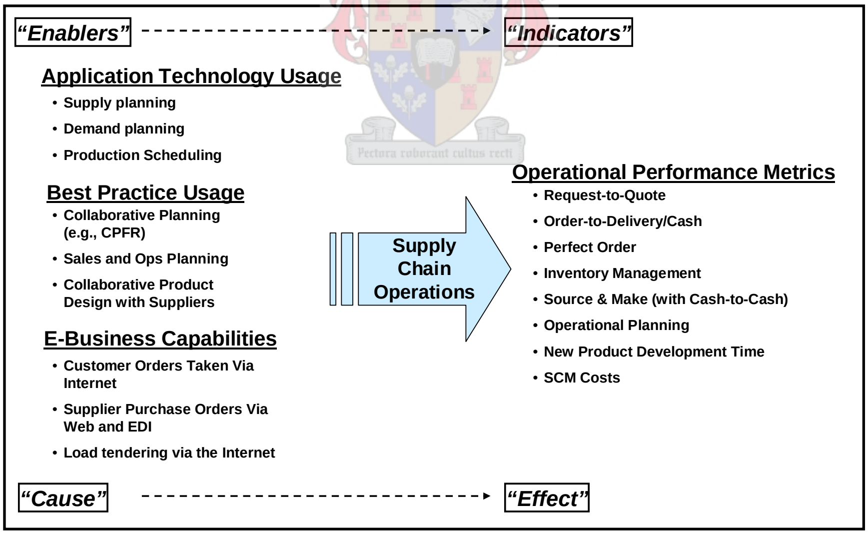


Figure 3.13 : Typical performance enablers and indicators
[Source: O'Marah & Hofman, 2004:4]

3.2.2 Identification of performance indicators

Bowersox (1974:28) already indicated in the mid 70's that the dominate question to corporate logistics is related to delivery performance, and total cost expenditure. The trade-off between service and cost is still as valid as then and remains the ultimate test for relevance to the identified performance indicators in the drive for reaching supply chain excellence (Hofman, 2004:13).

3.2.2.1 Meaningful performance measures

Identifying **logistics performance indicators** requires a typical four step process (Christopher, 1998a:123). The process is aimed at getting things done better, faster, cheaper.

Step one: Articulate logistics and supply chain strategy
Step two: What are measurable outcomes of success
Step three: What are the processes that impact the outcome
Step four: What are the drivers of performance within these processes

Not all performance measures are applicable for a specific supply chain (Higgins & Hack, 2004:16). Potential measures should be assessed for:

- ***relevancy***—is worth collecting and answers a question to support decision making,
- ***validity***—measures what it claims to measure,
- ***reliability***—returns consistent value with each measurement,
- ***accuracy***—matches the true value of the attribute, and
- ***cost effectiveness***—is not too costly to track and report.

Logistics performance measures are quantitative measurements that track certain processes within a company's logistics framework. Some of the key issues in using logistics performance measures are: the criteria for performance measures (must be easy to understand), units of measure, reporting and understanding the drivers of the measures. Based on this a company could use the following steps to design logistics performance measures (Kasilingam, 1998:214):

- Define a system that needs to be measured
- Determine the functional requirements/expectations of the system
- Identify performance measures that can quantitatively measure the functional requirements

The following ten criteria are also an efficient guide for identifying meaningful performance measures (Whalen, 2002:35):

- Is quantitative. The measure can be expressed as an objective venue
- Is easy to understand. The measure conveys at a glance what it is measuring and how it is derived
- Encourages appropriate behaviour. The measure is balanced to reward productive behaviour and discourage "game playing"
- Is visible. The effects of the measure are readily apparent to all involved in the process being measured
- Is defined and mutually understood. The measure has been defined by and/or agreed to by all the key process participants (internally and externally)

- Encompasses both outputs and inputs. The measure integrates factors from all aspects of the process measured
- Measures only what is important. The measure focuses on key performance indicators that are of real value to managing the process
- Is multidimensional. The measure is probably balanced between utilization, productivity and performance and shows the trade-offs.
- Uses economies of effort. The benefits of the measure outweighs the cost of collecting and analysis
- Facilitates trust. The measurement validates the participation amongst the various parties

According to Contrada (as referenced by Higgins & Hack, 2004:24), when selecting a critical few measures, organizations must be cognizant of the need for two primary factors. One is a balance of ***financial*** and ***non-financial*** indicators, and the other is a balance of ***leading***, ***current***, and ***lagging*** indicators. Too frequently scorecards are dominated by financial and lagging measures; this leaves a rear view look at what happened last month or in previous months but no way to understand why, or predict what needs to change in the future. Measures must identify what levers to pull when the outcomes they are reflecting are not producing the desired results.

3.2.2.2 Balanced scorecard

The balanced scorecard, developed by Kaplan and Norton, has created enormous interest in recent years. It is based on the idea that managers have to evaluate their business from at least four major perspectives: customers, internal business, innovation and learning, and financial. The performance measures developed to monitor these four perspectives should answer the following questions: (Miller, 2001:224)

- How do customers view a firm?
- What business processes must the firm improve and exceed at?
- Can the firm continue to learn, improve, and thereby create value?
- How does the firm appear to its shareholders?

Measures should be reflected in a balanced, cascading scorecard (Higgins & Hack, 2004:10). A balanced scorecard helps to align measures with key strategies, enable progress tracking, assign accountability, capture gains already made, predict future movement, and connect current strategic and tactical improvement activities. Organizations can achieve this balance by establishing measures in four quadrants that reflect key objectives.

- ***Customers***—measures performance against expectations (e.g., satisfaction, loyalty, retention, acquisition, and profitability)

- ***Financial***—measures economic consequences of actions already taken (e.g., income, return on equity, return on investment, growth, and cash flow) and predicts future performance
- ***Operational***—measures effectiveness, adaptability, and efficiency of internal processes (Such measures may identify a need for new processes.)
- ***People***—measures employee skills, information exchange, and organizational procedure

The balance scorecard is designed to achieve a balance between financial and non financial performance across long and short term horizons (Brewer & Speh, 2001:49). It moderates the tendency to overemphasize financial performance (lag indicator) by including measures related to the underlying drivers of long-run profitability. (Namely business process measures, innovation and learning in measures, and customer-satisfaction measures).

The principles of supply chain management readily dovetail with the balanced scorecard framework (Brewer & Speh, 2001:52): As indicated in Table 3.5 (in more detail) the following supply chain issues relate to the four perspectives of the balance scorecard:

SCM goals	*relates to*	Business process perspective
Customer benefits	*relates to*	Customer perspective
Financial benefits	*relates to*	Financial perspective
SCM Improvement	*relates to*	Innovation and learning perspective

A number of tactics exist for adopting a supply chain balanced scorecard (Brewer & Speh, 2001:56). It is important to ensure that each supply chain partner is managing its portion of this supply chain in a cross functional manner. Don’t even bother investing time and political capital in balanced scorecard initiative if senior management does not wholeheartedly support it. Begin the process of formulating a supply chain balanced scoreboard by thinking small. Think small in terms of the number of measures initially adopted. Remember that the participants are operating largely in uncharted waters (approach it as a learning process).

The hurdles to overcome in applying balanced scorecard for supply chain management include (Brewer & Speh, 2001:53): overcoming mistrust, lack of understanding, lack of control, different goals and objectives, information systems, lack of standardized performance measures, difficulty in linking measures to customer value, and deciding where to begin.

Table 3.5 : Linking supply chain management to the balance Scorecard
[Source: Brewer & Speh, 2001:52]

Supply Chain Management	Balanced Scorecard
SCM goals: Waste reduction Time compression Flexible response Unit cost reduction	**Business process perspective**
Customer benefits: Improve product/service quality Improved timeliness Improved flexibility Improved value	**Customer perspective**
Financial benefits: Higher profit margins Improved cash flows Revenue growth Higher return on assets	**Financial perspective**
SCM Improvement: Provide/process innovation Partnership management Information flows Threats/substitutes	**Innovation and learning perspective**

3.2.3 Performance measures (metrics)

Supply chain performance measures are similar to budgets in that they set standards or incentives for superior managerial behaviour within the firm. (Shapiro, 2001:249). Performance measures should typically focus on:

Utilization (actual input/norm input); e.g. machine hours used/machine capacity
Productivity (actual output/actual input); e.g. ton-miles delivered/costs incurred
Effectiveness (actual output/norm output); e.g. on-time shipments/total shipments

3.2.3.1 Measurement Categories

Fawcett and Cooper (as referenced by Miller, 2001:221) provide the following common logistics performance measurement categories and some examples:

- Asset management: Capacity utilization, return on investment
- Cost: Cost per hundredweight, transportation cost per unit
- Customer Service: Average transit time, transit time variability
- Productivity: Orders delivered per vehicle, full versus partial loads
- Quality: Damage in transit, documentation accuracy

Key considerations for logistics performance measurement are the importance to recognize that logistics performance should be measured across all echelons of a supply chain. Miller (2001:223) indicate that the complexity and potential dimensions of a supply chain performance measurement system have increased rapidly in recent years as networks and companies have become truly global.

Performance measures can also be categorized according to the competitive and logistics process measures supplied by Frazelle, (2002:40). Detail of each of these measure categories is:

- ***Competitive Measures***
  - Financial Measures,
  - Productivity Measures,
  - Quality Measures, and
  - Cycle Time Measures.
- ***Logistics Process***
  - Customer response (CR),
  - Inventory planning and management (IP&M),
  - Supply,
  - Transportation and distribution (T&D), and
  - Warehousing or DC operations (DCO).

Key logistics performance indicators should be concentrated on those aspects that are of key importance to a business. Wainwright (1991:2) indicates that these indicators can typically be categorised into customer service, productivity and cost.

3.2.3.2 Relevant key performance indicators for SCM

Most standardized units of measure were agreed upon centuries ago (Gardner, Harrity, & Vitasek, 2005:20). For instance, businesses have long been speaking a common financial language. But factories, distribution centres (DCs), and logistics facilities have few shared terms for crucial operating measures. APQC and CSCMP narrowed down to 150 performance measures spread across the following five critical process areas and functions: new-product development, procurement, customer order management, manufacturing, and logistics. Of these, they recommend a management dashboard that contains the top 20 key performance indicators. These "top 20" key performance indicators are the following:

Logistics

Customer-order cycle time in days
Order-fill rate

Manufacturing

Asset turns
Inventory days of supply
Inventory obsolescence as a % of the total number of products sold
Percentage of defective parts per million

Procurement

Days payable
Dependency on top 10 suppliers

New-product Development

Percentage of sales due to product/services development projects
Time to market in days for new-product/service development projects

Percentage of new-product/service developments launched on time

Percentage of new-product/service developments launched on budget

Customer Order Management

Key customer profitability

Market share

Total supply chain management cost as % of revenue

Supply Chain Diagnostics

Annual total inventory turn rate

Cash-to-cash cycle time

Return on assets

Value-add productivity per employee

Demers & Sathyanarayanan (2003:53) indicated the following three key measures for SC success:

- Order-to-delivery cycle (predictability and response time)
- Cash-to-cash velocity
- Revenue and margin contribution

A useful ***inventory management*** performance measure relate to inventory turnover ratio. This is the ration annual sales/average inventory level (Shapiro, 2001:477 and D. Simchi-Levi, Kamisnsky & E. Simchi-Levi, 2000:64).

Typical ***logistics cost*** can also be summarized under the related categories, considerations, and relationship of logistics activities from production to consumption (Daganzo, 1999:18). These key logistics activities relate to:

- carried (handled) from the production area to a storage area
- held in this area with other items, where they wait for a transportation vehicle
- loaded into a transportation vehicle
- transported to the destination
- unloaded, handled, and held for consumption at the destination.

Daganzo (1999:18) also indicate that the typical logistics costs associated with motion and holding (showing some typical considerations) are the following:

- Costs related to "***motion***" (i.e., overcoming distance)
    - Handling costs
        - Motion Cost
        - Lot-size trade-off with handling cost
    - Transportation costs
        - Relationship to headway
        - Relationship to Distance
        - Relationship to Size; Capacity Restrictions
        - Relationship to Size; Multiple Transportation Modes

- Cost related to "***holding***" (i.e., overcoming time).
    - "*rent*" costs (Cost for Space/Facilities)
        - Machinery/Equipment needed to store the items in place, plus
        - Any maintenance costs (such as security, utilities, etc.) directly related to the provision of storage space.
    - "*waiting*" costs (cost of delay to the items)
        - The opportunity cost of the capital tied up in storage
        - Any value lost while waiting, etc.

Capital efficiency is another important measure for supply chain performance (Johnson, Marsh & Tyndall, 1999:82). The balance sheet reveals fixed capital efficiency and working capital efficiency through performance measures such as:

- Fixed asset turnover
- Accounts receivable days of sales outstanding (DSO)
- Inventory turns
- Accounts payable days of purchases outstanding (DPO)

The logistics mission for a business or business unit can be defined in terms of the type of market served, by which products and within what constraints of service and cost (Christopher, 1998a:75). Using logistics performance measures, typical comparisons (and the contribution by each) can be made between the following:

- Logistics and Return on Investment (ROI) (refer to Figure 3.14)
- Logistics and the balance sheet (refer to Figure 3.15)
- Logistics and Economic Value Added (EVA)
- Logistics and customer profitability

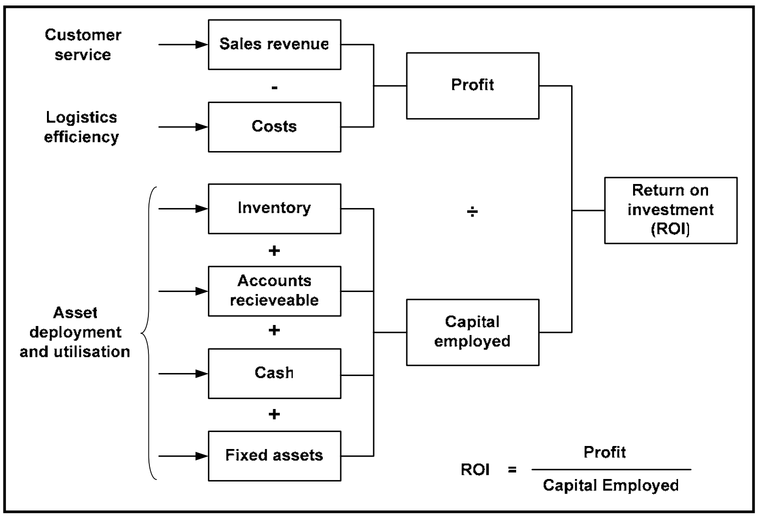


Figure 3.14 : Logistics Impact on ROI

[Source: Christopher, 1998a:79]

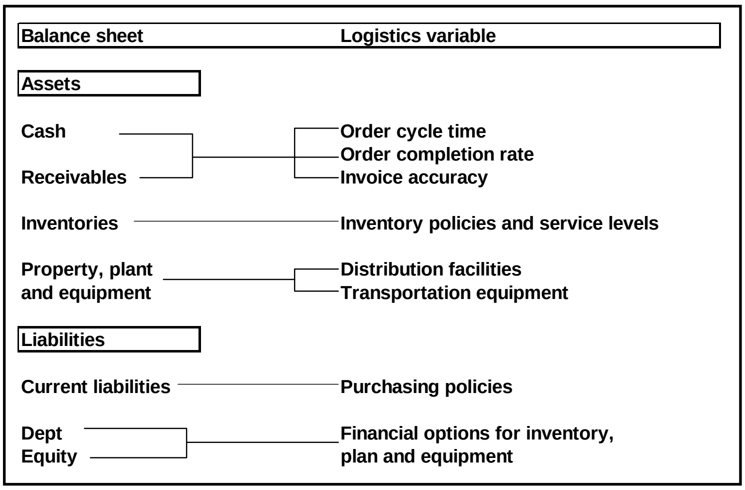


Figure 3.15 : Logistics and the balance sheet
[Source: Christopher, 1998a:81]

3.2.3.3 Supply Chain Operations Reference-Model (SCOR) performance measures

As indicated in par 2.1.2.1 the supply chain council defined the five major supply chain processes; plan, source, make, deliver and return. Apart from being a reference model for defining a supply chain, these four processes provide the basis for benchmarking one company's supply chain with another. The integrated supply chain performance measures framework focus on metric type, outcomes, and diagnostics to be used (Christopher, 1998a:106). The performance measures are typically focused on customer satisfaction/quality, time, costs and assets. Different levels (one to three) of performance measures are also used with Level 1 typically being the basis for a performance dashboard.

The SCOR performance measures falls into two major dimensions of customer facing and internal facing performance measures (Supply-Chain Council, 2005:8). The performance attributes or categories and the first level performance measures are as indicated in Table 3.6. Level two and three performance measures form the hierarchy of more detailed performance measures.

The SCOR model provides companies with a performance measures basis to conduct supply chain benchmarking (providing a common language and performance measures definition for standardisation). Companies like The Performance Measurement Group (PMG) typically conduct quantitative and qualitative benchmarking services based on these performance measures (The Performance Measurement Group, 2006). Table 3.7 provides a summarised view of these typical performance measures used per major category.

Table 3.6 : SCOR level one performance measures (slightly modified)
[Source: Supply-Chain Council. 2005:8]

Performance Dimension	Performance Attributes	Level 1 performance measures
Customer-Facing	Reliability	Perfect Order Fulfilment
	Responsiveness	Order Fulfilment Cycle Time
	Flexibility	Upside Supply Chain Flexibility
		Upside Supply Chain Adaptability
		Downside Supply Chain Adaptability
Internal-Facing	Costs	Supply Chain Management Cost
		Cost of Goods Sold
	Assets	Cash-To-Cash Cycle Time
		Return on Supply Chain Fixed Assets

Table 3.7 : A comprehensive set of performance measures
[Source: The Performance Measurement Group, 2006]

Delivery Performance (%)
- Scheduled Order to Customer Request
- Delivery Performance to Request Date
- Delivery Performance to Commit Date
- Fill Rate for Ship-From-Stock Products Lines/Orders
- Perfect Order Fulfillment to Delivery

Order Fulfillment Lead Time Metric (Days)
OFLT Metrics Depend on Manufacturing Strategy, but may include:
- Lead Time from Customer Signature to Order Receipt
- Lead Time from Order Receipt to Order Entry Complete
- Lead Time from Entry Complete to Start Manufacture
- Lead Time from Start Manufacture to Complete Manufacture
- Lead Time from Complete Manufacture to Customer Receipt
- Lead Time from Customer Receipt to Installation Complete
- Total Order Lead Time

Total Supply Chain Cost Metrics
May be shown as % of Revenue and/or % of COGS
- Order Management Cost*
- Material Acquisition Cost*
- Inventory Carrying Cost*
- Supply Chain Related Finance and Planning Cost*
- Supply Chain Related IT Cost*
- Total Supply Chain Management Costs

Financial Metrics
- COGS as a % of Revenue
- Year over Year Change in COGS
- Profitability (EBIT) as a % of Revenue
- Expenses (SG&A) as a % of Revenue
- Sales Growth (1 Year)
- Net Asset Turns

Value Added Productivity
- Value Added Productivity per Employee
- Value Added Productivity per Payroll dollar

Upside Production Flexibility
- Key Production Flexibility: Principle Constraint
- Key Components or Material Availability
- Direct Labor Availability
- Internal Manufacturing Capacity

Cash-to-Cash Time Component Metrics
- Days Sales Outstanding
- Average Payment Period for Production Materials (Days)
- Total Inventory Days of Supply: Raw Materials
- Inventory Days of Supply: WIP
- Inventory Days of Supply: Plant Finished Goods
- Inventory Days of Supply: Field Finished Goods
- Inventory Turns
- Cash-to-Cash Cycle Time (Days)

Materials Planning Metrics
- Unit/Dollar Forecast Accuracy
- Capacity Utilization
- Schedule Accuracy
- Supply Chain Related Planning Costs

Response Time
- Forecast Cycle Time
- Re-plan Cycle Time
- Intra Manufacturing Re-Plan Cycle Time
- Total Source Lead Time
- Release-to-Ship-Time
- Total Cumulative Source Make Cycle Time

Returns
- Return Costs
- Return Lead Times
- Return Inventory Status
- Total Return Costs

* Level 2 metrics; Level 3 metric percentage breakdowns also available

The SCOR model also provides the following level two performance measures that are applicable for the "Plan the supply chain" process (Meyr et al., 2000:43):

- Reliability
  - Forecast accuracy
  - Delivery to customer request date
  - Fill rate
  - Product and process data accuracy
- Flexibility and responsiveness
  - Cumulative source/make delivery time
  - Re-plan cycle time
  - Cash-to-cash cycle time
- Cost
  - Total order management costs

- o Delivery/source planning cost
- o Inventory carrying costs
- o Value-added productivity
- o Obsolete inventory
- Assets
  - o Return on assets
  - o Capacity utilization
  - o Total inventory days of supply

3.2.4 Supply chain improvement opportunities

The supply chain typically represents 60% - 80% of a manufacturer's cost structure. A 10 percent reduction in supply chain costs can bring about a 40% - 50% improvement in before tax profits (AT Kearney, 1997:7). Ribbers (1994:26) indicates that a properly designed logistics system can reduce the level of both a fixed asset and working capital. This is possible through rationalising production, warehousing, distribution centres and transportation.

Superior supply chain management can result in substantial benefits to any company due to the integrated and horizontal management approach. The benefits typically fall into the following four categories (IBM, 1999:25):

Cost reduction. These benefits are readily apparent, easily identified, easily quantified, and easily tracked. Typical benefit areas: stock reduction, materials and MRO prize reductions, transactional cost reduction, logistics cost reduction, warehouse space reduction, supplier optimization.

Cost avoidance. These benefits are readily apparent, easily identified, but hard to quantify and hard to track. Typical benefits areas: duplicated efforts, resource utilization, cross-skilling, exchange rate fluctuations.

Revenue enhancement. These benefits are readily apparent, but hard to identify, hard to quantify, and hard to track. Typical benefits areas: increased sales, reduced churn.

Asset utilization. These benefits are readily apparent, easily identified, but complex to quantify and complex to track. Typical benefits areas: Working capital reduction, improved asset utilization.

Youngblood (as referenced by Hunt, 1996:5) established a number of ways to improvement business processes. The following is a sample of these improvement possibilities:

- Eliminate duplicate activities
- Combine related activities
- Eliminate multiple reviews and approvals
- Eliminate inspections
- Simplify processes

- Reduce batch sizes
- Process in parallel
- Implement demand pull
- Outsource inefficient activities
- Eliminate movement of work
- Organize multifunctional teams
- Design cellular workplaces
- Centralize/decentralize

3.2.5 Benefits from Advanced Planning and Scheduling (APS) systems application in SCM

As a business becomes larger and more complex, it becomes increasingly difficult to control costs and meet ever-higher expectations for customer service (Supply Chain Consultants, 2004:3). Cost reduction and customer service improvements are the primary drivers for adopting supply chain planning (SCP). SCP benefits come from two sources:

- A shift to a broader perspective from a local, silo oriented one.
- Analysis such as what-if's and optimization that improve the quality of decisions.

Companies buy SCM software to get a handle on the five elements of working capital, inventories reduction, compressing of supply and demand, lost and waste factors and transportation (especially crucial for manufacturers of paper, plastics, and metals) (Kelly, 2002:77).

It is important to understand that benefits from advance planning and scheduling systems never come from neither software or IT alone (Hunter, 2005:9). Other key enablers include best business processes, motivated and skilled staff and the right supply chain values (the intangibles), are just as important. The benefits can be split into *Quantitative*, and *Qualitative:*

QUANTITATIVE

- Forecast accuracy: increased from 40 to 80%
- Delivery performance: increased from 70 to 90%
- Inventory reduction: improvement varies between 13% and 53% in pipeline, average 25%
- Planning lead time: reduced from four weeks to one week, ten days to three days, average 60%
- Production adherence to plan: increased from 43 to 82%
- Stock outs: reduced by 5%
- Sales due to reduced stock outs and stock in the right place: increased 5%

QUALITATIVE

- Increased certainty from improved demand forecasting (with improved accuracy) helps to reduce required stock cover, or increase service levels with the existing stock cover
- Matching stock cover optimally to product characteristics (predictability, replenishment time, value to the business, etc) makes best use of inventory
- Collaborative input such as market intelligence and amendments to plans from key supply chain players, keeps supply chains in-sync and adaptable, hence less stock is required to buffer the traditional disconnects, for example, supplier to manufacturer, production to distribution, etc.
- Ability to plan where to keep stock, DC or depot or both and to perform multiple sourcing and "fair share" distribution
- Improved vehicle utilization due to better load planning
- Ability to give access to relevant plans to transport operators
- Ability to use IT to drive alert processing to drive management by exception through the supply chain
- Visibility of demand and stock through the supply chain due to integrated planning,, execution and coordination (tracking) systems
- The ability to make best use of proactive exception management

The direct benefits achievable for APS system implementations are (PWC, 1999a:99):

- Increased sales through better service (2-15%)
- Reduced inventory (20-70%)
- Reduced cost (12%)
- Reduced capital (15%)

PWC (1999a:99) also indicate that apart from the direct benefits achievable for APS system implementations, there are also the following related benefits:

- Facilitates fundamental changes in organization from functional based to process driven
- Improve customer service at lower total cost
- Improve production throughput
- Allow demand driven synchronization
- Key enabler for efficient customer response
- Improves advisable to promise (ATP) and capable to promise (CTP) and real time reservation
- Better handling of unplanned emergency orders
- Reduction in error costs (Enabled by local level of work in progress)
- Leverage the planner's knowledge to make better decisions
- Faster adaptation to changing customer requirements

According to Langemann (2002:5) the following are general benefits that could materialize from adopting an SCM approach and using APS technology:

- Planning cycle from monthly to weekly
- Manufacturing cycle time 40% down
- ROI after 1 year 113%
- Inventory Level down 30%
- Transportation cost down 10%
- Inventory turnover up 60%
- Supply Chain costs down 40%
- Delivery promise reliability up 20%

The ability to truly articulate the benefits of APS has long been debated. By evaluating a company's "ability to manage complexity", both qualitative and quantitative benefits need to be assessed and play a role in the justification of advanced planning and scheduling enabling technology (Sasol Logistics, 2002b:29). Figure 3.16 indicates that the qualitative benefits don't necessarily directly reduce the total cost of an enabling technology but contributes to the ability to manage system complexity. The quantitative benefits contribute by reducing the total cost of the system and add business benefit (objective).

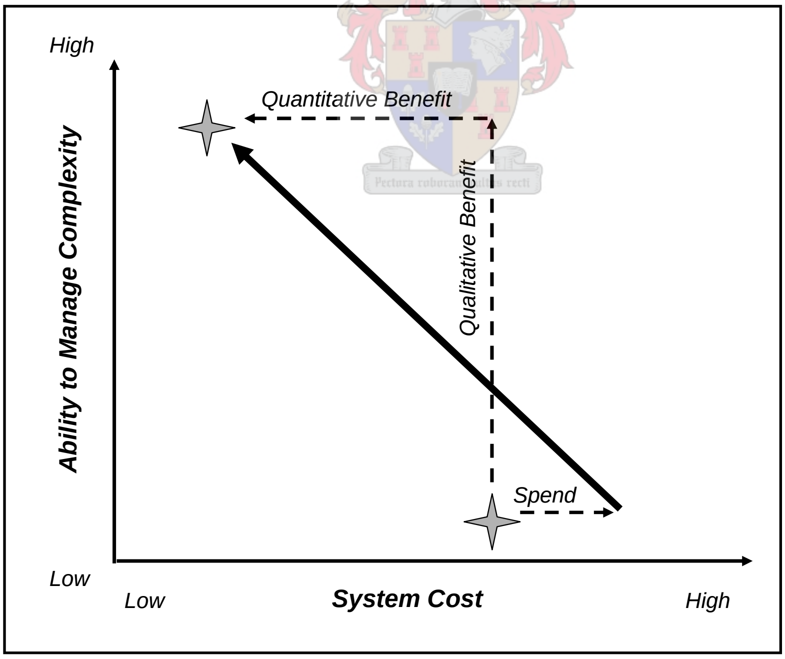


Figure 3.16 : Cost of system complexity
[Source: Sasol Logistics, 2002b:29]

3.3 Roadmaps and strategy for intervention

The benefits indicated in paragraph 3.2.5 are neither achievable nor sustainable if there is not a sound approach and adequate planning done for specific interventions.

To sustain the benefits, a process must also exist to manage and monitor the benefits continually.

3.3.1 Approach, process and planning for an intervention

Any company should carefully plan interventions related to a process approach in managing the company and using enabling technology for decision support. For this a framework and programme roadmap must be tailored to suit the business specific realities and challenges.

Programmes and projects differ substantially from one another. A programme is driven by a vision which polarises the way of thinking. A programme is also perpetual in nature and move across boundaries (Beesly, 1995:17). On the other hand, a project has a key objective, with a beginning and an end set across a defined area of scope. Although programmes and projects differ in their approach, both are needed and must be used correctly to reach intended objectives.

The typical supply chain innovation life cycle goes through a number of major focuses as indicated in Figure 3.17. (Demers & Sathyanarayanan, 2003:50). The integrated operating systems model is spearheaded by two strategic shifts. Firstly is the recognition that supply chain velocity is fundamental to performance, efficiency and competitive differentiation. Secondly is the shift in understanding and application of systems thinking in the transformation of supply chain models (more holistic view). Supply chain models are engineered with four critical "DNA" building blocks in mind; process, information, cash and organization (PICO). Major focuses in the innovation life cycle are:

- **Drive** for continuous improvement
- Use performance measures and **diagnostics** to analyze and select appropriate DNA building blocks
- **Configure** and design a DNA solution pattern
- **Assemble** / **re-assemble** solution into an integrated supply operating system

Using the collaborative planning forecasting and replenishment (CPFR) approach as basis (as described in paragraph 2.2.3.2 a), Loshe & Ranch (2001:62) has established the following change process:

Phase 1: Establish the ground rules, core performance measures, and the value-add proposition

Phase 2: Communicate the vision repeatedly to cross-functional business teams

Phase 3: Emphasize the Core CPFR Process approach to customer and business channels

Phase 4: Systematically integrate CPFR into the existing S&OP process and explore the automation potential of electronic and web-based communication.

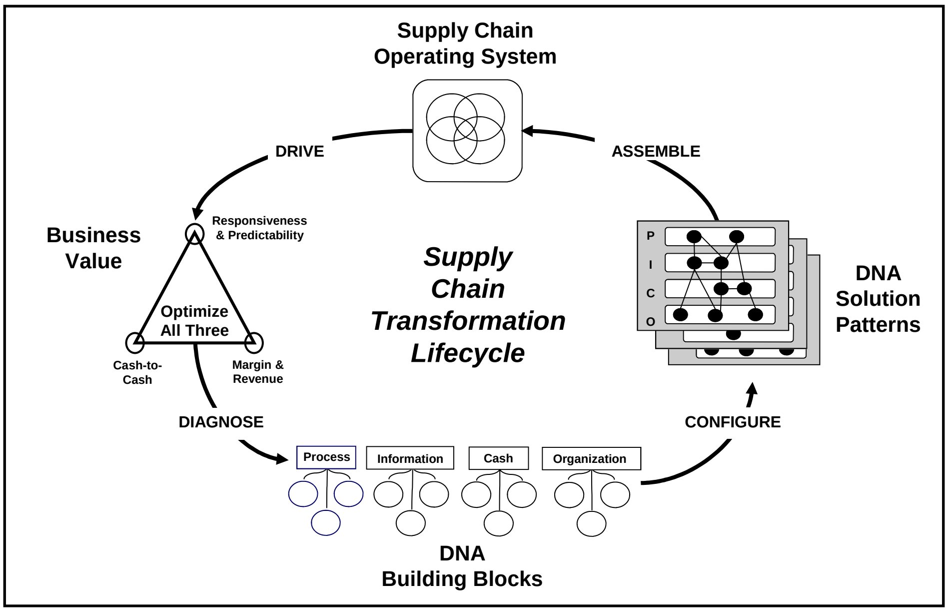


Figure 3.17 : Supply chain innovation/transformation lifecycle
[Source: Slightly modified from Demers & Sathyanarayanan, 2003:50]

3.3.1.1 Planning for interventions and transformation

Planning and carrying out successful process investments require some essential principles for ensuring economically sound investment (Keen, 1997:159). These principles are based on the following (also relate to explanations in par 2.1.1.2):

- Take a broad view of processes and process investment
- Be open-minded and imaginative about the salience of processes
- Think “process worth” and EVA
- Protect "identity asset processes"
- Continually improve "priority asset processes"
- Outsource "background and mandated processes (liabilities)"
- Get the whole organization on board
- Remember that meaningful change takes time

Demers & Sathyanarayanan (2003:54) indicate that a transformation roadmap should be clarified upfront and could consist of the following.

- Organization and running of innovation concurrently across the areas of process, information, cash, and organization.
- Benchmarking against the competition is an effective way to determine relative ranking. Collaborate proactively amongst all strategic partners.
- Understand the issues with the current SC “model".
- Prioritize the critical building blocks based on their contribution to performance, the logical sequence of implementation and ease of implementation.
- Design solution patterns (Balance quick-win opportunities with a systematic long-term investment)

- Create a time-faced roadmap that provides continuous releases of business values in short time frames (e.g. quarterly).
- Ensure ongoing organizational alignment by creating a senior leadership forum/steering team supported by a program management office.

Marien (2000:63) also provide the following SCM process-improvement phases and nine step process improvement plan:

- ***Mobilize***
  - (1) Identify corporate vision, mission, leadership
- ***Analyze***
  - (2) Define SCM mission, vision, and identify improvement opportunities
  - (3) Establish SCM performance requirements
  - (4) Establish process for implementing SCM improvements
  - (5) Select SCM process for improvement
- ***Redesign***
  - (6) Redesign SCM process(es) and address enables
  - (7) Select trading partners and allied services to implement
- ***Implement***
  - (8) Implement pilot, report on results and roll out full implementation plan
- ***Realize***
  - (9) Monitor for performance

Typical first up actions for process transformation could include the following (Easton, Brown & Armitage, 1998:453):

- Align cultures with strategic response
- Appoint a process owner
- Reshape performance measures
- Develop and train the workforce
- Communicate and demonstrate top management commitment
- Involve stakeholders and gain commitment to change
- Implement a system to track benefits
- Communicate with all stakeholders
- Create an integration map

Cates & DeRuiter (1999:65) provide an approach to ensure that the supply chain initiative focus on the right problems in order to achieve the improvements on the bottom line. A typical approach to follow is:

- Understand your starting point
- Go internal before external
- Define opportunities carefully (go to the root of the problem)
- Define processes and data requirements (unique process requirements often have an impact on the systems of choice; this is an essential step before selecting systems tools
- Assure that executive sponsorship exists

- Select necessary systems tools. This requires determining the application needs and ascertaining technology/standards requirements.

An example of an enhancement program at air products captured a number of sound considerations for innovations (HCB, 2002:34). The key ingredients of their Supply Chain Operations Process Enhancement Europe (SCOPEE) consisted of information, selective system enhancement, organizational changes and effective human resource management. They also drafted the following seven pillars of wisdom:

- Identify the key stakeholders
- Define performance expectations
- Invest in people and create capability
- Consistency and ability to stay with a plan
- Ability to execute decisions quickly and remove uncertainty
- Measuring and communication
- Celebrate the successes

Copanico & Byrnes (2001:29) developed a five step process that can be followed to achieve supply chain mastery (as indicated in Figure 3.18). The first step is to develop a fact base by following the following generic channel mapping process indicated in Table 3.8. Next the counterparts should be engaged. The new business model must then be sold to the counterparts and must drive change in the other functions. A roll-out game plan must be created and could include the following:

- Identify opportunity for an early showcase project
- Organize the initiative
- Map the markets
- Systematically realign the business model

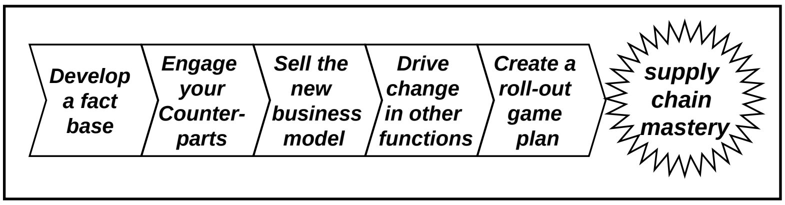


Figure 3.18 : Moving towards supply chain mastery

[Source: Copanico & Byrnes, 2001:29]

Table 3.8 : Generic channel mapping process elements

[Source: Copanico & Byrnes, 2001:28]

Segmentation and selection
Channel analysis
Customer operations analysis
Channel modelling
Business model creation
Business model confirmation and benefit estimation
Benefit confirmation
Business model functional alignment

3.3.1.2 *Managing supply chain projects*

The SCOR model also provides a standard methodology for managing supply chain projects (Loshe & Ranch, 2001:57). This methodology consists of a road map to identify current issues and position an organization for the future (as indicated in Figure 3.19). This is a four level (*phase*) process to be followed and consists of:

Level 1: Analysis of the operations strategy and basis of competition; Use relevant supply chain performance measures and screen operations strategy

Level 2: Analysis and design of the "as-is" physical material flow compared to the "to be" material flow

Level 3: Analysis and design of the "as-is" work and information flow and its comparison to the best practices and "to-be" work and information flow (Align performance levels, practices, and systems)

Level 4: Implementation of the new supply chain to improve performance

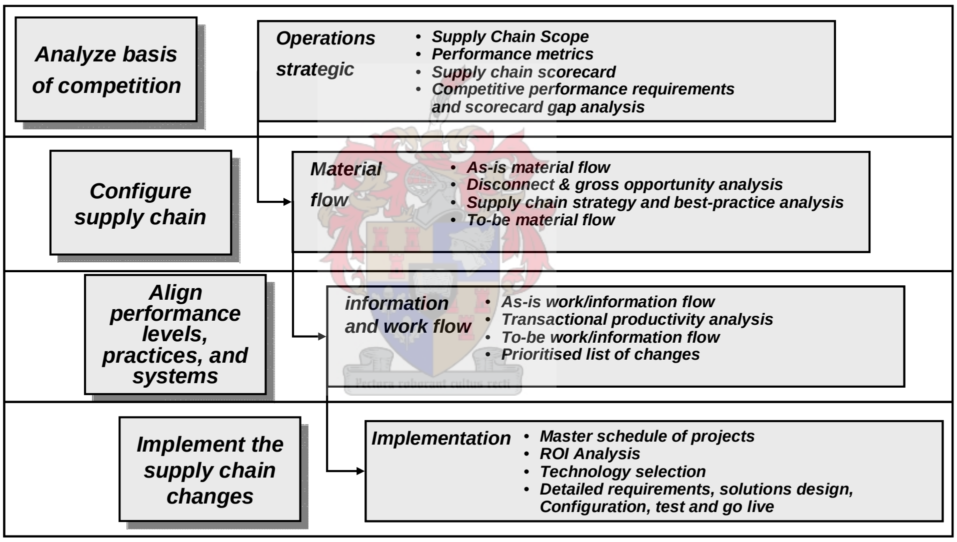


Figure 3.19 : SCOR project roadmap

[Source: Bolstorff & Rosenbaum, 2003:5]

Computer Sciences Corporation (2001) also provides a methodology that approaches the implementation of advanced planning systems in a phased approach. This provides a funding mechanism for the entire project and quickly brings in bottom line results. Making major changes in supply chain planning with APS technology, it is important to think about the process or methodology to accomplish the goals. Since a company is changing the way it does business (taking a supply chain approach), a methodology that focuses on the business process should be considered, as well as a set of phases tailored to a company's specific environment. Each phase should build upon work completed in the previous phase. The following methodology provides the typical phases to drive/unlock business value:

Conduct high impact assessment. Provides a prioritized list of changes needed in supply chain planning and execution and the estimated benefits. This includes an analysis of your organization's readiness to undergo significant change.

Develop a vision and strategy for supply chain planning. A conceptual framework needs to be developed for areas pinpointed during the Assessment phase. Each business process is defined by describing its future state. Enabling software could be required to support the new processes. A software selection process needs to be completed and can be expedited through the use of a Request for Proposal (RFP). Using the RFP, the key processes are converted into business problem scenarios and sent to the prospective software vendors. The software vendors normally need to respond with customized demonstrations on how they propose to solve the business problems. An implementation plan needs to be developed. This plan should be composed of a series of cycles or releases. Each release is designed to provide business functionality and value within a specified time frame.

Iterate through cycles of design, build and deploy. The last phase should be designed to deliver the business functionality and value. For successful implementation, performance measurements should be calculated and procedures put in place to track success as the implementation progresses. Preparation of employees by upgrading skills and training in new roles is critical to a successful implementation. Strong project management techniques are required to prevent scope increase and to keep the project on schedule. Each release should be designed to last between 3 and 6 months. This is required to sustain project momentum through regular financial business successes.

3.3.1.3 Requirements for successful implementation

Companies recognize that the successful implementation of a supply chain strategy can directly improve their competitive advantage (Lummus, Alber & Vokurka, 2000:83). Some sound guiding principles of how to get started are:

- The change initiative needs a champion
- The initiative requires a "cross section" of all relevant disciplines
- The company needs to understand its current capability
    - Self assessment begins by analyzing the structure of the supply chain
    - It then maps the supply chain processes
    - Lastly it determines how well it currently performs
- The overall categories of assessment
    - Supply chain processes
    - Information technology capability
    - Organizational enablers

From a sound business case developed, requirements that need to be reinforced for successful implementation are (Held & Kelton, 2002:631):

- Active, visible and strong top management involvement
- A serious appreciation for the change management requirements
- Rigorous project and partner management
- Accelerated decision making process
- Creative project team incentives
- Plenty of training, education, support and communication
- Focused alignment of the organization, team and scope
- Reengineering in the correct dose at the correct times
- Strategic and tangible benefits and a programme to measure progress towards stated goals

3.3.1.4 Key issues

The company should strive to integrate processes back into first tier suppliers that will deliver quality and responsiveness at the lowest possible total landed costs (Fawcett & Magnan, 2002:351). Their research indicated that few companies have really engaged in extensive supply chain integration as indicated in Figure 3.20. These different schools of thought and levels of advancement are however a reality and would face any cross-functions or inter-organization integration initiative.

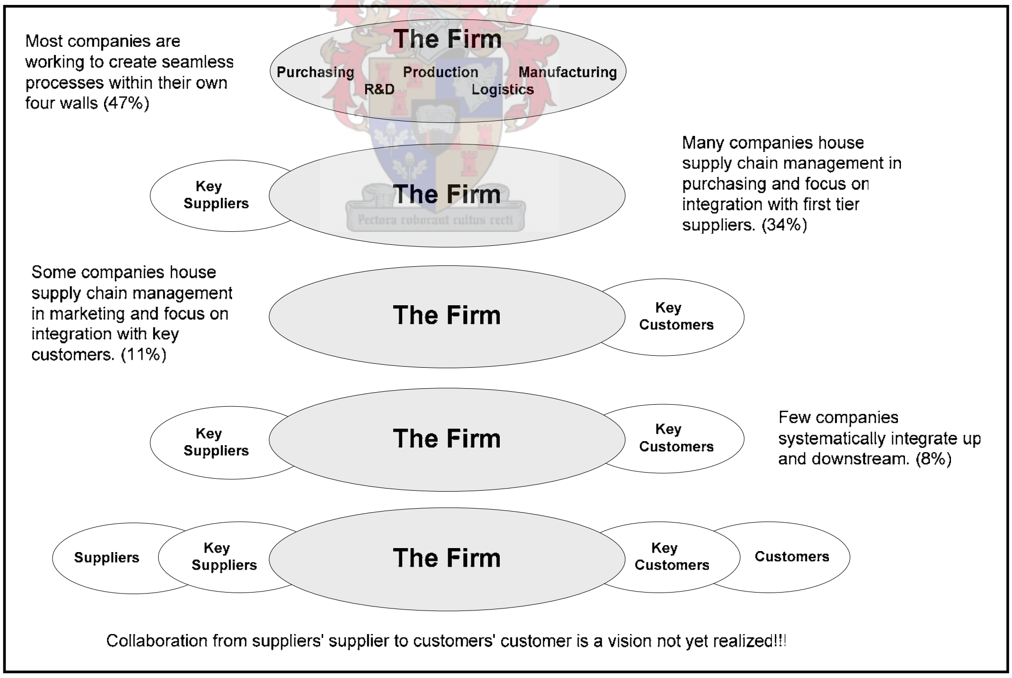


Figure 3.20 : Different views of supply chain integration
[Source: Fawcett & Magnan, 2002:354]

Companies have to close the gaps that still exist among the various internal functions. To advance and extend supply chain integration (up and down stream), the value added capabilities of all partners in the supply chain should be aligned and focused on the identified key customers. The customers' competitive requirements and critical success factors should then be evaluated and worked back into the supply chain strategy.

Mulani (2001:28) indicate some key issues to consider in the approach to improve supply chain planning capabilities (Else the organization will only make the same errors in advance planning and supply chain management that they made in the past – albeit faster):

- The company must first be operationally excellent before tying itself to point-to-point collaboration or exchanges
- Determine how ready you are to break into the e-Synchronised world
    - Evaluate competence in accepting the common way of operation in developing collaboration between business units
    - Learning from external role models
    - Building a new level of capability by combining the best of existing practices with new ways of using Web-based technology
- Once the above has been reached, then the company is ready to take these steps:
    - Master business fundamentals
    - Learn to operate in a Web-based world
    - Build new capabilities and relationships
    - Manage complexities in real time and embrace change

3.3.2 Organizational development (requirements, culture, leadership)

Technology alone is not the total answer for redesign (Kafoglis, 1999:50). Several critical levers must be exercised to truly redesign the supply chain and fully realise its benefits. These include aligning the organization, business processes, facilities and partnerships, as well as technology to the new supply chain approach.

As the supply chain organization matures, the participants in supply chain teams become more cross-functional (Cecere, O'Brien, & Martin, 2006:6). Companies that structure their supply chain organization closer to their customer, have greater capabilities to sense true channel demand and react fast to changes. Companies that are better in demand sensing also have higher success rates in S&OP as well as new product/business development and introduction efforts.

Bender (2000:58) states that for sustainable change, the following needs to be combined in an organization:

- The right technology for the right process
- The people who uses the technology and follow the processes
- Right structure and culture
- Right motivation and spirit
- Support by solid ongoing education and training

Integrated supply chain planning requires technological development, learning, and business process redesign within a company and its supply chain partners (Shapiro, 2001:23). The solution for integrated supply chain planning has the following two aspects:

> ***Technological Solution:*** Develop and deploy modelling systems for analyzing strategic, tactical, and operational decisions affecting the company's supply chain.
>
> ***Organizational Solution:*** Redesign company processes and revise managerial incentive schemes to promote and facilitate competitive strategies for supply chain management based on data, models, and modelling systems.

Based on an organizational survey done by AMR in 2005, supply chain organization structures don't also include a supply chain planning group (Cecere, O'Brien, & Martin, 2006:3). While 75% of companies have a supply chain organization, only 61% reported having a supply chain planning group. When both are present in the same company, the survey indicated that only 50% of supply chain planning groups had a direct reporting line to the supply chain organization. The other half was evenly distributed throughout their firms, with direct reporting relationships to sales, marketing, or manufacturing.

Teams will in future play a greater role as supply chains evolve (Trent, 2005:32). As indicated in Figure 3.21, the widening involvement of teams have evolved during the three decades from Functional (1970's), Cross-Functional (1990's) to Cross-organizational Excellence (2000's). It is expected of teams to solve more and bigger problems. Teams now not only face problems across multiple time zones and departmental boundaries, but also across companies. Supply chain planning processes are inherently cross-functional cross-organizational, and need to solve problems of this nature.

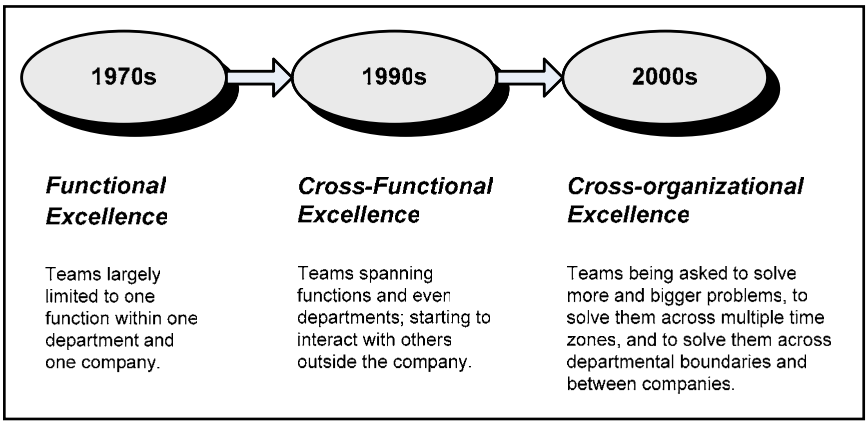


Figure 3.21 : Teams play greater roles as supply chains evolve
[Source: Trent, 2005: 32]

Companies and businesses are made and run by individuals (Moyen, 2004:3). Their values, beliefs, and skills make up the genetic material (the corporate DNA). This corporate DNA (driving force, ambition, passion, execution, innovation, and ethics) determine the effectiveness of an organization and not only the business models, strategies, and visions that guide them. For effective supply chain planning a sound understanding of a company's DNA is critical in facilitating alignment. In selecting and working with external supply chain partners, genetic incompatibility (the differences in corporate DNA) must be avoided as far as possible.

3.3.2.1 Organizational models

According to Gattorna & Hanlock (1999:14), the most successful organizations will be those that can abandon their hierarchical, command and control styles of operation and change to start building a collaborative internal culture. The following can be used to build a collaborative culture internally:

- Abandon command and control hierarchy and develop the ability to influence
- Empower people to make their own decisions and understand the significance of their specific tasks while not losing sight of the 'bigger picture'
- Retain critical experience through knowledge management
- Develop specific supply chain integration skills at all levels
- Structure the organization into cross-functional consulting teams

In meeting the challenges of the 90s it was indicated that world class organizations are restructuring to improve the responsiveness to customer needs and to reduce the overall logistics cost structure (Franz, 1995:D2-4). Organizations are moving to an integrated logistics function characterized by:

- A process oriented logistic organization
- Common goals and performance measures aligned to customer needs
- Cross functional, customer-focused teams
- Integration and partnering with external logistics partners
- Sharing of logistics resources across companies
- Using timely, accurate information to reduce uncertainty
- Shared incentives and rewards
- Using outputs as basis for organizing, planning and managing

Bowersox, Closs & Theodore (2003:23) state that with enterprises embracing process management, crystal clear lines of authority and responsibility (typical of functional command and control) becomes difficult and undesirable to maintain.

One structure often used to facilitate cross-functional integration is commonly referred to as a matrix organization (as indicated in Figure 3.22). Two senior managers share responsibility for an enterprise. One senior manager (business) focuses on financial and operational aspects, retaining responsibility for the profitability of specific business units that are often organized around product categories, geographic proximity, or classes of business. The other senior manager (resource) is responsible for the deployment of human and physical assets to meet the requirements of organizational units. While skilled personal are directly responsible to this resource manager, they are assigned to the business manager. Matrix organizations typically work well in consulting and advertising, but it is more difficult to implement in manufacturing, distribution, and retail businesses. The horizontal organization is designed to facilitate processes and not to perform work tasks. It has three essential attributes:

- A highly involved, self-directed work environment that empowers employees to generate maximum performance
- A focus on managing processes (rather than functions) that lead to higher productivity
- Rapid assimilation and sharing of accurate information that allows all the facets of the organization to be integrated

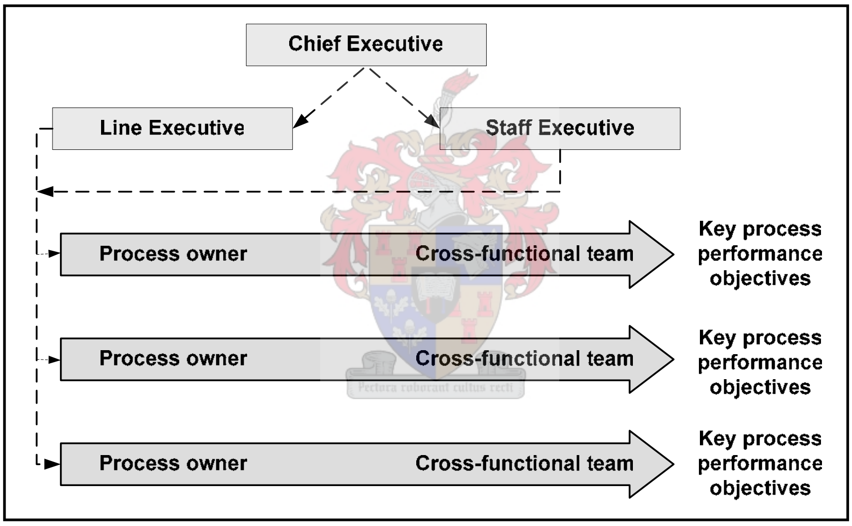


Figure 3.22 : Horizontal organizations
[Source: Bowersox, Closs & Theodore, 2003:24]

As indicated in Figure 3.23 horizontal processes may be extended across enterprises via electronic connectivity, visibility software, and integration of specific work assignments (Bowersox, Closs & Theodore, 2003:24). Horizontal organizations can be viewed as a composite of the specific business functions that are motivated and directed by common interests and goals.

McAdam & McCormack (2001:117) also state that the most common organizational structure today is the matrix formation. The matrix organization is a compromise between functional focus and product (or customer) focus. Members communicate through peers in the same function or peers in the same product line. As organizations continue to build global supply chains this trend towards informal communication structures will inevitably increase. This approach is an integral part of supply chain integration. To enable effective integration of the primary activities in the value chain, employees must be able to talk directly to their peers in other activities.

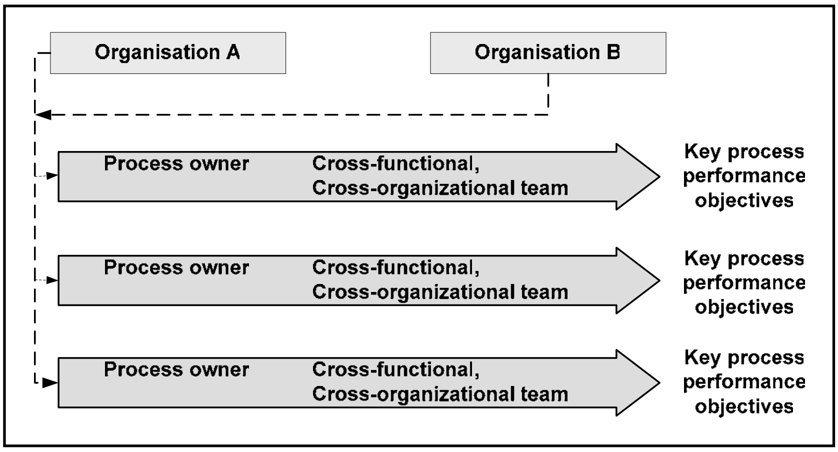


Figure 3.23 : Cross enterprises process organizations
[Source: Bowersox, Closs & Theodore, 2003:24]

Frentzel (as referenced by Bowman, 1996:33) indicated that tomorrow's company will be organized among different lines. Today, organizations are separated into manufacturing, logistics and marketing (Each working independently and often at cross purposes with one another). In the future organizations will be dividing into product development, product supply and demand fulfilment. Companies will form "process teams", consisting of experts from procurement, manufacturing, marketing, finance and distribution (Horizontal process management).

Companies structured into broad process teams rather than narrow functional departments have less internal conflict and stronger team spirit (McCormack & Johnson, 2001:34). According to Christopher (1998:223) radical solutions must be sought which may require a restructuring of the conventional "vertical" organization and lead to the creation of a "horizontal" or market-facing business. Figure 3.24 contrasts the vertical with the horizontal organization. The horizontal organization is typically organised along processes (not tasks), is flat and de-layered, built upon multi-functional teams, and guided by performance measures that are market based.

There is however a risk in overemphasizing a process organization. This can happen when a company becomes so enchanted with the elegant process ideology that "process" becomes the end instead of the means (Stanton, 2005:1). What is needed is an organization full of high performing processes; a company where processes create high value and immense profits, operate at low costs, and generate constant customer delight. The focus must be on performance. In the world of process, it is always the outcomes that matter.

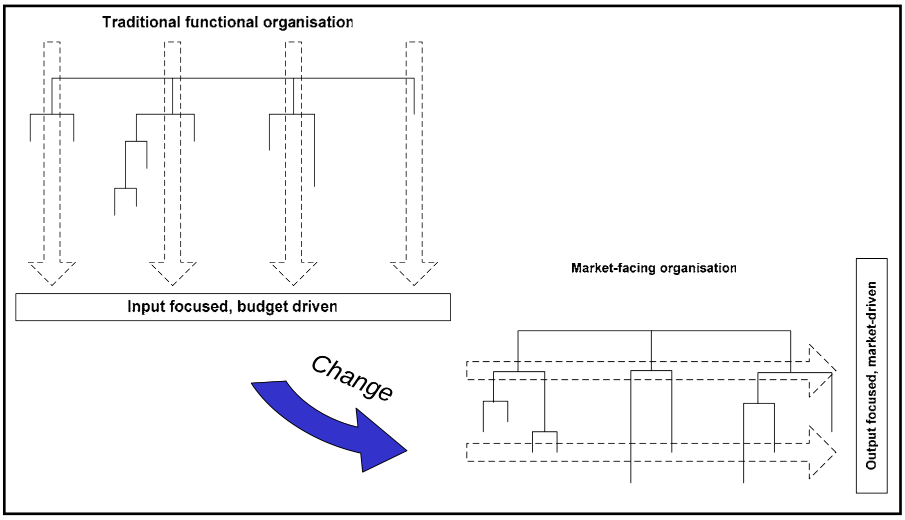


Figure 3.24 : Organizational transition - vertical to horizontal focus.
[Source: Christopher, 1998:223]

According to Armistead (as referenced by McAdam & McCormack, 2001:117) to integrate various companies in the supply chain, equivalent communication must be created between activities in different organizations. Communication is predominantly between members of the same business process and less between members of the same function or location.

Nagel (1995:D1-7) provided an alternative to dealing with the conflicting dilemma of corporate logistics and business unit logistics of large-scale organizations, and suggested that a completely decentralized management philosophy can be followed. Corporate logistics plays a support role to the primary activities of business unit logistics. The business unit's logistics are organized as a function (Alongside marketing, finance, operations, etc.). Various centralised specialist support units serve the business unit's logistics functions. These include:

- Logistics channel design and optimization
- Environmental matters / risk
- Information systems and technology
- Logistics related services / procurement and supply management
- Performance measurement and customer service levels / performance enablement
- Inventory management
- Logistics organizational development

Comprehensive decentralisation in many large corporations has created a situation in which different business models have evolved (Bentley West, 2003:39). There is now a need to integrate these business models from an organizational and governance perspective, to allow and promote cross unit cooperation where appropriate to achieve enterprise strategic alignment, to reduce confusion and reduce the cost of decentralisation. The most popular organizational approaches directed at resolving tensions, duplications and issues of centralisation vs. decentralisation, specialisation vs. generalisation, and formal vs. informal organization are:

- ***Hub 'n Spoke:*** Contains a central owner (Hub) of an issue or specialisation and requires other organizational elements (Spokes) to execute
- ***Holistic integration;*** "Organization-wide integration and alignment of all capabilities to achieve congruence between strategy, structure, process, people and culture to improve short and long term organizational competitiveness and sustainability" – Translates the enterprise strategy into functional and business unit actions
- ***Federal organization:*** A governance model driven by two precepts: (a) The splitting of supply from demand; recognition that drivers of efficiency mitigate against drivers of effectiveness and (b) Subsidiarity (reverse delegation); the centre being in the service of the regions, based on negotiated roles and responsibilities.
- ***Shared service:*** mandated to provide specialised functional services on a reverse delegation basis

Each of the above approaches has its strengths and weaknesses in addresses the key issues faced by large corporate structures. Figure 3.25 provides some insights of which approach best addresses specific issues.

	Federal	Hub 'n Spoke	Holistic integration	Centres of excellence
• Duplication of effort	⬭	⬡	⬡	⬭
• Duplicate functions	⬭	⬭	⬡	⬭
• Wheel reinvention	⬡	⬡	■	⬡
• Strategic mindset	⬭	⬡	⬭	⬡
• Aligned activities	⬭	⬡	⬭	⬭
• Not invented here	⬡	⬡	⬡	⬭
• Systems integration	⬭	⬭	■	⬡
• Re-use	⬭	⬭	■	⬡
• Decide on best practice	■	⬭	■	⬡
• Access to specialists	■	⬭	⬡	⬭
• Globalisation	⬡	■	⬭	⬡
• IT across business units	⬭	■	■	⬡
• Power bases	⬭	■	■	■

⬭ Specifically addresses the issue ⬡ May address the issue ■ Does not address the issue

Figure 3.25 : Corporate structure options and the ability to address issues.
[Source: Bentley West, 2003:40]

An emerging organizational trend is to view the supply chain from an integrated holistic perspective rather than as a collection of independent activities (Trent, 2002:32). Organizations have started to create new positions and to develop systems which support the balanced and continuous flow of inventory in the supply chain from suppliers to end customer. Typical responsibilities for a "vice president" (high up in the hierarchy) of supply chain management include:

- Responsible for worldwide supply planning and replenishment
- Responsible for demand and finished-goods forecasting and inventory planning
- Responsible for primary customer order fulfilment centres and logistics
- Responsible for integrating supply chain activities with operational positions

For the new trend of horizontal process structures to work properly, demand transparency across the supply chain is a key ingredient for alignment. Demand planning structures must be committed to the three guiding principles of focus, ownership and balance (Smith, Mabe & Beech, 1998:124). In the corporate structure the function typically resorts under marketing or operations. The organizational structure for demand planning typically includes product planners and functional specialists. Key technical competencies for demand planners include analytical skills, understanding of the statistical tools and demand planning technology.

With Supply Chain Management (SCM) practices starting to mature in the 1990s, many organizations developed divisional support structures to align manufacturing with marketing strategies (Cecere, 2005). These structures however did not cater for global supply chains with the complexities of many products in many markets. An increasing number of companies are now redefining their supply chains based on product, channel, and demand characteristics, with the aim of addressing the changing practices as indicated in Figure 3.26 .

Primary Focus	Marketing and Sales	Operations Teams	Procurement Teams
Today	Brand and brand positioning	Divisional support	Divisional support
Focus of Leaders	Channel and account strategies	Grouping of supply chains by demand and product characteristics	Shared-services model based on global commodity councils

Economies of scale →

← **Responsiveness**

Figure 3.26 : Supply chain redefinition
[Source: Cecere, 2005]

Well-established organizational mechanisms and principles are one of the critical success factors essential for successful process investment (Keen, 1997:143). Key organizational mechanisms and principles are:

- Establishing the right kind of process investment committee to get the right processes right
- Involving long-term planning units in process investment planning
- Developing a common, inclusive language of change
- Maintaining a strong and continuing connection among all levels of the firm
- Providing incentives so that those who implement change benefit from it.

Each of these organizational mechanisms and principles are briefly discussed in the following paragraphs.

a) *Establishing the right kind of process investment committee to get the right processes right*

It is vital to set up a corporate committee to supervise the development and management of the process investment portfolio. Characteristics, roles, or reputations these committee members should have are:

- Movers
- Senior line managers
- Chief financial officer
- Human resources senior manager
- Director of information services
- Senior corporate executive

b) *Involving long-term planning units in process investment planning*

These units can look beyond the current strengths and weaknesses that are likely to absorb the attention of business units, and often senior managers. Four critical functions are performed:

- Analyze the firm's business environment in process terms
- Move the firm away from the limiting concepts of "the industry" and "core processes"
- Look for process predators (look out for future "killing" business innovations)
- Ensure an extensive process portfolio

c) *Developing a common, inclusive language of change*

Language shapes how we understand reality.

d) *Maintaining a strong and continuing connection and trust among all levels of the firm*

Firms that successfully carry out large-scale process change maintain strong and continuing connections among all levels of the organization. The vision and commitment of senior management can encourage, support, and direct change but can't make it happen. Companies that create or maintain collaborative cultures in such a climate have to work hard to build (or rebuild) employees' trust. Those that succeed in doing so usually do three things well:

(i) They maintain open communication with the whole firm, providing clear information about what is going on and being honest about the down side as well as the benefits of changes being contemplated.

(ii) They help the survivors as well as the victims of downsizing or reengineering to make the transition to a new situation. It is appropriate that those who lose their jobs receive outplacement services; it is equally appropriate that those who remain be given a clear understanding of how the restructured company will be more effective and how their changed jobs can be satisfying, not just more difficult.

(iii) The trust-building companies demonstrate their commitment to employees.

e) Providing incentives so that those who implement change benefit from it.

A first appropriate incentive is ***education***. Education is of lasting use to employees, whether they remain with the firm or not. ***Empowerment*** that gives people at many levels real responsibility to manage their own work and participate in setting the future course of the firm is another excellent incentive. Companies should modify performance criteria to reflect the importance of and rewards for creativity, collaboration, and communication.

3.3.2.2 Leadership

Culture, structure and leadership style strongly affect the kind of process changes a company will attempt, and the kind that is likely to be carried out successfully (Keen, 1997:125). Leadership, culture, organizational confidence, and expectations, all "change drivers," collectively define the degree of a firm's commitment to change. The extent of change (and also the level of commitment to it) falls into four categories as described is Table 3.9.

Table 3.9 : Degree of a firm's commitment to change
[Source: Keen, 1997:125]

Categories	**Management commitment**	**Description**
Incremental change	Commitment to move forward in deliberate and phase steps.	Streamlining and relative low risk adjustment such as outsourcing, self sourcing, and abandoning
Step-shift change	Commitment to making significant process changes but not changing the basic direction of the business and how it generates value.	Applying value builders such as hubbing, pre-empting, and work netting to a portfolio of priority processes
Radical change	Commitment to aggressive actions that leaves the existing business entity and its basic assumptions intact.	The identity of the firm is not in question, but the way it carries out business may be significantly altered.
Fundamental change	Commitment to creating what will in effect be a new company.	Processes, structure, markets, strategy, and even identity are up for review

Keen (1997:130) also provides some guidance regarding leadership and management styles. As in every area of organizational innovation, leadership in business process investment, not delegation, is as vital as the specific value builders in most instances are. A firm's strategic style has to be explicitly considered when developing and implementing a strategy for business process investment. Each style has a distinctive influence on how firms decide which processes to get right and how to improve them. Table 3.10 indicate the six strategic styles and driving principles that could be followed to approach strategy (with varying degrees of success).

Table 3.10 : Strategic leadership styles
[Source: Keen, 1997:130]

Strategic style	Driving principles
Transformational Leadership	The personal credibility, commitment, and energy of the CEO drive the change. Education and a shared language mobilize the organization.
Delegate Mandate	Management commitment to change is unambiguously communicated, but the plan for changes generated at lower levels in the organization.
Reactive Urgency	Is crisis-driven; in response (often late) to explicit competitive pressures and shifts in the business environment.
Individual Initiative	Individual business leaders are expected to discover opportunities for change and set programs in motion.
Sustained Improvement	Characterized by commitment to continuous improvement.
Opportunism	Willingness to take action when needed to anticipate and prevent crises without stepping to far ahead of competition

A very effective tool for aligning an organization towards its strategy is to steer organizational behaviour through a performance tracking and reward system. Approaches like balanced scorecard provide a sound dashboard for measuring and tracking the implementation of strategic objectives (Brosset, 1999:22). Wise and timely structural changes are a second powerful means to communicate strategic evolution.

3.3.2.3 Competencies/requirements

The new supply chain environment impacts on both organization and people (Bauknight, 2000:35). To guide a company into the future, it will need to have high-calibre people who have a vision that extends beyond functional silos and who can manage the complexity of a supply chain-wide viewpoint. The mastering of recruitment, management and development of supply chain personnel will become crucial to future success.

To be successful, a supply chain manager needs to be of that rare breed; a non-hierarchical, facilitation oriented manager (Brosset, 1999:22). This person needs sufficient authority to overcome functional boundaries, balanced with functional expertise in required places. The ability of the supply chain planner is also a key ingredient to success (Bonner, 2001:20). No matter how sophisticated, the contribution of the advanced planning and scheduling (APS) technology is highly dependent upon the skill, knowledge and ability of the planner.

According to Wierichs & Hughes (2004:46) supply chain leaders should be able to manage complex supply chain issues, whether they are overseeing a global supply chain or looking to improve internal cross-functional processes. Some of the important skills and competencies for successful leaders include being a great communicator, driving and inspiring teams, being committed to delivering results and, most important, being customer focused. Supply chain executives need to forge strong relationships both internally and externally. This will support the drive to achieve more transparency in the supply chain. While having a global perspective supply chain leaders (leading teams or being a specialist) must also have the ability to evaluate the performance of each function in the chain and assure alignment to a common goal. Supply chain executives who exhibit the critical characteristics—leadership, global perspective, business-minded and a relationship builder—can improve a company's chances for long-term success dramatically.

When implementing cross-enterprise processes, organizations requires information sharing, coordinated execution, and optimized planning. (Bowersox, Closs & Theodore, 2003:24). The complicated nature of all APS applications requires a sophisticated and well-trained user-base to ensure effective system deployment (OMR, 2003:4).

Pienaar (2005:90) identified a number of quantitative skills and techniques that logisticians should master:

Competencies: Make rational decisions, Forecasting, Scheduling, Determine routes for vehicles, and Control inventory levels.

Most important Tools: Forecasting, Analysis with simulation, Decision-making, Facility location, Route planning, Inventory control, Scheduling, and Application of queuing theory.

Operational research techniques: Linear programming, Integer programming, Feasibility analysis, Transportation modelling, Deterministic and probabilistic inventory modelling.

3.3.3 Successful change management

The basic questions for change are: where are we now, where do we want to be and how are we going to get there? (Lummus, Alber & Vokurka, 2000:83). Without an effective change management strategy, which reinforces a commitment to quality, an organization will not achieve appropriate results from new systems, software or processes (Cameron & Duckett, 1996:4).

There are two major types of adoptions in managing change (CLM, 1995:29): continuous / constant change and fundamental change / reinvention. As indicated in Figure 3.27, the logistics change management model progresses from visioning, need to renew, system modification, and enhance competitiveness, to eventual success.

In the mid 90s the indication was that only 7% of logistics managers had a technical degree (Ballou, 1995:50). Translating solutions into understandable terms are of key importance for non-technical people. Communicating to non-technical people as to how a model solves the location problem is not always easy. The integration of maps, charts and spreadsheets into an otherwise elegant solution process increases the transparency of the modelling process and communication.

Integrating logistics is as much about cultural change as it is about rearranging the physical processes and networks or establishing new information systems. According to Ribbers (1994:28) the following are six key enablers that can help with managing change:

Communication: compelling reasons for change.

Sponsorship: senior management must demonstrate their commitment to change. Must reveal the benefits to the individuals who will naturally ask: "what's in it for me?"

Vision clarity**:** the future state must be seen desirable and attainable by all participants. There must be faith in the leadership's judgment.

Readiness assessment: assess the costs, risks and benefits for change, objectivity must conquer illusionary thinking.

Transition planning: detailed plans.

Transition implementation: training and managing the start-up of new processes and technology.

According to Lee (1999:2) evolution, rather than revolution, results in incremental changes with step-change results. Global competitiveness elevated supply chain optimizing as a management priority. Defining the perfect end-state optimized supply chain is easy. Getting there while having a business to run is not so easy. To achieve dramatic and sustainable results, it is necessary to put in place a process for improvement rather than a one-time project for improvement. Combining substantive business process changes (accomplished through cross-functional and inter regional teamwork) with the provision of key information and decision support systems is required.

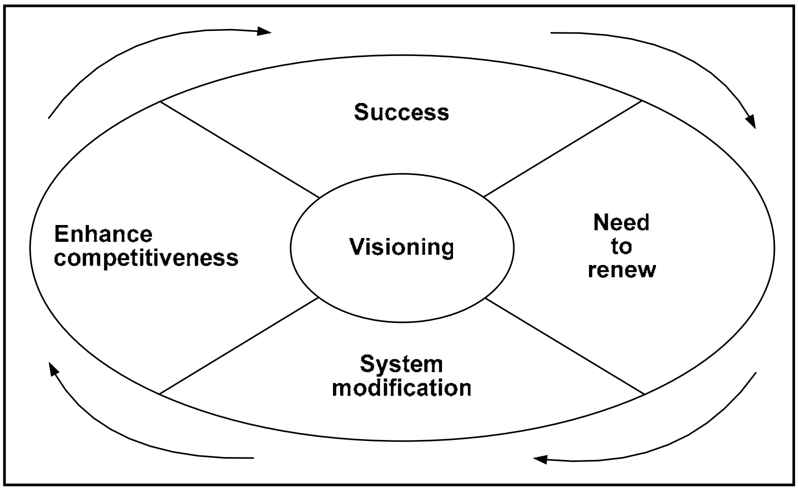


Figure 3.27 : Logistics change management model
[Source: CLM, 1995:30]

3.3.3.1 Change management process

According to Walsh (2000:59) leadership, not management, makes change happen (change leadership). Leaders create the basic blue print and managers take that blue print and turn it into reality. Leaders drive change and managers keep the process under control. Support for initiating change has to come from the top. To gain the support of senior management helps eliminate organizational barriers that undermine change (Mercer Delta Consulting, 2000).

The following major activities form the basis for a change management process (CLM, 1995:302):

- Situation Assessment
- Decision to change
- Action planning
- Develop supporting logic
- Cost and benefit analysis
- Management recommendations
- The implementation plan

A number of reasons lies at the hart of the question “Why change?” (CLM, 1995:283). The four main drivers for change include crisis elimination, waste reduction, value improvement and external or environmental changes. There must be a constant search for unique ways to favourably impact customers and create competitive advantage. The change process includes stimulus, perspective, focus, and eventually results. Change happens when the gap between the current and desired performance warrants the perceived risk. The magnitude of change required can be: continuous improvement, reasonable change or radical change.

The following are however a number of obstacles to change (CLM, 1995:287):

- Lack of real focus on customers
- Lack of information that has strategic value
- Information not organized and distributed to facilitate strategic use
- Difficult team in revamping organization structure and tasks
- Lack of a clear and appropriate strategy and mission
- Overcoming the deadly inertia created by the accepted ways of doing things

Easton, Brown & Armitage (1998:447) indicate that some crucial factors to manage change exist. These include pressure for change, clear shared vision, capacity for change (skills, incentives, resources) and actionable fist steps. As indicated in Figure 3.28 all of these factors must be present else sustainable change is not achievable and negative consequences will result. Easton, Brown & Armitage (1998:453) also indicate that many change initiatives fail because they don't carry out the essential actions required to direct the actions of people. The following are essential first-up actions:

- Align culture with strategic response
- Appoint a process owner
- Reshape performance measures
- Develop and train the workforce
- Communicate and demonstrate top management commitment
- Involve stakeholders and gain commitment to change
- Implement a system to track benefits
- Communicate with all stakeholders
- Create an integration map

How to lead change leadership is a critical success factor for successful change management (Caillet, as interviews by Walsh, 2000:63). The company must set attainable, measurable goals, develop a blueprint, and empower the organization for success. A vision statement is required and it must be definitive and concise (for everyone to understand immediately). Strategic objectives must be developed and tied to the vision (Putting the objectives into words issues a challenge to employees and motivates them). A "guiding coalition" must be established that creates the game plan for change (blueprint). An appropriate project leader must be selected (must be fairly optimistic, a good listener and excellent with project management). Communication is of paramount importance. Always let employees know that the team is meeting and will be recommending some changes; spread the word consistently (electronic, paper, and face-to-face). Get people to comply; in every organization there's an ingrained resistance to change and it runs from top to bottom. Some people never comply; instead they have a change in perception. (People behaviour is the best predictor of how well change was adopted). Clear away the last barriers and empower teams to do their jobs. Change is a process that has no end. Eventually a new organizational culture is established that accepts change as a permanent part of the landscape.

Regarding reasons for change, Lapide (2005:31) advises companies to rather focus on identifying the underlying principles leveraged by a benchmarked company's best practices. It is the principle of a practice that are responsible for the benefits (rather than the practice itself). Thus, rather than replicating another company's best practice, a company should assess whether the principle can be leveraged with a practice that makes more sense in their own business environment. Companies should avoid the first impulse to copy other business practices exactly, and first conduct a thorough analysis to identify the underlying reasons why the practice is working well for the benchmarked company.

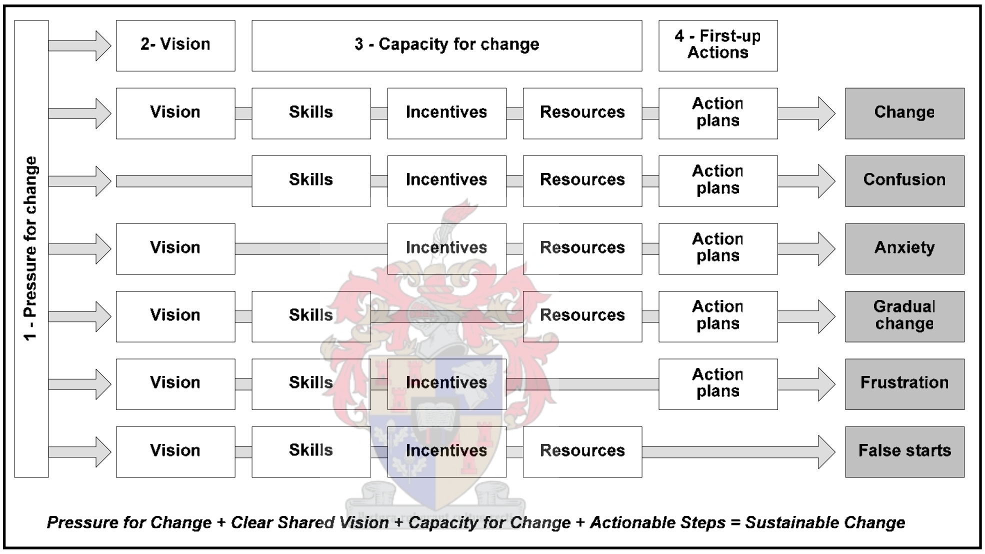


Figure 3.28 : Prerequisites for sustainable change
[Source: Newland (as referenced by Easton, Brown & Armitage, 1998:448)]

3.3.3.2 *Change challenges and lessons learned from failures*

Planning projects fail mainly due to a lack of process alignment across the functional silos within a corporation (Mulani, 2001:28). Companies that are implementing new planning solutions sometimes fail to agree with or absorb the changes required in process reengineering across departmental lines. Rarely do they have the right performance measures to give participants incentives to make the process alignment effective. Companies should recognize that planning is cross-functional, that information must pass between the functional silos within an enterprise, and that these silos most work together towards a common objective.

The challenges in changing from a logistics to a supply chain approach are complex (Walt & Gattorna, 1998:489). In a process of joint reduction of inventory along the channel certain facilities are rationalized and shared. There is a movement away from cost minimization at the individual level and seeking instead channel-wide or even industrial-wide economics. This normally leads to rationalizing the supplier base, with the associated risk of some channel partner becoming obsolete. The primary focus should stay on inventory velocity across the entire supply chain.

Functional barriers are a major challenge for reaching supply chain excellence (AT Kearney, 1997:47). The focus must however move beyond functional excellence to looking for ways to manage processes across functions. Internal processes must be tied together with external relationships. The appropriate technology must be developed/utilised to do these things.

According to Richmond et al. (1998:515) some critical issues should be addressed in the decision for supply chain applications:

- The technology should be aligned with the industry direction and business strategy requirements
- Identify opportunities that can lead to potential benefits
- Decide on which tools are required (Consider the value offered, timeframe, payback, and disruption impact)
- Choose a vendor (Consider the level of specialization, systems included in solution, and required supply chain capabilities)
- Drive implementation from rigorous business case

Senior management encounters several organizational barriers when it tries to advance its supply chain business with the use of strategic modelling systems on a regular basis (Shapiro, 2001:43). Some remedies are available. (a) The company must commit to the design and implementation of IT procedures for collecting and updating the supply chain decision database. (b) Training entails a complete transfer by the system developers and, in many cases, the external consultants who perform the study, of the modelling system to the company. (c) The company must implement processes whereby senior management works with analysts and lower-level managers in performing modelling studies, reviewing results, and implementing plans that they suggest.

An inability to build trust among the different parties in the supply chain is the major reason for implementation failures (D. Simchi-Levi, 2000:76). The best designed supply chain strategy fails because of people's resistance to change.

Only 30% of major business process reengineering projects are ever completed. But only 30% of those completed deliver the anticipated business benefits (Collinge, 2000:24). The problems are not in the rigour of design, but in the execution of the necessary change. Pollalis (2002:333) also provide the following reasons why business process reengineering initiatives fail:

- Lack of management commitment and leadership
- Resistance to change
- Unclear specification
- Inadequate resources
- Technocentricism
- A lack of users' and customers' involvement
- Failure to address the human aspects of planned change

No less than 70% of all major projects fail to deliver on time, in budget and project deliverable benefits. Some of the major reasons are (King & Wright, 2002:42):

- Failure to understand the current business processes before attempting to design new ones.
- Temptation for management to cut corners to reduce project costs
- Failure to gain the full support and commitment of staff to the change
- False belief that the project must continue and more time and money will get everything back on track

Holmes (as quoted by Redmond, 1998:50) states that many companies put much effort in deciding what to buy and then are not prepared to put any effort into implementing the decision effectively. Some of the reasons for poor implementation are:

- The right people are not made available
- Time scales are unrealistic
- The time is not taken to allow the users to understand the system fully or work out how best to use its
- Not all suppliers have the necessary experience to provide the support required
- Cheapest system is chosen rather than the one which is most suited to do the job

3.3.3.3 Approaches and frameworks for change

The fundamental question is always asked: "Why change when all is going fine?" Today's success is based on past and present action. Future success means a possible change in today's course; "Not where the ball is now, but where would it be tomorrow" (CLM, 1995:36). Some change stimuli are:

- ***From internal sources***
  - Strategic direction (Strategic specifies the intended goal and path expected to follow)
  - Management
  - Performance measurements
- ***From suppliers***
  - Materials and components
  - Services
- ***From customers***
  - Products at lower cost

    - Enhanced products at the same price
    - Enhanced products for which customers are willing to pay more
- ***From competitors***
    - Actions
    - Anticipated actions
- ***From alliances***
    - Motivated
    - Success factors
- ***From the environment***
    - Industrial
    - Macroeconomics (Governments , international events, demographics and culture, technology push, market fragmentation, industrial concentration, stakeholders and financial institutions, activist groups)
- ***From success***
    - Be aware, perfectionism can lead to a technocratic approach
    - Becoming complacent
    - Entrepreneurial (could over-expand)

Caillet (as interviewed by Walsh, 2000:61) also provide a number of change triggers or drives of change. These include:

- Competitors are stealing market share
- Market forces require expansion or adaptations
- The company is spending too much
- Customers are complaining
- Employees' dissatisfaction is becoming public, perhaps to recruiters
- Productivity is down; operations are inefficient and ineffective

Any company should be cautious using supply chain management as a buzzword without adopting the mindset and developing the required infrastructures (largely due to potential limitations) (Fawcett & Magnan, 2002:359). SCM definitions vary a lot and a company must be precise in discussions of specific practices. Functional divide in enterprises is a major limitation. In many cases it is easier to integrate externally than internally between functions of an enterprise. The supply chain complexity is another major challenge. A strong focus on immediate results limits a company's ability to change culture and establish appropriate relationships.

With the emphasis on strategic planning, most managers are capable of formulating strategies that are, as much as any forecast can be, technically correct (MacMillan & Jones, 1986:2). Too often the strategist has failed to anticipate organization politics and built it into the formulation process. Strategy formulation must include the political plan; how one intends to manage the key stakeholders. Figure 3.29 provides a framework for political strategy formulation.

The political strategy formulation typically goes through the following four major considerations (MacMillan & Jones, 1986:99):

- Analysis of the total situation
- Identification of future threats and opportunities
- Political analysis
- Political strategy formulation

Ignoring current processes implies that people are unimportant and by inference, that what staff currently do and what they know, is of no value. It also implies that their input to any changes is unwanted and unnecessary (King & Wright, 2002:45). Allowing staff to contribute helps to "buy into" the change.

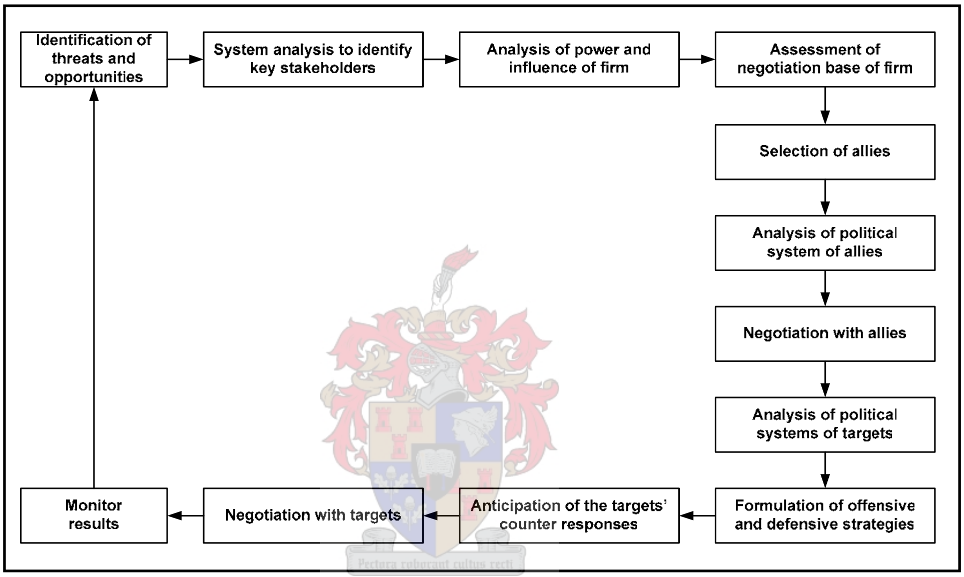


Figure 3.29 : Political strategy formulation
[Source: MacMillan & Jones, 1986:4]

A sound change management approach is the '3-P' approach. This change management approach is based on the relationship between philosophy, principles and processes (Chapman *et al.*, 2002:63). It is fundamental to understand the meaning of each of these from a change management perspective. Figure 3.30 and the following is a brief overview of the meaning of each:

Philosophy: Broad or fundamental believes; It guides behaviour in organizations. A number of descriptors are beliefs, viewpoint, thinking, values, attitude, idea, way of life (system of thought or doctrine), theory, or policy.

Principles: More explicit than philosophy issues; a general approach.

- Principles or concepts underlying a particular sphere of knowledge
- Concept, rule, assumption, law, code, standard.
- An important underlying law or assumption required in a system of thought
- The basic way in which something works

Processes: Processes, techniques and tools. It reflects a series of actions directed towards a particular aim.

Each management movement (such as MRPII, JIT, TQM, TOC, etc.) has a primary focus, a set of basic concepts and a related set of techniques (Demming & Petrini, 1992:8). For any new management movement to be implemented successfully, it is of prime importance that the primary focus, basic concepts and techniques are unilaterally defined and understood. A brief overview of their meaning is:

> ***Primary focus:*** defines the driving force, the orientation and the criteria for decision making
>
> ***Basic concepts:*** define the fundamental beliefs that provide the framework for decision making
>
> ***Techniques:*** To convert concepts into reality

Cultural remodelling is an essential part of change management. To affect cultural change, organizations can implement such techniques as (Cameron & Duckett, 1996:5):

- Involvement, communication and support (participation in system design)
- Training (a learning organization)
- Review organizations' structure (movement to flatter decision making structures)
- In-built flexibility (minimise rigid lines of responsibility)

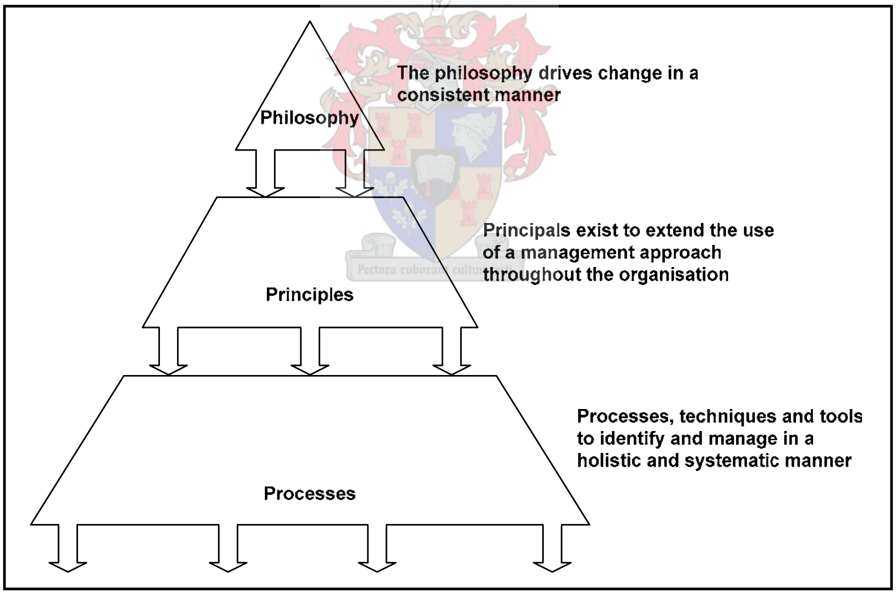


Figure 3.30 : The '3-P' approach of philosophy, principles and processes
[Source: Chapman et al., 2002:62]

3.3.4 Business Case Development

When developing a business case for process change, or justification for enabling technology, the focus should be on proving the worth to the company.

The maturity (competency) level of an organization can be gauged by evaluating a company against a set of basic questions. These questions can be positioned in a two dimensional matrix (with some sample questions) as indicated in Table 3.11. On the one dimension the competency is measured related to goals (supply chain strategy), design, management, and measurement. On the other dimension the competency is measured related to organization, process, people/jobs and technology. The more yes answers, the more competent the firm. This assessment could indicate possible opportunities for improvement.

Table 3.11 : Supply chain competency matrix (sample questions)
[Source: Bolstorff & Rosenbaum, 2003:133]

	Goals (supply chain strategy)	**Design**	**Management and measurement**
Organization	Has the organization's supply chain strategic direction been articulated and communicated?	Does the formal organizational structure support the supply chain strategy and enhance the efficiency of the system?	Is the customer-facing, internal-facing, and shareholder-facing performance measured?
Process	Are the appropriate enabling processes in place to support supply chain planning and execution?	Are these the most efficient/effective plan, source, make, delivered, and return processes for accomplishing plan, source, make, delivered, and return process goals?	Has the appropriate plan, source, make, delivered, and return process sub-goals been set?
People/jobs	Are job outputs and standards linked to plan, source, make, delivered, and return process requirements?	Are plan, source, make, delivered, and return process requirements reflected in the appropriate jobs?	Do the performers understand the job goals (outputs they are expected to produce and standards they are expected to meet?)
Technology	Are the technology goals linked to customer/organization requirements?	Is the most efficient/effective technology being put in place to accomplish the plan, source, make, delivered, and return processes?	Is the technology performance managed?

As part of a business case development process in supply chain management (SCM), it is important to assess competencies and opportunities (Bolstorff & Rosenbaum, 2003:132). As a rule-of-thumb a 3% profit improvement to the sales value of the supply chain is a typical starting point for an opportunity assessment (for $100 million in revenue, an extra $3 million dollars in earnings opportunity). The more competent a company is at SCM, the less the opportunity (less than 3%.) Less mature companies could yield opportunities in excess of 3%.

A supply chain pre-study is normally conducted to screen for opportunities to improve the competitive position through supply chain design/re-design (J.B. Ayers, 2002:619). The study process comprises the following major phases:

- Define market segments
- Map products to segments
- Identify the supply chain (Describe)
    - o Physical flow
        - "Sites" echelons (suppliers plants, DC's, Warehouse, customer segments)
        - Transportation between echelons
        - Volumes of cash flow in dollars, units, volume
        - Cycle time
        - Inventory level
    - o Document Information flow
        - Point of sale information generated
        - Decision point
        - Information systems used to plan and control the process
        - List of formal and informal contacts
    - o Financial flow
        - Cash to cash cycles
        - Balance sheet figures
        - Activity cause across the supply chain
    - o New product flow
- Document management processes
    - o Basic planning processes and recent initiatives
        - Strategic plans and initiatives
        - Improvement projects
        - Justification process for capital investments
- Interviews
    - o Describe customer requirements by segment
    - o Assess related strength and weaknesses by segment
    - o Understanding barriers
        - Human resources
        - Financial
        - Capacity
        - Product lines and customer
        - Past capital of investments

All too often the justification of information technology take a one-dimensional approach that centres on the IT's ability to process transactions more effectively (Krass, 1999:19-26). The more compelling arguments underscore the investment's hard benefits; the impact of an IT-enhanced supply chain on return on investment (ROI), net income and cash flow. As depicted in more detail in Figure 3.31, the developing of a business case for Supply Chain Management (SCM) applications should comprise of these major steps:

- Define the drivers of the IT initiative
- Let the business drive the requirements
- Perform internal benchmarking
- Survey the playing field
- Understand the company's performance measures
- Develop a program portfolio of improvement projects
- Finalise the business case

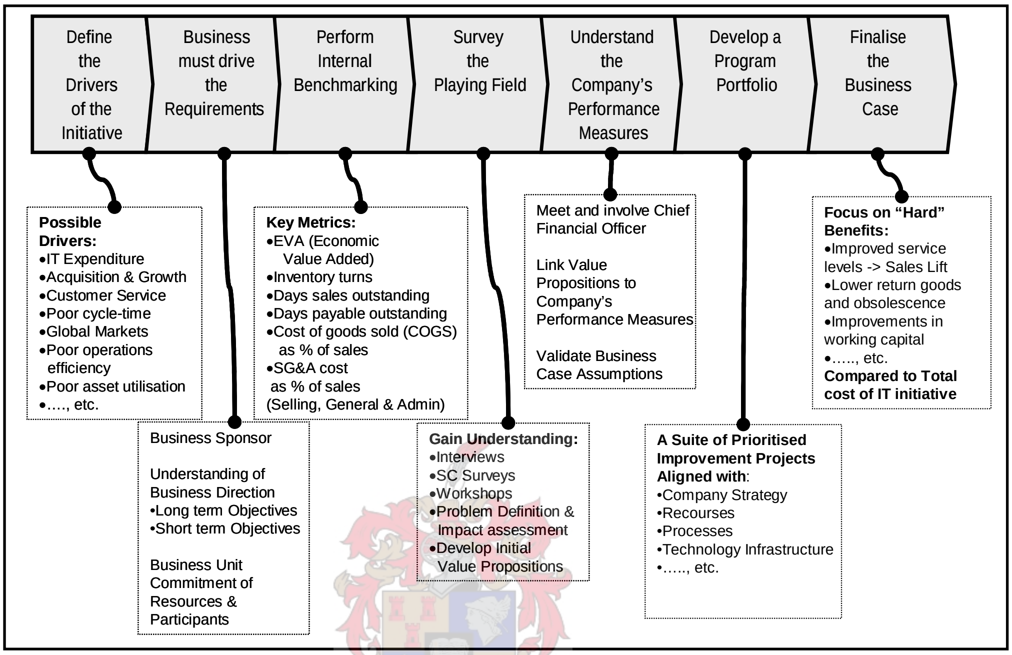


Figure 3.31 : Developing a business case for SCM enabling technology
[Source: Krass, 1999:19-26]

Langemann (2002:12) also provides a number of high-level steps that develop into a "case for change". This supply chain value assessment (SCVA) process approach, as developed by KPMG, is shown in Figure 3.32. This is a combination between processes and technology (practice solution), and the required supply chain controlling and value management activities.

Field (2002:55) states that although managers should hope for the best case scenario in putting together the cost justification for a project, they need to plan for the worst case scenario. By performing some sensitivity analysis, project managers can gain insights into how "wrong" the data (defined ranges on each data item) can be and still remain confident that the project is financially viable.

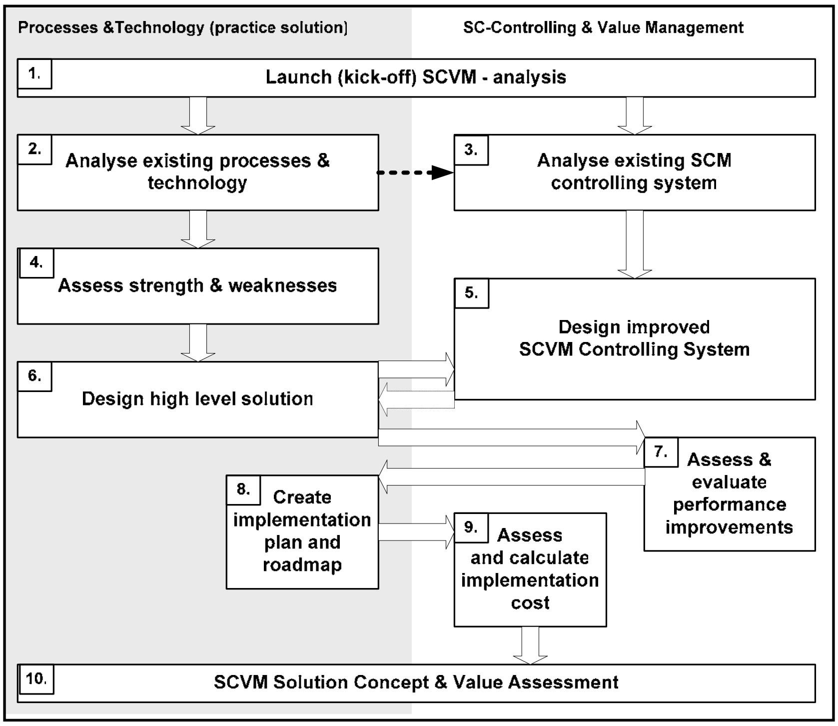


Figure 3.32 : Supply chain value assessment (SCVA) approach
[Source: Langemann, 2002:12]

Supply chain management (SCM) has the potential to help provide higher returns to shareholders (Timme, 2004:2). Few companies yet use SCM as the enabler to manage overall financial performance. To make the financial and SCM connection, a top-down approach should be used. Making a financial (SCM) connection can be achieved by a top-down approach comprising three steps:

Step 1: Calculate value of gaps in key financial performance measures

> *(SCM drives key financial performance measures such as revenue growth, percentage cost of goods sold, and days in inventory (DII)*

Step 2: Link gaps in financial performance measures to SCM business processes and strategies

> *(This linking/mapping provides a better understanding of the cause-and-effect relationships between SCM business activities and financial performance)*

Step 3: Map SCM initiatives to financial performance gaps

> *(Step 1 and 2 is used as the foundation for exploring SCM solutions that improve the SCM-related business processes and strategies underlying the gaps in the key financial performance measures)*

3.3.5 Enabling technology: application for supply chain planning

Information technologies provide the means to enabling a number of best practices in advanced supply chain planning. There are some challenges and risks associated with the application of information technology. Notice should be taken from the lessons learned in supply chain improvement and Advanced Planning and Scheduling (APS) projects, whether successful or failure. Selecting the correct APS system for the problem at hand is of vital importance to derive the benefits anticipated. Once a supply chain planning improvement project has been completed, a continuous improvements program should be put in place to assure the sustaining of value and benefits promised before implementation.

3.3.5.1 Challenges and Lessons learned from implementations

Improving decision making isn't only about putting a new system in place. There are a number of major implementation challenges. These challenges for an APS system include: unclear responsibilities and accountabilities; new behaviour required; resourcing the change; the process challenge; manage the tradeoffs; technical challenge; traditional integration; multi-vendor gateways required; powerful tools but not yet a reality; and communications (PWC, 1999a:111).

Brosset (1999:27) indicate that many IT implementation programs fail due to the following reasons:

To complex: programs lose momentum as users lose patience waiting for the ultimate solution

Too costly to develop: management support gets eroded by the evaporation ROI of the program

Too costly to maintain: systems stop evolving because the cost of just keeping them alive is all the firm can bear

Langemann (2002:6) indicate that some major reasons for cancellation and refusal regarding supply chain enabling technology implementations are:

- Benefit not recognisable
- Function inappropriate for industry
- Function inappropriate for business processes
- Estimated project costs to high
- Technological lack at partners
- Lack of integrating the software
- SCM Market too in-transparent
- Rejection from business partners
- Security risk by exchanging data
- No suitable realisation partners found
- Immature supply chain software
- Lack of understanding for collaboration
- Internal factors
- Other external factors

According to Cameron & Duckett (1996:4) failure to effectively introduce new systems, or to automate manual processes, can be costly. As indicated in Figure 3.33 there are a number of common faults made during implementation. The cost can be either direct or indirect:

Direct costs

- Correction of defects in the system's post-implementation
- Exceeding the development time and budget
- High and unnecessary cost of excessive system maintenance

Indirect costs

- Lower employee motivation and commitment
- Opportunity cost of not doing alternative projects
- Potential customer dissatisfaction due to inefficient system

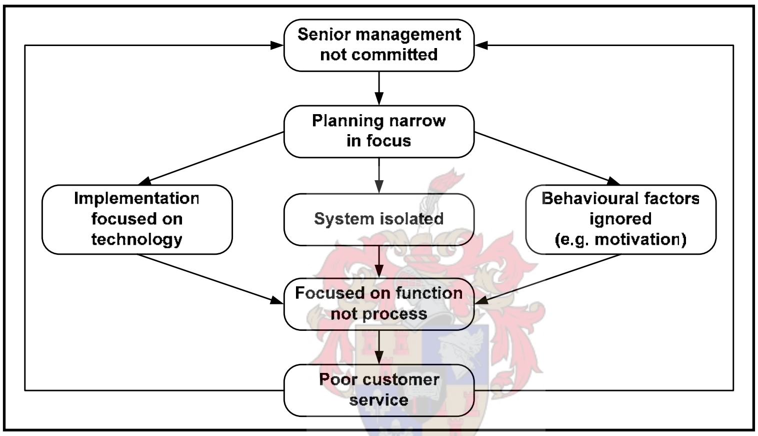


Figure 3.33 : Common faults made during implementation
[Source: Cameron & Duckett, 1996:4]

3.3.5.2 *APS and supply chain improvement projects*

According to Shen, Lee & Van Buskirk (2001:69) planning software implementation is actually about integrating data, business processes, and support systems (all three must be in place for successful implementation).

The APS implementation process typically goes through the following phases (Wetterauer, 2000:229):

- Focus (project activities are planned for each of the identified focus areas)
- Design conceptual solution (proposed solution is refined, adapted to the selected software and presented to senior management for review and approval)
- Design detailed solution (change management and assuring quality of basic data)
- Build and test (key components of the detailed business solution are constructed)
- Deployment (the business solutions is made fully operational)

A typical APS and supply chain improvement project primarily requires focus on the planning processes and the relationship to the partners in the supply chain (C.

Kilger, 2000a:197). A good understanding of the business is vital. Assessment of potential improvement areas requires thorough understanding of the following questions: Where are we today? Where do we want to go? How do we get there?

C. Kilger (2000a:198) also indicates that a proper supply chain review is required through interviews, questionnaires and review of available information. The typical business areas to cover are:

- Executive management
- Sales
- Product management and engineering
- Procurement
- Order management
- Production
- Distribution
- Suppliers, customers and competitors
- Coordination and integration technology

Supply chain potential analysis would normally include performance measures of profits enhancement, ROI/ROA and cash flow improvement (C. Kilger, 2000a:207).

The project road map need to create a value network comprising of the following interrelated components as indicated in Figure 3.34 (C. Kilger, 2000a:211):

- Identify all the major value components
- Link the major value component to expected improvements in the following logistical KPIs:
    - Forecast accuracy
    - Planning cycle time
    - Customer service level
    - On time delivery
    - Order fill rate
    - Order lead time
    - Inventory turns
    - Inventory age
- Determine which functionality of APS technology will enhance the logistical KPIs

Supply chain planning implementation projects consists of a series of business releases (BRs) with increasing capability and broadening scope (Shen, Lee & Van Buskirk, 2001:69). The first business releases are normally driven by four main costs components: foundation building and business analysis; data migration and cleanup; functionality tests; parallel run.

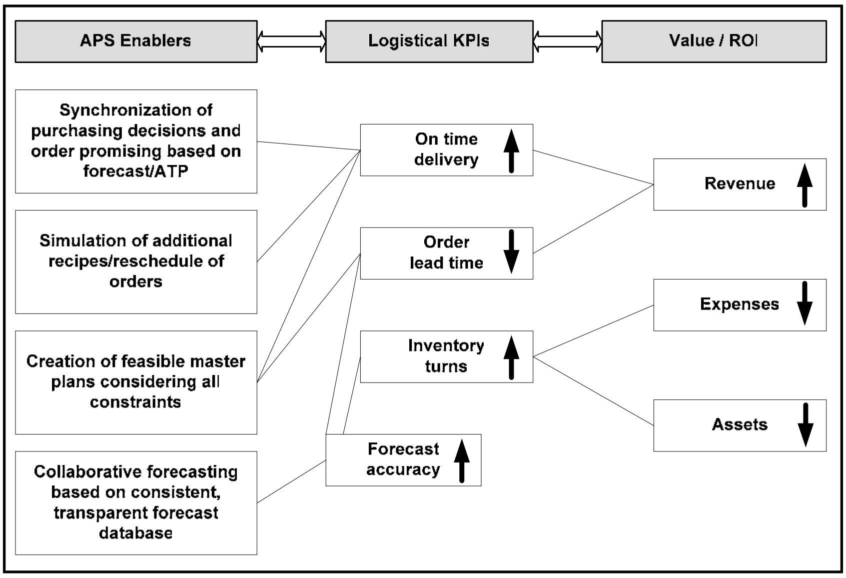


Figure 3.34 : Enabler and KPI value network
[Source: C. Kilger, 2000a:213]

The major cost items to budget for with the execution of large-scale APS projects and programs are infrastructure, software, integration, data cleanup, internal staff and external staff (Peterson, 1999:15,16). An in-house competency centre is normally a practice for companies with large-scale company-wide APS projects and programs. These competency centres fulfil the following purpose:

- Thought Leadership
- Release Planning and Testing
- Business Strategy Synchronization
- Central Configuration
- Program Office
- "Consulting"
- Help Desk Support
- Integration

Peterson (1999:17) indicates that consulting partners should be selected very carefully. A company should select the consulting partners from a strategic point of view. The actual consulting resources should however be selected tactically (i.e. pick the individuals that would have the right competencies and provide the skills mix to make the project successful). Use a SCP best-practice checklist to utilise the appropriate organizational and infrastructure practices. The typical team structure for large-scale APS projects and programs consist of the following:

- Executive Champion (The "Executive Connection")
- Program Manager (Keeper of the Plan)
- Consulting (30%)
- Business Team (50%)
- IT Professionals (20%)

Firms can leverage greater benefits from IT investments if they align their strategies, systems and processes by adopting a concurrent approach to technology implementation and supply chains strategy (Gattorna & Hanlock, 1999:11). The concurrent approach involves companies devising their supply chains strategy, reviewing organizational capability and implementing change at the same time as introducing the underpinning technology (see Figure 3.35). Through this approach a company can accelerate the benefits of this technology investment, achieve greater integration of their supply chains and be equipped to sustain the benefit. Organization strategy should build capabilities for integration and collaboration and manage the efficient flow of information. Change strategy is needed to mobilize the workforce, provide training on new systems and build a new culture that supports an integrated approach to managing the supply chain.

3.3.5.3 Selecting an advanced planning and scheduling (APS) system

According to Peterson (1999:1) the evaluation of SCP solution providers (providing APS technology) should include the assessment of the vendor's vision, viability, technology, functionality, service/support and technology cost. A company should also assess the vendor's domain expertise, functionality of the technology and advancement in industry-specific functionality.

A company should choose a system that matches the company's industry, business style, corporate culture and IT infrastructure (Murphy & Sherman, 1998:66). The approach to modelling and optimization should also be assessed. ***Firstly,*** this includes assessing what type of mathematical models (major category) would describe the aspect of the supply chain that the company wants to improve (scope). ***Secondly*** it would indicate what sophisticated mathematical optimization techniques are employed to find the most optimal solution to the model. These two important factors would assess if the model fit the business as closely as possible, and that the optimization techniques are suitable for the model.

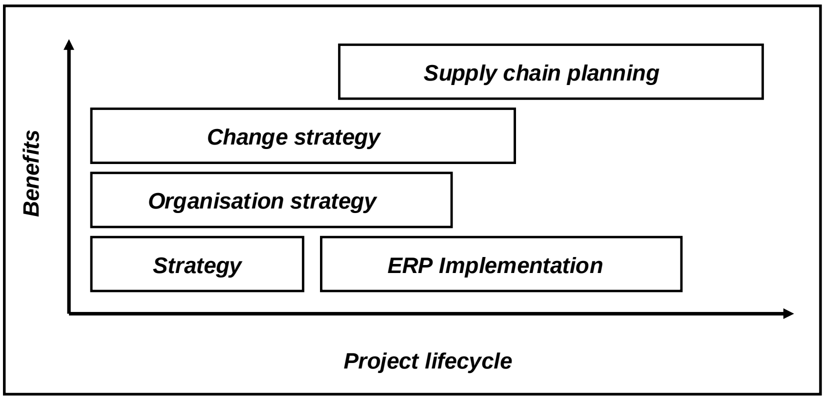


Figure 3.35 : Concurrent intervention approach
[Source: Gattorna & Hanlock, 1999:11]

Organizations should take a tactical approach to the investment decisions when selecting APS systems. They should make sure to get payback on their APS investment decision within that timeframe, or risk costly upgrades. The following guideline should be followed for selecting an APS system (PWC, 1999a:109):

- Select a system that can solve the business problems, not provide you with functionality
- Must be able to create a solution for the business problem at hand
- The vendor must be able to provide support in the countries required
- Does the system follow the industry trends and best practices?
- Select a system that has already been integrated with the company's transaction system

According to Ferrari (2000:4) process and discrete manufacturing industries solve, optimize, and manage planning and scheduling problems differently. The context and logic are different for each industry sector. Unique planning and manufacturing process characteristics drive each industry, and each industry grouping has certain degrees of complexity, variations and emphasis. Manufacturers want their planning and scheduling applications up and running as quickly as possible to start realising the benefits. So, they must evaluate the time, fit, and resources required for a successful overall implementation. APS vendors tend to pre-configure software components and industry templates for a positive impact from all three of these criteria. A brief description of each criteria is:

Time: How long until benefits are realized

Fit: The ability of the software to solve the planning business problem and, from a vertical industry perspective, to know upfront that the functionality has a higher probability of solving specific user needs

Resources: The sum total of the cost, people, and management attention needed to ensure that risk is minimized and a successful implementation is achieved

Selecting an appropriate DSS (e.g. APS) for a supply chain should be based on the following considerations (D. Simchi-Levi, Kamisnsky & E. Simchi-Levi, 2000:272):

- Scope of the problem addressed
- Data requirements
- User interface capabilities
- Analysis requirements
- Systems ability to generate a variety of solutions
- Presentation requirements
- Compatibility and integration with existing systems
- Hardware and software systems requirements
- Overall price (Basic model, customization, and long term upgrade)
- Complimentary systems

According to Lowe (as quoted by Hill Jr., 2000:65), if a company already has some supply chain applications installed, they should probably consider extending those by purchasing additional applications from the same vendor unless the vendor is clearly no longer focused on your market. In choosing distribution software, aspects that should be assessed are (Redmond, 1998:50):

- Is it sufficiently easy to use?
- Can it be set up to produce efficient, automatic schedules reliably in my operation?
- Will I get the support and backup I need from the supplier (implementation)?
- Can the supplier help modify the system when needed?

As Supply Chain Planning (SCP) system deployment becomes more important, and enterprises feel the pressure to choose and implement quickly, the risk of selecting the wrong product for the wrong reasons grows (Peterson, 2000:1). Some of the selection guidelines are:

- Vendor's SCP Domain Expertise: (Application maturity)
    - Functional maturity. (Maturity may not span the whole suite)
    - Vertical maturity. (Industry experience)
- Choice of the number of SCP planning suites to purchase: (large suite selections vs. taking an incremental approach)
- A reference is not always a reference: (References should be from companies with the same demographics)
- One should see the SCP solution in action: (Demos / Pilots should be driven by enterprise data and a scripted scenario)
- Assess the collaboration capabilities: (Selecting an SCP system that enables collaboration is now a necessity)

The choosing of a supply chain planning system involves a lot of self analysis as well as a vendor research (Murphy & Sherman, 1998:66). First and most important is to undertake a self analysis (what APS can do realistically and plan on first implementing the planning solutions that provides the highest return on investment). The company should examine its data on a number of levels to determine whether proper formats have been used in doing statistical scans of data for the anomalies that might adversely affect planning.

C. Kilger (2000b:217) also provide an APS selection process comprising of the following major steps and considerations:

- Short list of APS systems based on the following criteria:
    - Industry focus and experience
    - Size of APS users community
    - License fees
    - Implementation time and costs
- Functional requirement (SC Planning Matrix)
- Implementation and integration issues:

- o Implementation of APS functionality
- o Integration technology
- Post implementation
  - o Yearly Maintenance
  - o Cost of release updates
  - o Cost of system administration
  - o Costs for users support

The trend towards manager friendly supply chain solutions has been evident only in the last few years (D. Simchi-Levi, 2000:80). One thing, however, hasn't changed. To use these tools effectively, you still need to know your subject matter. A firm still needs to grasp the basic principles of logistics and supply chain management.

3.3.5.4 Successful implementation

In following a concurrent approach to IT investments there are a number of key capability requirements (Gattorna & Hanlock, 1999:15). It is important to have strategic alignment of supply chain strategies with overall business strategy. There should be adequate technology competence (to access and effectively use existing technology). The organization should have the ability to move away from operating in functional silos to adopting a true process orientation. The organization's capacity for change and the ability to institutionalize change is of prime importance. The ability to execute also hinges on navigation, enablement, leadership, and ownership.

High levels of information availability are related to successful implementation of the integrated distribution concepts (Gustin, Doughtery & Stank, 1995:13). It will however be necessary to require:

- High levels of logistics information availability for strategic, tactical and operational decisions.
- High levels of availability of information from other functional areas of the firm
- Enhanced information system performance

Supply Chain software [Advanced Planning and Scheduling (APS), Advanced Planning Systems (APS), Advanced Planning and Optimisation (APO), Supply Chain Management (SCM)] falls into the "beyond ERP" and "decision support" space with the objective of optimising the Supply Chain (Louw, 2002:1). A number of lessons learned from ERP implementations also apply to APS Technology:

- There is an underlying value and benefit (business case) in implementing these systems.
- These system implementations are similar to ERP implementations in their heavy focus on supply chain business processes and impact across the organization.
- Both in South Africa and worldwide, companies experienced significant trauma in implementing ERP systems over the past ten years.

- Unless radically challenged, Advanced Supply Chain implementations will experience the same trauma as ERP.
- The key barriers to realising business value are organizational, rather than underlying technology.
- South African companies have the ability to learn from other company's experiences, time and money.

In many cases SCP initiatives start with the implementation of a demand planning module (Bermudez *et al.*, 2003). This is a sound strategy, since an accurate demand forecast (the best representation of future customer needs) from demand planning modules drive other tactical and operational planning, including supply planning and replenishment and production scheduling. Demand planning is also the module that is most often operated at a central, sometimes enterprise level for tactical and strategic planning, requiring less real-time integration into legacy systems. This makes system implementation somewhat easier. (Bermudez *et al* (2003) also suggest that in implementing SCP software, companies must make sure to fully understand what they are getting into. In this regard, recommendations to users are:

- Focus heavily on project management throughout the implementation, as each SCP module can take from six months to longer than a year to install with the requisite business process changes. While there is wide variation in implementation times, these can be shortened with disciplined project management.
- Provide enough internal resources throughout the implementation, since SCP installations involve heavy doses of business process change and integration with legacy systems. These resources need to include both IT and business owners that are movers and shakers, unafraid to make the business process changes needed and willing to be involved for an extended period of time.
- Allow project team members extra time up-front to learn the software and how it needs to be integrated to existing systems. Work with your software vendor to get this training, or SI, if one is involved.

3.3.5.5 Sustaining value as a result of interventions

According to Lapide (as quoted by Murphy & Sherman, 1998:62) there are a number of requirements for sustainable change relating to APS system implementations. APS systems need to be properly introduced into a corporate culture.

> *"You don't get sustainable change if you can't implement the software, and if the people don't use the software. If it takes too long to implement and to get the return on investment, you don't get the benefit."*

Supply Chain Performance Management (SCPM) during implementation is an important ingredient to monitor if the solution will still adequately reflect the design intent (Langemann, 2002:24). The major steps if the SCPM process is shown in Figure 3.36.

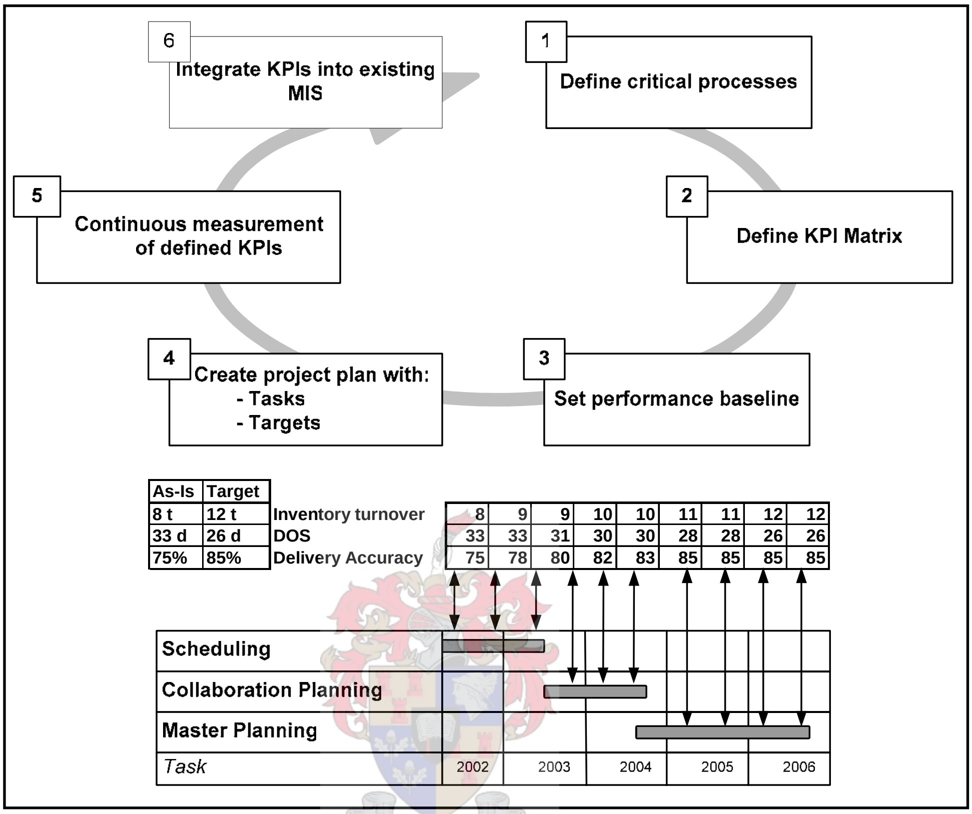


Figure 3.36 : Supply Chain Performance Management (SCPM) during implementation
[Source: Langemann, 2002:24]

Supply chain improvements typically require a series of well-timed projects. These projects should be sensibly separated by periods of institutionalization (Supply Chain Consultants, 2002:1). There is a substantial risk, during these periods, to regress to the "old ways of doing things." A successful project is necessary but not sufficient for sustainable supply chain improvement. Some reasons why companies struggle to sustain step change improvements are: (a) The software doesn't do what you need it to do, (b) The users move on, or (c) The planning is "too successful". The companies that are successful in sustaining improvements have three things in common:

- They consider supply chain planning and execution to be a key competency.
- Supply Chain management is viewed as a professional activity.
- Within an overall Information Systems (IS) strategy, these companies are constantly looking for improved technology.

To get the additional value from SC investment, initiatives should act directly on improving supply chain value drivers (Gray et al., 2003:22-27). The performance in these value drivers are easily measured and indicate their ultimate impact on financial performance measures. A process to follow is:

a) Analyse supply chain value drivers

A company should analyse causes for supply chain value improvement, not just the effect. The traditional return on investment (ROI) analysis focuses on the financial performance impact while most supply chain initiatives usually deliver much of the business value by improving operational performance.

Identifying value drivers (SC operations performance measures) should adhere to/must be directly affected by a supply chain solution or initiative; must have an impact (direct or indirect) on at least one of the firm's key performance indicators (KPIs).

A company needs to understand its supply chain value drivers. These are typical levers that an initiative can turn into enhanced business performance. Some examples are:

- Procurement cycle time (days)
- Master planning cycle time (days)
- Supply lead time (days)
- Production planning cycle time (days)
- Premium freight costs ($)
- Demand planning cycle time (days)
- Forecast error (%)
- Customer service management costs ($)
- Defective orders (% of total orders)
- Invoice errors (% of total invoices)
- Total order processing time (days)
- Volume of returns (% of sales)
- Order ship to customer invoice (days)

b) Quantify value driver impact

It involves the building of a model to evaluate the link between supply chain performance and business value (financial performance). The methods that can be used include: interview subject matter experts, analyse historic data, multiple regression analysis, pilot projects, mathematical models, Monte Carlo simulation and discrete event simulation.

c) *Use a common framework (be consistent)*

A company needs to develop a common, consistent framework for comparing and evaluating initiatives. This framework should use the same evaluation criteria and typical value drivers for proposed supply chain planning solutions.

d) *Link ROI to business strategy (don't just follow the money -ROI)*

Consider management objectives that go beyond immediate financial benefits and focus on strategic intent. Link the analysis directly to a balance scorecard that includes both financial and non-financial performance measures. Identify a set of KPIs considered critical to business success and provide additional insight that can improve decision making.

e) *Consider the risks*

Understand each initiative's likelihood of success and how it helps the supply chain adapt and respond to changes in your business environment. The two major types of risk include:

Implementation risk: project delays, cost overruns, outright project cancellation

Business risk: changes in business or operations environment (must execute scenario analysis)

f) *Put ROI to work*

Don't just use financial analysis to define initiatives and the associated value drives. Instead, use the value drives to define the supply chain strategy and to focus and manage supply chain efforts during deployment/rollout and after they have been implemented.

3.4 Summary of literature study related to Decision Support Systems (DSS) and roadmaps for interventions

The advancement and reduced cost of information technology created numerous opportunities to computerize best practice applications. Decision Support Systems (DSS) typically provide analytical capability to aid in supply chain planning. The major components of a DSS are a database, a model base and some form of graphical user interface. Enterprise Recourse Planning (ERP) and Advance Planning and Scheduling (APS) Systems are two major types of decision support systems for the supply chain domain. APS systems are well suited to support the decisions applicable in supply chain planning and use some of the ERP's aggregated data as input. Supply chain planning systems also need information from other parties in the supply chain that does not always reside in the focal company's ERP system. An appropriate data repository for inputs and outputs of DSS is a critical part of the architecture. For two separate applications to share data in a seamless, "plug-and-play" fashion they must share a common data model.

Performance measures and indicators play an important role in the quantification of benefits and ensuring the sustaining of benefit. The SCOR performance measures framework provides a sound basis for deriving an appropriate supply chain balanced scorecard. The key is to focus on the few critical performance measures that really matter and to understand the interdependencies among theses performance measures.

An emerging organizational trend is to view the supply chain from an integrated holistic perspective rather than as a collection of independent activities. Any company should carefully plan interventions related to a process approach in managing their company and using enabling technology for decision support. The correct organizational structure approach can facilitate intra- and inter-organizational integration. Comprehensive decentralisation in many large corporations has created a situation in which different business models have evolved. These business models should be integrated from an organizational and governance perspective, to allow and promote cross unit cooperation where appropriate to achieve enterprise strategic alignment, to reduce confusion and to reduce the cost of decentralisation.

Planning to incorporate advance supply chain planning processes into a corporation's long/medium term decisions also require a cross-functional and systems approach. For this a framework and programme road map must be tailored to suit the business's specific realities and challenges. The approach and process followed should be appropriate for the business challenges, and must incorporate key enablers for change. Well-established organizational mechanisms and principles are one of the critical success factors essential for successful process investment. To be successful in the future, a supply chain manager needs to be of that rare breed; a non hierarchical, facilitation oriented manager.

Integrated supply chain planning requires technological and organizational development within a company and its supply chain partners. Culture, structure and leadership style strongly affect the kinds of process changes a company will attempt, and the kinds it is likely to carry out successfully.

Conducting a high level impact assessment is normally the best way to identify if substantial benefits could be achieved through advancement in supply chain management approaches. A clear vision and strategy for supply chain planning interventions ensures alignment among all the stakeholders involved. The role-out plan should be a portfolio of interrelated releases of new supply chain planning process. Strong project management techniques are required to prevent scope increase and to keep the project on schedule. Each process and system release should be designed to last not more than 3 to 6 months. This is required to sustain project momentum through regular financial business successes. Releases of new/reengineered supply chain planning processes should iterate through cycles of design, build and deploy. These cycles assure the delivery of the anticipated business functionality and value.

Chapter 4: Overview and challenges of the petrochemical industry; areas of improvement in integration

Chapter 4 is the last chapter in the literature review and provides the required orientation about the petrochemical industry. The fundamental differences between process and petrochemical manufacturing businesses compared to other discrete manufacturing businesses are highlighted. Supply chain planning challenges and typical problems to solve in the petrochemical industry are related to the typical nature, structure, current situation, level of advancement, organizational issues, and opportunities for improvement.

4.1 Current situation: petrochemical industry

The petroleum industry is currently organized into several businesses along the supply chain: crude oil acquisition and trading, refining, wholesale supply, trading and distribution, and retail marketing and distribution (Petrolsoft, 2000:2). Figure 4.1 indicates the typical stages in the petroleum supply chain. It also highlights the major activities upstream and downstream of the refinery.

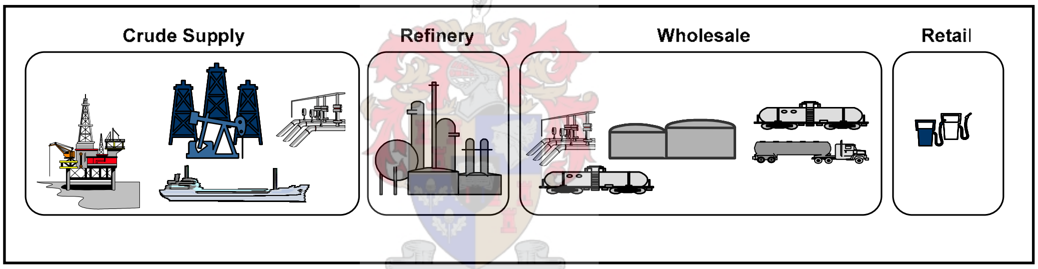


Figure 4.1 : The petroleum supply chain

[Source: Adapted from Petrolsoft, 2000:2]

Since the early to mid eighties most international petrochemical companies have slashed fixed costs and staffing by 25% to 30%. (Krenek, 1997:97). The industry remains highly cyclic (mostly due to commodity prices). There are a multiplicity of new companies in developing regions and entrenched multi-nationals scrambling for and defending global market share. Global chemical companies have close interaction with feedstock suppliers, thus making them very dependent. Frequently they deal with the parent company as a supplier and/or customer (internal transfers; intermediate commodities to value add products). Proper planning and forecasting is critical in the chemical industry due to the 24 hour operations, which leaves less production flexibility.

4.1.1 Types of manufacturing processes

Products are manufactured through a number of different manufacturing processes as indicated in Figure 4.2 (Waller, 1999:167). These manufacturing processes differ largely due to their flexibility, product volume and unit cost. The various manufacturing processes are:

- Job shop
- Assembly line
- Batch and campaign process
- Continuous flow

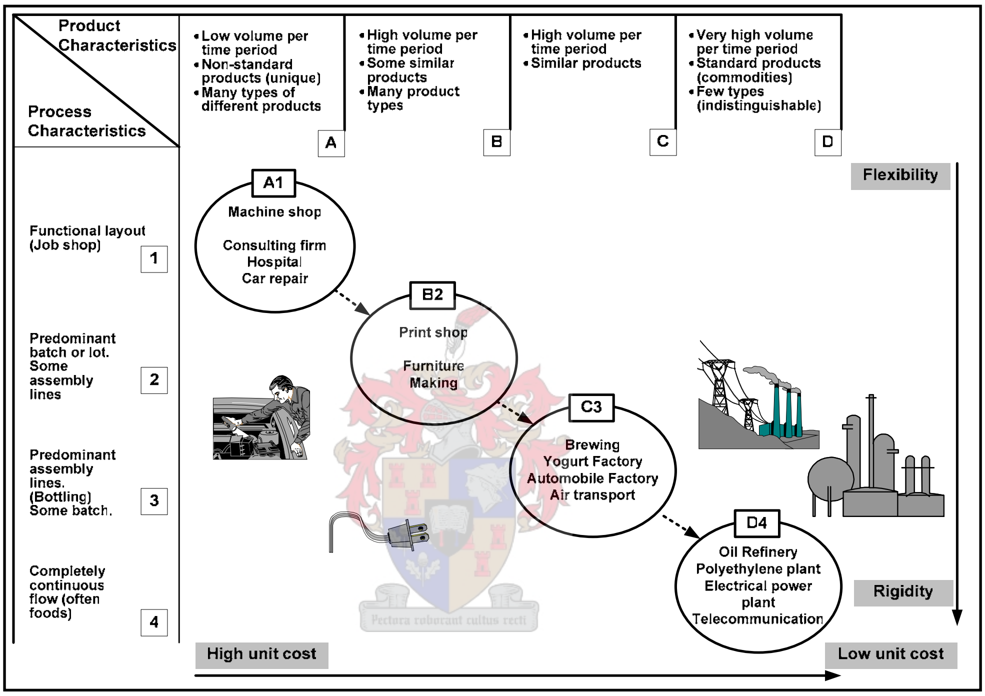


Figure 4.2 : Correlation of the product and the process
[Source: Waller, 1999:167]

The North American Industry Classification System (NAICS) classifies the economic sectors into twelve major super-sectors. This is a helpful starting point in understanding the major industry sectors (see Table 4.1). These sectors can also be categorised into primary (production, e.g. mining), secondary (manufacturing, e.g. clothing) and tertiary (services, e.g. transport & distribution). The Department of Trade and Industry (2004a) uses the Standard Industrial Classification (SIC) system in South Africa. As indicated in Table 4.2, the manufacturing sector is divided into ten sub-sectors — SIC 2 (Aggregated view of the 27 manufacturing sub-sectors (SIC 3)).

Process industries typically account for half of all types of manufacturing, and this number is growing. The South African chemical industry contributes around 5% to GDP and approximately 25% of its manufacturing revenue (Centre for Logistics, 2005:20).

Based on these SIC classifications, the manufacturing processes used can be viewed as two extremes; from discrete to process (Rossouw, 1994:26). Figure 4.3 indicates the major manufacturing groups ranging from project, jobbing, batch, line to process. Process manufacturers differ from discrete manufacturers fundamentally in their nature and the philosophies followed. This implies that the rules for discrete industries are invariably not directly applicable to process industries.

Table 4.1 : Twelve major super-sectors
[Source: U.S. Census Bureau, 2002]

Super-sectors
Construction
Education and health services
Financial activities
Government
Information
Leisure and hospitality
Manufacturing
Natural resources and mining
Other services
Professional and business services
Transportation and Utilities
Wholesale and Retail Trade

Table 4.2 : Ten manufacturing sub-sectors (SIC 2)
[Source: Department of trade and industry, 2004]

Manufacturing sub-sector:
Manufacturing of food products, beverages and tobacco products
Manufacturing of textiles, clothing and leather goods
Manufacturing of wood and of products of wood and cork, except furniture; Manufacturing of articles of straw and plaiting materials; Manufacturing of paper and paper products; publishing, printing and reproduction of recorded media
Manufacturing of coke, refined **petroleum products** and nuclear fuel; Manufacturing of chemicals and **chemical products**; Manufacturing of rubber and plastic products
Manufacturing of other non-metallic mineral products
Manufacturing of basic metals, fabricated metal products, machinery and equipment and of office, accounting and computing machinery
Manufacturing of electrical machinery and apparatus N.E.C.
Manufacturing of radio, television and communication equipment and apparatus and of medical, precision and optical instruments, watches and clocks
Manufacturing of transport equipment
Manufacturing of furniture; manufacturing N.E.C.; recycling

Liquid and discrete products also differ in relation to the logistics and supply chain practices applicable. A liquid product supply chain network (when properly designed) has some specific attributes and requirements (Klatch & Walker, 2005:90). Table 4.3 articulate some specific liquid and discrete products characteristics.

Dimention	Discrete		Process
Examples	Ships	⟷	Petroleum
Raw materials	Many	⟷	Few
No of sub-parts	Many	⟷	Few
Work in progress	Variable	⟷	Constant
Finished products	Few	⟷	Many
Production quantity/volume	Low	⟷	High
Production lead time	Long	⟷	Short
Production rate	Low	⟷	High
Skill & experience level	Low	⟷	High
Equipment and tooling	General	⟷	Specific
Throughput constraints	Materials	⟷	Capacity
Production control	Low	⟷	High
Manufacturing cost (fixed)	Low	⟷	High
Marketing cost	Low	⟷	High
Value per mass	High	⟷	Low
Process reversibility	High	⟷	Low
Measurement	Unit	⟷	Quantity
Manufactured / market unit	Same	⟷	Varies
Facility expandability	Simple	⟷	Complex

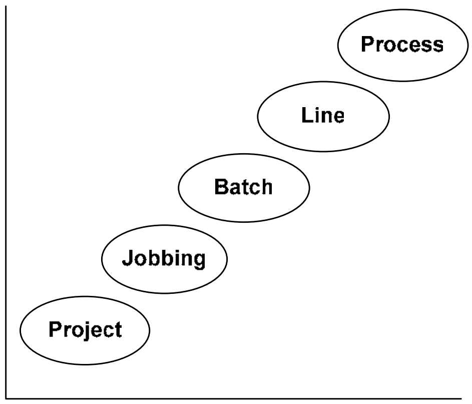


Figure 4.3 : Fundamental differences between discrete and process manufacturing [Source: Rossouw, 1994:26]

Table 4.3 : Liquid and discrete products characteristics
[Source: Klatch & Walker, 2005:91]

Liquid Products	Discrete Products
Ingredients defined by a recipe are multiplied to increase product quantities.	Parts defined by a bill of materials are multiplied to increase product quantities.
Tend to flow.	Tend to remain stationary.
Can be ubiquitous throughout the network.	Are concentrated within the network.
Product and transport can be integrated.	Require non-value-added packaging to be transported.
Product and storage can be integrated.	Require non-value-added packaging to be stored.
Require parallel networks or time segmentation or physical segmentation to handle multiple products.	Multiple products can be easily integrated into a single supply chain network.
Are generally treated as a special case of packaging within discrete networks.	Are never treated or transported or stored within liquid networks.

4.1.2 Petrochemical products

Organic compounds comprise more than 95% of all compounds known to exist (Burdick & Leffler, 2001:1-5). All petrochemicals have hydrogen and carbon as the generic atoms forming hydrocarbon bonds. Some examples of the chemical structure of these petrochemicals are shown in Figure 4.4.

Burdick & Leffler (2001:1-5) also provides a helpful overview classification of organic chemicals. Figure 4.5 provides this generally accepted breakdown of organic chemicals. Typical examples of end products based on this breakdown are:

- ***Aliphatic hydrocarbons:***
    - o *Saturated* (Single bond)

      E.g. Paraffins (Methane, Ethane, Propane, Butane).

      These products are found more in refineries and distillation and fractionation are used to produce them.

- *Unsaturated* (Multiple bonds - less stable)
  E.g. Olefins (Ethylene, Propylene, Butylene)
  These products are found more in chemical plants and reaction and distillation are used to produce them.

- ***Cyclic hydrocarbons:***
  - *Alicyclic* (closed loop single bond) - Cyclopropane; Cyclopentane; Cyclohexane
  - *Aromatics* (Double bond loops) - Benzene, Toluene, Xylene
  - *Heterocyclics* (Other atoms also in bond - e.g. Oxygen, Nitrogen, Sulfur)
    These are typically oxygenated hydrocarbons (Alcohols, Ketones, Aldehydes, Acids, Esters, Ethers, Anhydrides) and nitrogen based organic compounds (Amines, Nitro-compounds, Nitriles)

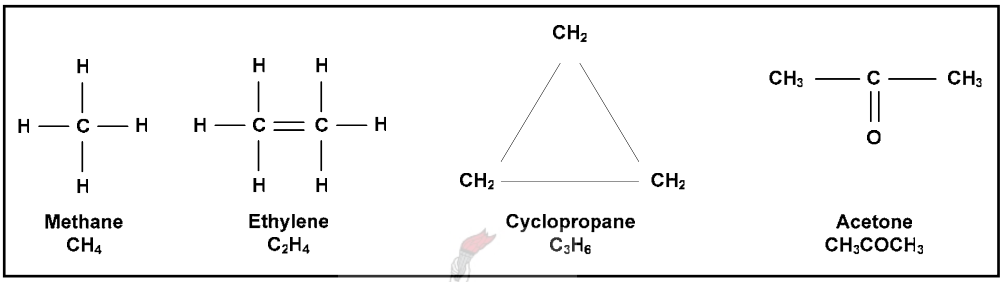


Figure 4.4 : Example of the structure of some petrochemicals
[Source: Burdick & Leffler, 2001:1-5]

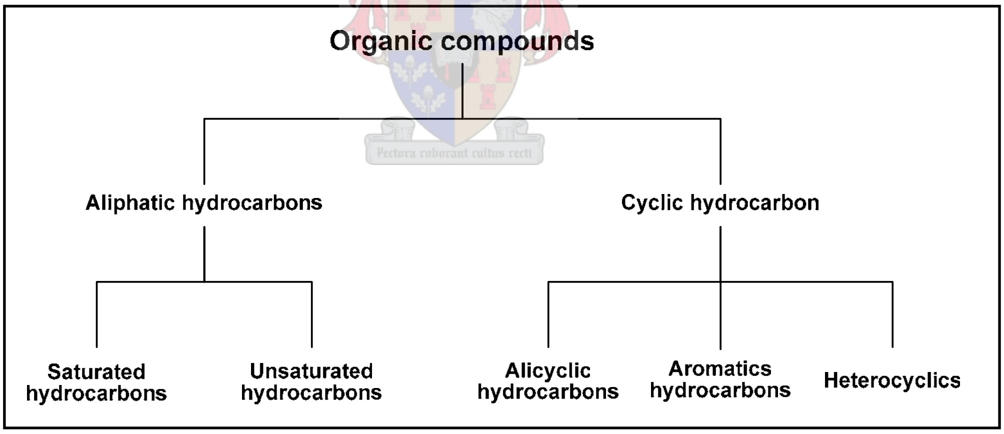


Figure 4.5 : Classifications of organic chemicals
[Source: Burdick & Leffler, 2001:5]

The petrochemicals value chain starts with its basic raw material sources of coal, natural gas and oil (Burdick & Leffler, 1996:1). From these raw materials the chemical building blocks are manufactured. These chemical building blocks include Propylene, Ethylene, Methane, Butanes, Butylenes, Butadiene, Benzene, Xylene, and Toluene. The chemical building blocks can be further refined to produce derivatives. An example is the derivatives produced from Propylene. These include Cumene, Isopropyl Alcohol, Butyraldehyde, Acrylonitrile, Acrylic Acid, Acrylates and Polypropylene. The value chain ends where chemical products are typically utilised by end users. In the case of Polypropylene there are numerous end uses. These include carpeting, brushes, carpet backing, rope, tape, strapping, toys, non-woven fibre, film, sheeting, plastic bottles, ridged packing, boxes, and appliance parts.

Mbendi (2002) also provide a very good description of what typical products are produced in the South African chemicals industry. Figure 4.6 provides a "pipeline model" view of the chemical industry and indicates the relative position of products in the petrochemicals value chain. It is highly complex and widely diversified, with end products often being composed of a number of chemicals which have been combined in various ways to provide the required properties and characteristics. After the feed and consumption of inorganic and organic raw materials in the manufacturing process, the products being produced can be divided into three broad sectors:

- Primary products (feedstock and commodity chemicals)
- Secondary products (intermediate chemicals)
- Tertiary products (speciality chemicals and processed goods)

The South African chemical industry sector has a major focus on the production of base chemicals and petroleum constituting 60% of the total production value – the remainder focuses on downstream higher valued chemical production (Centre for Logistics, 2005:20). The industry is highly complex and diversified, with end-products often being composed of a number of chemicals. It is divided into four broad categories:

- Base chemicals (ethylene and other petrochemical building blocks, ammonia, acids)
- Intermediate chemicals (waxes, solvents, plastics)
- Chemical end-products (paints, explosives, fertilisers)
- Speciality end-products (pharmaceuticals, agro-chemicals).

In South Africa the Chemical Industry Sector is subdivided into 12 sub-sectors (Department of trade and industry, 2004a). Table 4.4 gives an indication of what type of products falls within each sub-sector.

The typical stages in the petrochemicals value chain with the associated feed streams and products are as indicated in Figure 4.7. The complexities of the process industry make it more challenging (than in other industries) to identify optimal economic trade-offs. For example:

- Raw materials are interchangeable, but have different impacts on manufacturing performance
- Order profitability is often dependent on the manufacturing sequence
- Economic impact of co- and by- products complicate production planning
- Requirement to comply with environmental legislation
- Competitors may compete through exchange agreements
- Transportation logistics is complex

- The majority of products are sold and delivered to internal customers
- The industry is a combination of supply push and demand pull. Optimum value comes from finding the right balance.

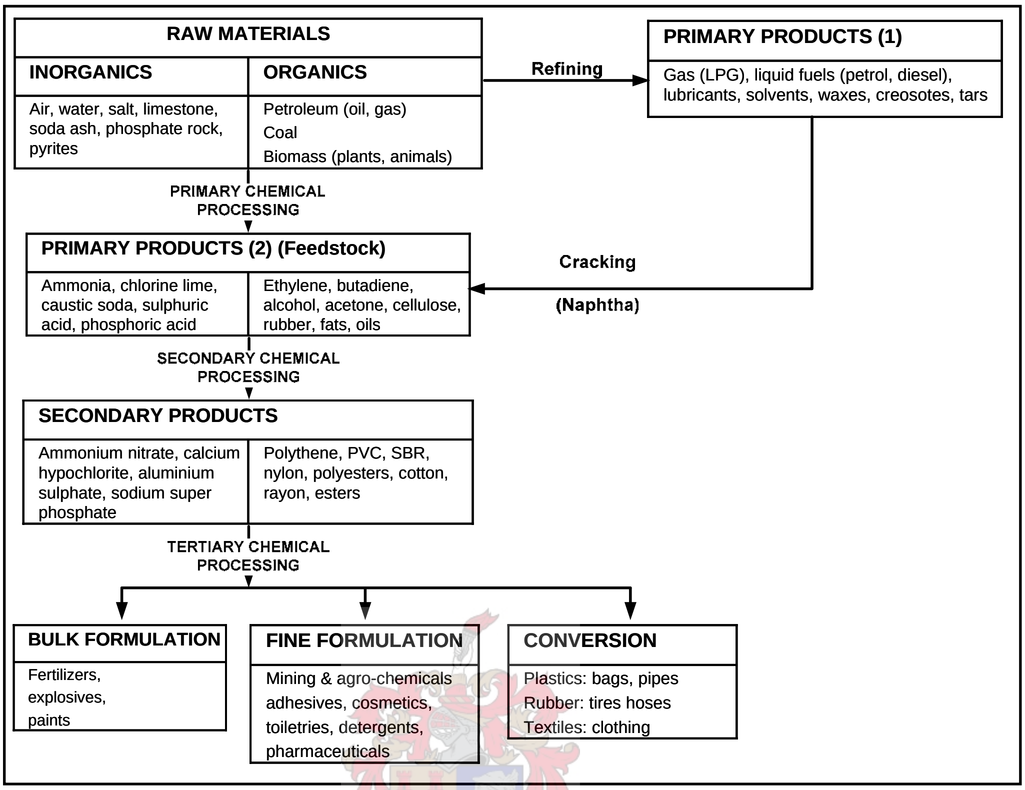


Figure 4.6 : Pipeline model of chemical industry
[Source: Mbendi, 2002]

Table 4.4 : Twelve chemical sub-sectors
[Source: Department of trade and industry, 2004]

Chemical Sub-sector	Some Major Products
Liquid Fuels	Gasoline, diesel, jet fuel, liquid petroleum gas (LPG) (Drives the Chemical Industry Sector)
Basic organic chemicals	Olefins (ethylene, propylene), and organic solvents. Derivatives (e.g. ethanol) from natural agricultural raw materials source like sugar/molasses, starch, essential oils, and dissolved pulp.
Basic polymers and rubbers	Polyolefins (polyethylene, polypropylene) and synthetic rubbers (Driver of Plastic product Markets)
Basic Inorganic	Gases, chlor-alkali, metallic salts, acids. These include industrial mineral derivatives (magnesium oxide, titanium dioxide, manganese dioxide) and inorganic gases (ammonia, oxygen, nitrogen).
Fine chemicals	Active ingredients, flavours (Pharma Active, Pesticide Active) (Pure chemical products; Higher value, low volume)
Specialty and functional	Surfactants, additives, emulsions (Water treatment, Lube additives, Mining chemicals). (Pure chemicals for Functional application & product names)
Bulk formulated	Fertilisers, explosives (ammonium nitrate). (High Volume, Lower value)
Pharmaceuticals	Analgesics, antibiotics, cardiovascular, respiratory and gastro-intestinal medicines.
Consumer Formulated	Toiletries, coatings, cleaning chemicals. (FMCG market focus)
Plastics	PE, PP, PS, PET, PVC
Rubber	Tyres, Belts
Synthetic Fibres (Textiles)	Polyester fibres (Nylon Spinner, Acrylic Fibres)

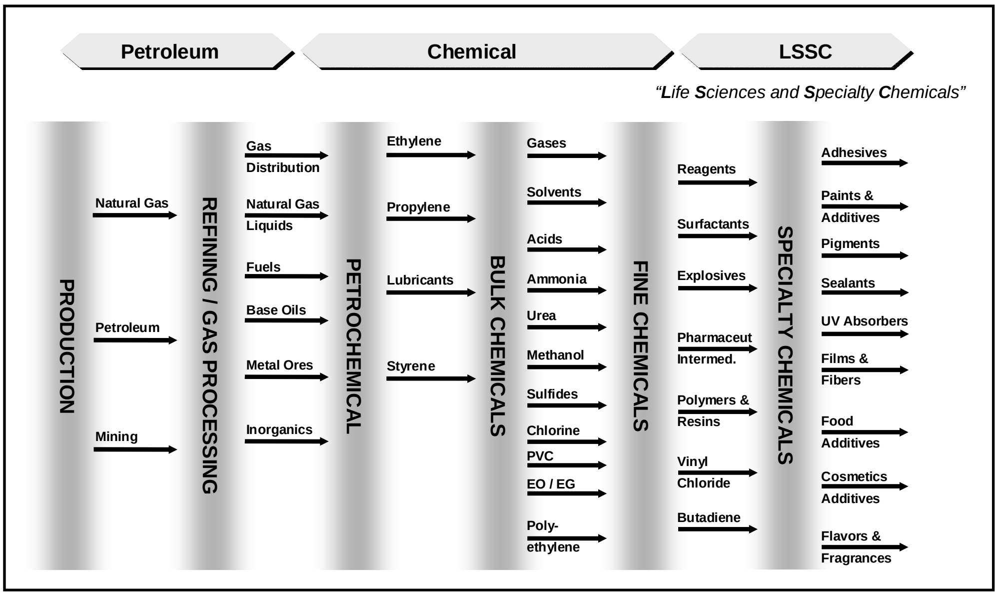


Figure 4.7 : Typical stages in the petrochemicals value chain
[Source: Source: Aspen Technology, 2003]

4.1.3 Petrochemicals: industry, structure, nature

Despite similarities the petroleum supply chain shares with those in other industries, it is still one of the most complex industry supply chains (Kafoglis, 1999:47). The following paragraphs will give more insight into the nature and structure of the petrochemicals industry.

4.1.3.1 Nature of petroleum and chemical companies

Petroleum companies deal with the dynamics of exchange economics, opportunities to use throughputs and daily decisions of whether to make or to buy a product to serve customer demand (Kafoglis, 1999:47). These companies frequently need to make major asset-intensive investment decisions related to new manufacturing facilities, upgrading of existing facilities or decisions to discontinue certain operations. These decisions, once implemented, tend to have a long-lasting effect.

The chemical industry differs from other industries (AT Kearney, 1997:50). These differences predominantly lie in:

- Dealing with products and mass materials that are largely non-perishable
- Manufacturing driven
- The value add is provided in further processing relatively inexpensive raw materials

Products produced by the chemical industry are inputs to nearly all other sectors of the manufacturing economies (AMR Research, 2004:2). Holistically, the industry comprises two primary groups: bulk/commodity chemicals and specialty chemicals. These two primary groups differ in several ways, such as in supply and demand complexity, manufacturing, transportation, and profitability. Table 4.5 articulate the differences between bulk/commodity chemicals and specialty chemicals.

Table 4.5 : Nature of bulk/commodity and specialty chemical businesses
[Source: AMR Research, 2004:2]

Characteristics	Bulk/commodity chemicals	Specialty chemicals
Value chain position	Upstream/Midstream.	Downstream.
Manufacturing Input	Crude oil, coal, natural gas.	Bulk/Commodity chemicals.
Typical customers	Other midstream chemical companies (to convert the base product).	Downstream, much broader set of industries and end user applications.
Transportation	Shipped in large volumes, by rail cars, trucks, or marine tankers, and most are slow moving.	Shipped in smaller and more discrete quantities. Packaging plays a larger role and most are faster moving.
Differentiate	Through branding and service levels.	Through product innovation, service still plays a major role and product application support is often required.
Profitability	Low or no margins.	Higher margins.

Chemical manufacturing process can also be characterized by (Supply Chain Consultants, 2003b):

- High fixed costs.
- Manufacturing assets that are relatively inflexible.
- Product transitions that are expensive and variable.
- A bill of materials structure that decomposes a few raw materials into many finished products.
- Production processes that require blending and large runs to make consistent products.
- Raw material prices that fluctuate continuously

Bayer Technology Services (2002:4) also indicate that the typical ***chemical manufacturing and distribution concerns*** for analysis and/or control are:

- Complex production chains (networked production, multiple phases, convergent/divergent material flows, recycling streams)
- Long production cycles (e.g. manufacturing of active ingredients, formulation and packaging)
- Dependence on raw materials with long replenishment times
- Alternative resource use with resource-specific lot sizes and/or container problems
- Dependence in terms of the production sequence (set-up/cleaning problems).

Although products are manufactured throughout the year, there could be highly seasonal demand with up to one-third of annual demand occurring within a four-week time span (Miller, 2001:33). This is especially true for the cyclical and seasonal nature of the agricultural sector. Management are looking for improved decision support related to the following typically questions:

- Where products should be shipped?
- Which demand should be met?
- Which company-owned distribution centres should be used?
- Where should new distribution centres be leased and what should be their size?
- Where and how much product exchange should be made?
- How many railroad cars should be leased and purchased?
- What level of customer service provides the most cost-effective results?
- Which plants or distribution centres should service which clients?

Related to the above questions, a decision support system could be developed with the objective of better integrating the efforts of the following three business segments:

The ***Supply Segment***, responsible for production, purchasing, and product exchange activities with other chemical corporations (co-producers)

The ***Storage and Customer Distribution Segment***, responsible for sizing and locating bulk distribution centres

The ***Demand Segment***, responsible for customer demand, and locations where products have to be supplied to end markets and co-producers (due to product exchange agreements).

4.1.3.2 Business structure

The petroleum industry divides itself into two parts with the refinery being in the middle (Schwartz, 2000:49). The upstream supply chain involves acquiring crude oil. This segment involves exploration, production, forecasting, and the logistics management of getting crude oil from remotely located oil wells to the refinery.

After the crude oil is manufactured into consumable product (whether diesel fuel, heating oil, lubricants, gasoline or any other oil-based product) the downstream supply chain takes over. Downstream supply more closely resembles traditional manufacturing supply chains (refer to Figure 4.1 for illustration). The upstream and downstream sides, when combined, require at least seven separate management functions. The challenge so far has been to get these separate business functions and processes to work as one. (or to convince them of its value).

In many cases oil companies have complete integration (vertical ownership) (Waller, 1999:172). Complete integration is the control or ownership of the entire supply chain (refer to Figure 4.8). Oil companies such as Texaco, BP, Shell or Exxon (Esso in Europe) are examples of completely integrated firms. These firms firstly own and operate the oil refinery that distils the crude oil into petrol, aviation fuel, diesel and other products. They are backwardly integrated owning the upstream production activities for the crude oil, including the drilling platforms and pumping equipment that bring the oil to the surface. In addition, they own the pipelines for delivering the crude oil to port and the oil tankers that transport the oil to the oil refinery. Then they are forwardly integrated, owning the marketing activities, including the tanker trucks, or the tanker ships, that deliver the refined products to the distribution outlet and, in many cases, the petrol retail outlets themselves. In some cases, oil companies go further and own the downstream chemical plant that produce a range of products based on petroleum feed-stock.

Coxhead (1998:3) indicate that refining is a continuous process and most refineries run near to full capacity all the time. Achieving optimal yields for a given refinery are only flexible within a narrow range. These inherent yield properties of refineries are determined by the hardware configuration which can only be changed through capital investment. Yields can be altered through varying the crude oil and by changing the way some of the processes work. It follows that a refinery can't produce only gasoline, the other products have to be made, stored, and sold as well.

According to Coxhead (1998:2) the organisations within the oil and gas industry do not directly cross-subsidise their operations. Each of the elements (i.e. exploration and production, trading, refining, marketing, chemicals) is expected to stand alone and is measured separately from each other.

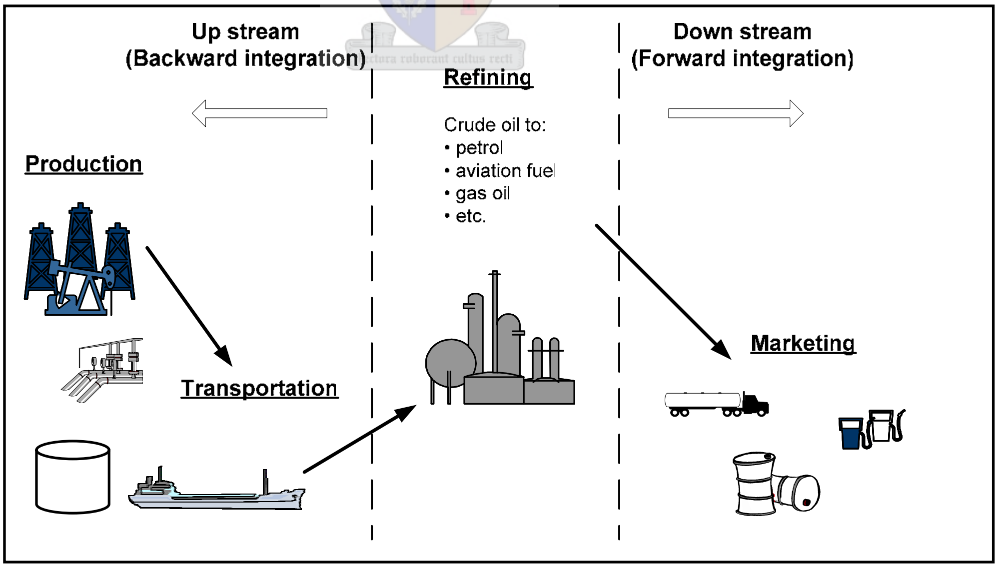


Figure 4.8 : Operation network for an oil company
[Source: Waller, 1999:173]

Hydrocarbon-processing plants and operations are commonly divided into on-sites, off-sites and logistics (Falcorn, 1994:40). On-sites typically focus on the reaction, separation and the unit operation to convert feed into products. Off-sites are the surrounding facilities which allow the first to work: Storage, utilities, safety systems, and infrastructure. Logistics fulfils the function as the movement chain which supplies feed, package and distribute product to the customer.

The two basic types of manufacturing plants that exist in the oil industry are refineries and lube plants (Ronen, 1995:379). Refineries produce light/white products (gasoline, kerosene, diesel oil, aviation fuel, etc) which are shipped in bulk to tank terminals (distribution centres) or to industrial customers. Refineries also produce heavy/black products (base stock for lubes, residual oil) which are shipped in bulk to industrial customers and lube plants (Figure 4.9 outlines the distribution chain of refinery products). Lube plants produce lube oils, greases, and waxes, which are shipped (packaged or in bulk) to distribution centres or industrial customers (Figure 4.9 also outlines the distribution chain of lube products).

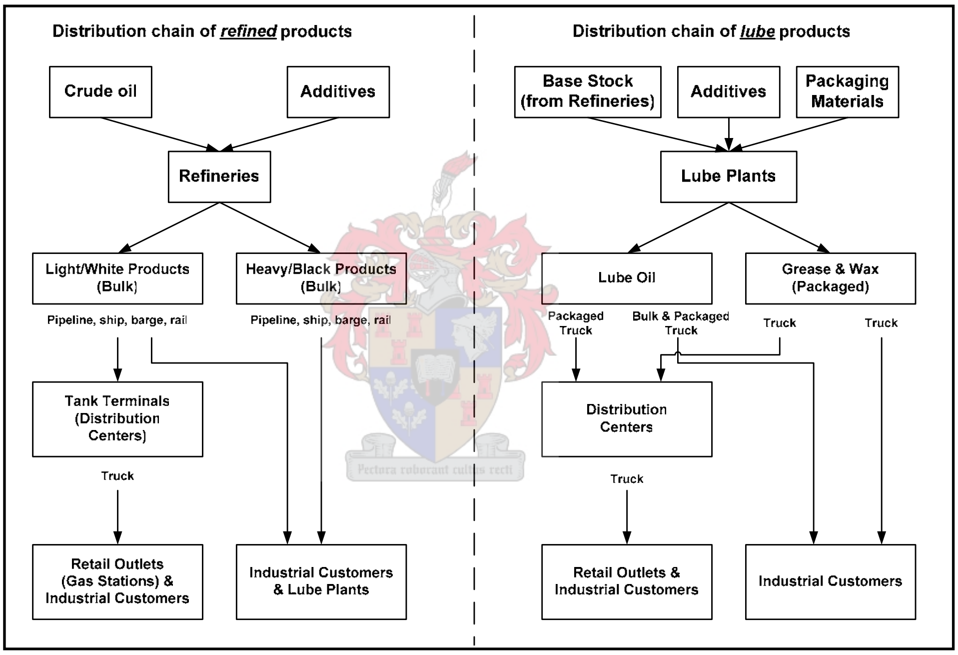


Figure 4.9 : Distribution chain of petroleum products
[Source: Ronen, 1995:380]

Big players in the chemical industry usually have dedicated divisions for the production and sale of both bulk and specialty chemicals. These divisions/business units often do not closely evaluate enterprise-wide trade-offs for total company profitability, compared to profitability in satisfying the demand for each (AMR Research, 2004:2). Manufacturers adjust product portfolios, trying to achieve the best synergy for profitability. Leaders not only have more clearly defined product customer segmentation, but also use a segmented fulfilment strategy. Most chemical manufacturers are going back to the basics with a focus on demand and revenue management. The priorities across the chemical industry relate to: asset utilization, cost reduction, operational excellence, and high service levels.

4.1.3.3 Conduct

A large multinational company that manufactures commodities such as refined petroleum products or aluminium will sometimes enter into an exchange agreement with a competitor that manufactures similar or identical products (Shapiro, 2001:245). The agreement states that the company will acquire a certain volume of product from the competitor at a specified geographical location at a specified price during a specified time period. The company will reciprocate by supplying the competitor with the same volume of product at another location, possibly during a different time period.

Kafoglis (1999:47) stated that the rules of competition have changed in the downstream petroleum business. With fixed commodity prices and slow demand growth, downstream petroleum businesses are finding it increasingly difficult to differentiate based on products and services. Prior to OPEC, the integrated majors dominated most of the elements in the supply chain. In a stable crude oil/product pricing environment, companies balanced and matched assets between supply, demand and facility capacity. This nurtured an asset-utilisation mentality and emphasised maximising refinery yields and throughputs, as well as integrating upstream with production, and downstream with petrochemical investments.

The majors however lost control of crude oil prices to OPEC in mid-1970s and the industry structure changed by necessity (Kafoglis, 1999:48). Decreased demand for gasoline and fuel economy legislation in the U.S. spawned a long-lasting trend of asset under-utilization. Spare capacity meant slumping margins for downstream businesses, ultimately leading to major restructuring. Asset consolidation, inventory reduction and developing new skills in trading and hedging characterised the new profitability paradigm. At the same time, change began to accelerate. Since the late 1980's, the focus shifted toward increased profitability, core competencies and consolidation. Asset rationalisation and sales of marginal refineries and divisions has prompted growth of independent refineries/marketers who acquired these assets to operate them under more profitable philosophies. Pacesetters in the industry are replacing an asset-driven approach to business with one of a trader's mentality. Joint ventures, alliances and mergers are also significantly changing the competitive landscape. Although most companies continue efforts to reduce capital employed, a new trend is emerging where careful inventory management allows companies to take advantage of trading opportunities in a volatile market. The retail site is also changing with new service offerings to increase traffic flow at the stations (e.g. convenience centres added).

In the bulk chemical industry, economies of scale and the location of plants often dictate which type of feedstock will be used (AMR Research, 2004:2). As a result, manufacturers of bulk chemicals are often captive to a limited number of suppliers, while supplier quality in this industry surpasses any other. Raw material prices are often quite volatile. Volatility and cyclicality in prices are also common for chemical products produced. Associated with the proximity to source, typical challenges to overcome include: increased customer service requirements, heavy emphasis on logistics excellence in bulk chemicals, and focus on reducing the highest transportation costs of any industry. With inconsistent, natural raw materials as its input, the exact output of manufacturing processes may not always be known until the process has been partially or totally completed. This results in product yield variability—an inherent characteristic in the bulk chemical industry. Over time, manufacturing processes however matured to reduce this variability with a high investment in quality control processes. Inventory at strategic locations in the manufacturing and supply chain serves the purpose to buffer variability as well as the effect of time-consuming changeovers on campaign/batch operation plants producing various grades of products. This enables the requirements to meet customer and market demand and sustain effective perfect order fulfilment. Chemical manufacturers have finely tuned source/make processes, but even with high finished goods inventory, still have somewhat long order-to-delivery time. This is usually due to laboratory lead times (for quality control and assurance) and slow bulk transit methods.

4.1.4 Petrochemical supply chains

As is apparent from the petrochemical industry's structure, conduct and nature, their supply chain would thus also substantially differ from other industries. According to Coxhead (1998:4) some of the major factors influencing the petrochemical supply chains include: pressure on margins; environmental, product specifications and emissions; crude oil prices; stagnant market in developed countries; global demand growth; taxation; supply chain costs (upstream oil & gas sourcing, production and downstream refinery and chemical product markets); vehicle utilisation; exchanges; multi-drop deliveries; working capital; compulsory storage; political/regulatory issues; product losses along the supply chain; fragmented management of the supply chain, most companies still in silo mode; seasonality of demand for some (heating) products; and poor network planning; refinery capacity; safety. The following paragraphs further elaborate on these factors.

4.1.4.1 Cost structure

Margin management, cost management, and the ability to be price-competitive in the marketplace are some of the great challenges bulk chemical manufacturers face. Feedstock and raw materials generally make up about 40% of a bulk manufacturer's total cost, with salaries for competent employees managing complex chemical processes averaging 10% of costs (ACC Guide to Business of Chemistry, as referenced by AMR Research, 2004:2). Depreciation is also a large cost component in this capital-intensive industry, and major players will often jointly invest in assets to help combat these costs. Required Environmental and security initiatives for consumer health and safety are no small expense. The certification of each bulk chemical grade produced is also time-consuming. In addition, the large investment in capital equipment these manufacturers make drives the heavy emphasis on plant utilization, and high occupancy will often take precedence over cost management. This drives ever-lower margins, and as a result, bulk chemical manufacturers sometimes take a loss.

Falcorn (1994:40) also indicate that the petrochemical value chain cost structure has its own unique characteristics. For nearly all petrochemicals and refined products, supplying and storing raw materials plus storage and distribution of finished products, equals the non-feedstock cost of production. As indicated in Figure 4.10, the costs are roughly split as follows: 30% feedstock, 40% fixed cost, 15% conversion, and 15% off-site and logistics. These percentages also depend largely on the organisation's supply chain structure and the business's sales terms (INCO terms).

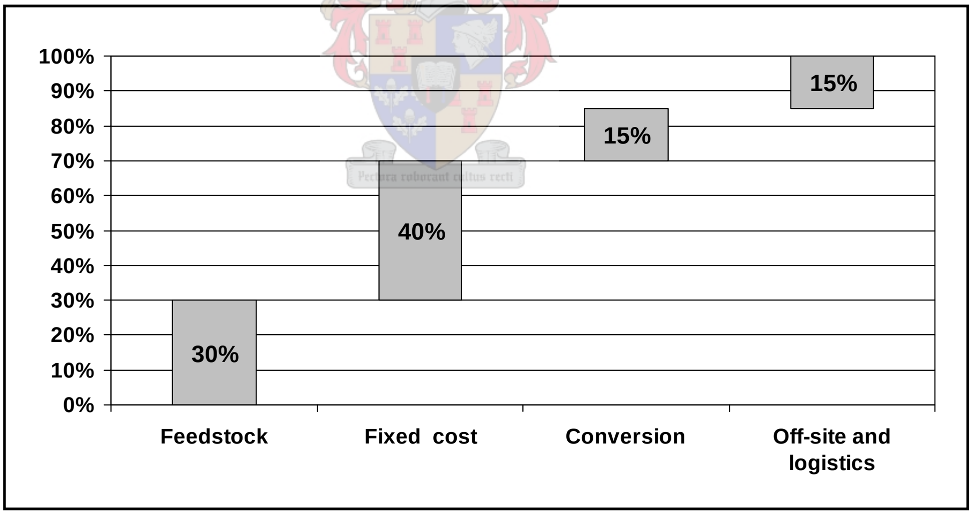


Figure 4.10 : Petrochemical value chain cost structure (% cost distribution)
[Source: Falcorn, 1994:40]

AMR Research (2004:5) also indicates that the bulk chemical industry has the highest supply chain management costs at 53.3% of revenue (more than twice that of other industries). This excludes direct material cost. Manufacturing operating costs make up more than 80% of bulk manufacturers' total supply chain management costs, and average more than 40% of revenue. Other manufacturing industries such as consumer goods, automotive, and electronic equipment have a median manufacturing operating cost of only 13.5%. Bulk chemical transportation is another significant contributor to total supply chain costs, with spending at 7% of revenue compared to other industries' median of 2.2%. Inbound costs are often negligible because of co-location with suppliers — sometimes a simple pipeline. Outbound transportation costs are a striking 5% of revenue, compared to the half-percent of other industries.

With limited flexibility in manufacturing, logistics is often the response buffer for Chemicals supply chains (Masson, 2005). Each mode of bulk chemical transportation, including rail, truck, and marine, must however comply with strict regulations and safe handling specifications. Many chemical companies are considering 3PL and 4PL providers as logistics costs being one of the last areas of opportunity for cost reduction in chemicals, but logistics may also be the strategic key to achieving the necessary level of supply network flexibility beyond the constraints of inflexible manufacturing assets.

4.1.4.2 Supply chain structure

Many supply chains may exist in a chemical company (AT Kearney, 1997:5). Raw material and intermediate products may go through multiple refined processes to create higher valued products (refer to Figure 4.7).

According to Hanrahan (2001:16), two major transportation types have traditionally dominated the oil scene since the need was recognised to move petroleum products over long distances (This applies to both raw material and downstream refine products). These two major transportation types are pipelines and marine vessels. Rail and road transport also play their parts, but the really big volumes move down the pipes and across the oceans. This particularly applies to crude oil, bearing in mind the current global spread of crude oil production. When compared with the major markets (typically centred in the US, Europe and the Asia-Pacific region) it is obvious that the supply chain is an area where a lot of attention needs to be placed. Figure 4.11 show the typical structure and interdependencies of an oil refinery's supply and transformation process flows.

Chemical companies have similar supply chain structures, except for the major manufacturing technologies that differ. These chemical operations are more focused on chemical reaction/transformation, distillation and refinement of feedstock into value add products. Product volumes are typically lower but the complexity of interlinked and interdependent processes increases exponentially. The product slate also expands, market segments are formed and end customers' different service expectations define the typical nature the downstream supply chain.

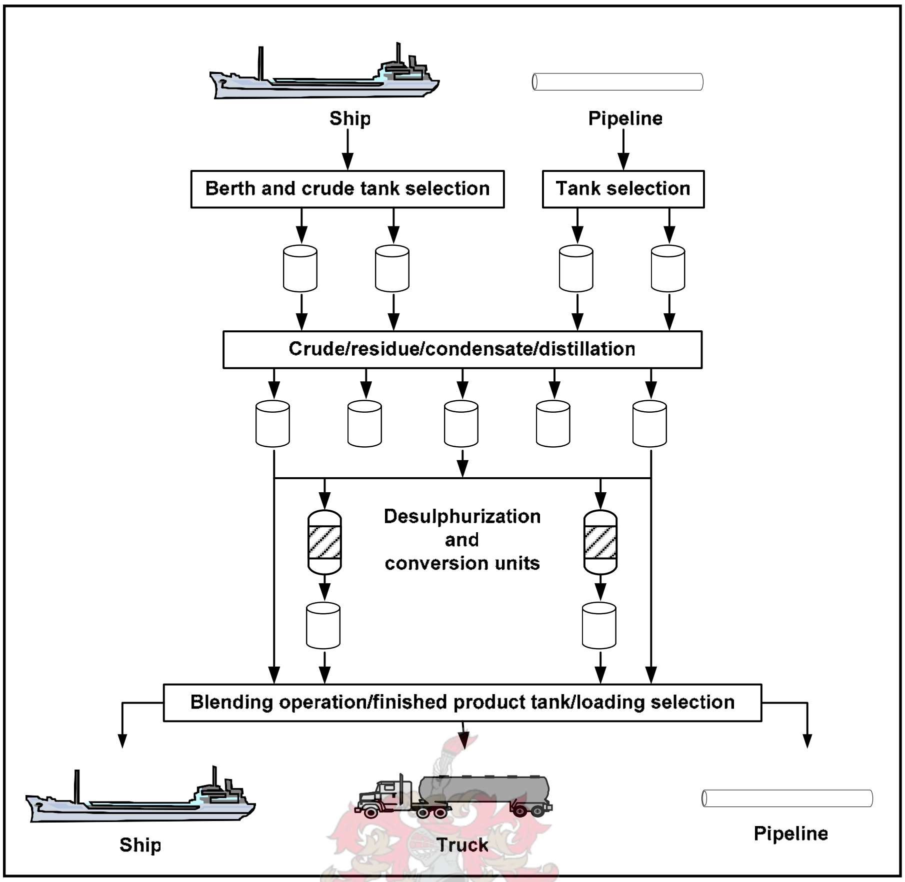


Figure 4.11 : Oil refinery process flow
[Source: Shapiro, 2001:434]

4.1.4.3 Chemical supply chain complexity

According to Falcorn (1994:40), there are some fundamental differences between steady state processes (inside the petrochemical plants) and discrete dynamic processes (logistics). Most on-site chemical operations runs according to steady state objectives (flow, temperature and pressure). However, this assumption cannot be made in off-sites and logistics. These processes are discontinuous, time variable and unsteady state by nature, necessitating applicable controls and management.

Process industries are those businesses that add value to materials by mixing, separating, forming, purifying or chemical reaction (Rossouw, 1994:26). Discrete manufacturing uses a bill of materials to make each finished product. The process industries often end up with more products than raw materials and result in having a bill of products (see Figure 4.12) as opposed to a bill of materials.

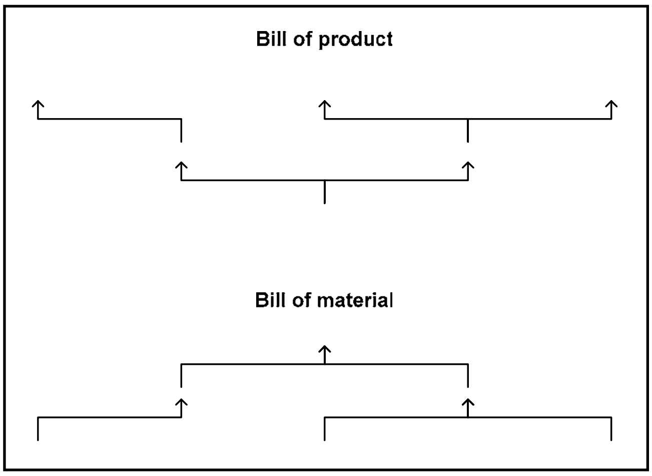


Figure 4.12 : Bill of product / bill of material
[Source: Rossouw, 1994:26]

Chemical companies are wrestling with major changes that will affect the way they do business. Industry consolidation, globalization and e-business are just a few of the challenges that are impacting performance. Others include regulatory compliance to environmental, health and safety issues; and an increasingly demanding customer base (IBM Global Services, 2005). To stay competitive, chemical companies must reduce costs, integrate their supply chains, improve performance and provide their customers with specialized services. Chemical companies today also need to deal with rising challenges in the complex chemical environment. Some of these challenges include (Wam Systems, 2001:1):

- External demands to improve customer response time, expand product offerings, and hold the line on prices.
- Internal pressures to enhance manufacturing efficiency, reduce inventory costs, and boost profit margins.

Due to the significant uncertainty in transportation operations, especially in marine bulk operations, it requires changes/problems to be addressed on a rolling horizon basis (i.e., implementing only immediate decisions and solving the problem again whenever things change from the generated solution) (Ronen, 1995:380). Most major oil companies, as well as chemical manufacturers, face this type of problem. The same tactical inventory routing problem also exists in the transportation of crude oil to refineries. Additional concerns that may exist in solving this type of problem, depending on the specific operation, are:

- Transportation units may have different sizes and compartments (e.g., ships, barges). As such, the timing, sizing, and product composition of shipments may depend heavily on the availability of transportation units and their operational restrictions.
- Facilities shared with other operators (e.g., pipelines, marine terminals) may be unavailable when needed, disrupting planned schedules.

- Cross contamination of products must be prevented when the same line or tank is used for different products.
- On a partially loaded leg of a vessel, the vessel must be loaded in a safe manner to assure stability.
- A vessel may load at more than one refinery/terminal.
- Single voyage (spot) charters of vessels may be unavailable.

A study conducted by Trade and Industry South Africa in 2001 highlighted specific ***chemical supply chain challenges*** from different perspectives. These challenges are briefly described according to three perspectives (Centre for Logistics, 2005:20):

Industry perspective: the lack of integrated planning between industry players through sharing common transport infrastructure for bulk chemicals leads to sub-optimal use of infrastructure. The lack of consolidation of loads for inbound goods, such as the co-shipping of raw materials in the bulk chemicals industry perspective sector, is of concern. There is no industry learning forum, which results in high learning costs for first-time exporters.

Firm-level perspective: sub-optimal responsiveness due to issues such as low adoption of management structures to ensure end-to-end responsibility of supply-chain processes, and failure to translate reductions in manufacturing cycle times into reduced order lead times, is a significant challenge.

Logistics service provider perspective: the transport of rail-friendly bulk chemicals has shifted to road, with an accompanying impact on cost. Inadequate port facilities for handling large export and import volumes of petroleum products are a further challenge.

According to (Masson, 2005) for most segments of the chemical industry, quick wins cannot be achieved by improving demand visibility. This is because the industry does not have access to Point-of-Sale (POS) data. Radio Frequency Identification (RFID) supply chain data is nowhere on the horizon (apart from well-proven asset tracking applications), and the industry feels the full sting of the bullwhip effect. As a result, the chemical industry struggles to achieve a high degree of demand visibility and has limited demand shaping opportunities.

4.1.5 Organizational complexity

The petroleum industry is also a victim of silo mentality (Reib, as quoted by Schwartz, 2000:49). While IT systems are available to provide visibility into the petroleum supply chain, few are being used cross-functionally. Breaking down existing silos may be a tough job because the oil industry is organized around highly specialized business processes which encourage fragmentation.

Changing to a supply chain management approach is a difficult challenge for large and complex chemical companies (Sharman, 2002:78). A number of different business units typically exist each with sourcing and logistics leaders, together with regional leaders. The chemical industry is one of the most "incestuous businesses" because the waste from one process becomes the material for others (This differs dramatically from for instance the High-Tech industry).

Figure 4.13 represents three of a number of possible dimensions/perspectives according to which a company can structure business processes in the petrochemical industry (Sasol Logistics, 2001:11). These high level dimensions already indicate the "complexors" and the different focuses that can exist in large-scale petrochemical companies.

> The **supply chain components** (Z-axis) represents facilities within the supply network (Process plants, storage facilities e.g. warehouses, distribution centres, terminals and ports), transportation required to link these facilities (e.g. Road, Rail and Pipe) and support services (e.g. surveying, clearing and forwarding). In large-scale petrochemical companies, 1st order ***commercial synergies*** can be derived through consolidation processes. Logistics service providers that serve a number of business units within a corporation can be leveraged for economies of scale.
>
> The Y-axis represents various **chemical type clusters**, consisting of specific chemical product families that move along business unit value chains. These consists for example of nitrogenous, oxygenate, hydrocarbon and inert type molecular groupings. The main focus is on ***horizontal supply chain processes*** spanning from suppliers through manufacturing to end customers. Value is created by tight feed stream allocation, integration, visibility and alignment towards market segments. The variety of chemical manufacturing processes and technology available provides a fair amount of flexibility in the allocation and utilization of feedstock and commodity chemicals to produce a wide range of more refined and value adding chemical products. Process yield, availability, chemical product prices and profitability are some of the factors taken into account in these allocation decisions. Such decisions constantly happen through the S&OP processes along most of the stages in the petrochemical value chain.
>
> The X-axis represents the aggregate **logistics value clusters**. Liquid bulk, dry bulk, gases and packaged goods are the typical configuration clusters that allows for ***cooperation*** and freight synchronisation across the supply chain processes of business units within a corporation. Packaged goods are material that exists within any form of packaging (e.g. bulk bags, containers, boxes, drums). Dry bulk is material that is solid (powder, flakes, granules or bigger sizes) and is transported via dry bulk containers etc. Liquid bulk is all forms of liquid products that move in liquid bulk containers (e.g. road fuel tanker). Gases are typically moved in specialised pressure vessels or pipelines.

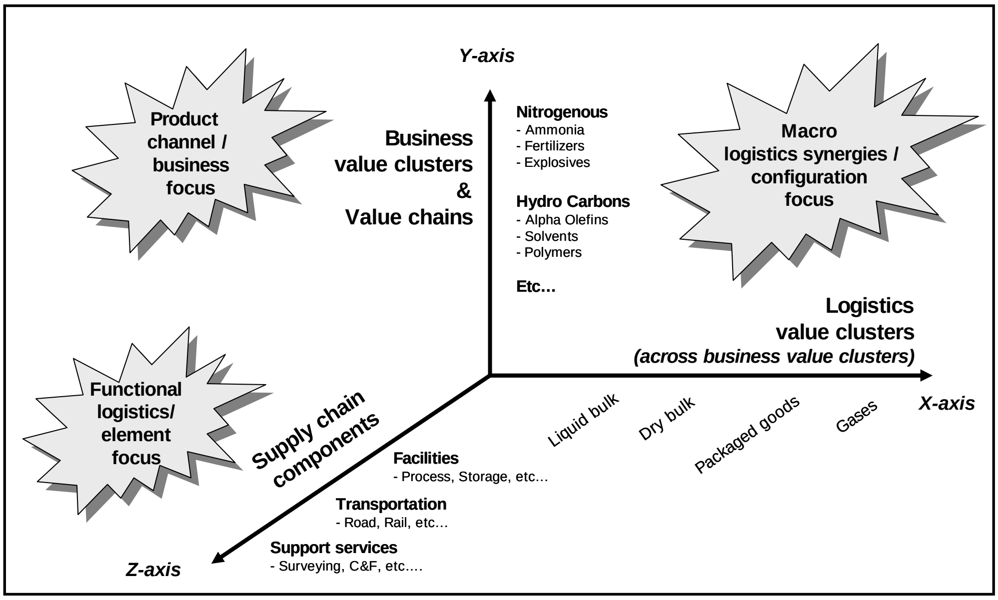


Figure 4.13 : Complexity of large-scale petrochemical companies
[Source: Sasol Logistics 2001:11]

4.1.6 Approach to supply chain planning business processes/modelling/decision making

There are a number of factors that increase the complexity of a petroleum supply chain (PWC, 2001:2). As indicated in Figure 4.14, these factors (plus the associated trade required) impact on all the stages in the petroleum supply chain and need thorough planning and synchronization to meet end consumer demand. To maintain the throughput of a 100 units per day petroleum supply chain consistently, there are typically 260 units per day of trades needed to meet demand. As also indicated in Figure 4.1, the petroleum supply chain can be approached from the following 3-tier/stage viewpoint:

- Supply related to crude oil (crude oil to refinery)
- Supply for wholesale (refinery to terminal)
- Supply for retail (terminal to retail market)

While the price of crude oil may always dictate the cost of gasoline, industry observers imply that many oil companies have ignored supply chain management as an enabler to gain some control over profits (Schwartz, 2000:49). Supply chain management needs to be at the centre of petroleum organizations because the supply chain is the only place where an oil company has the opportunity to manage and influence all its cost factors.

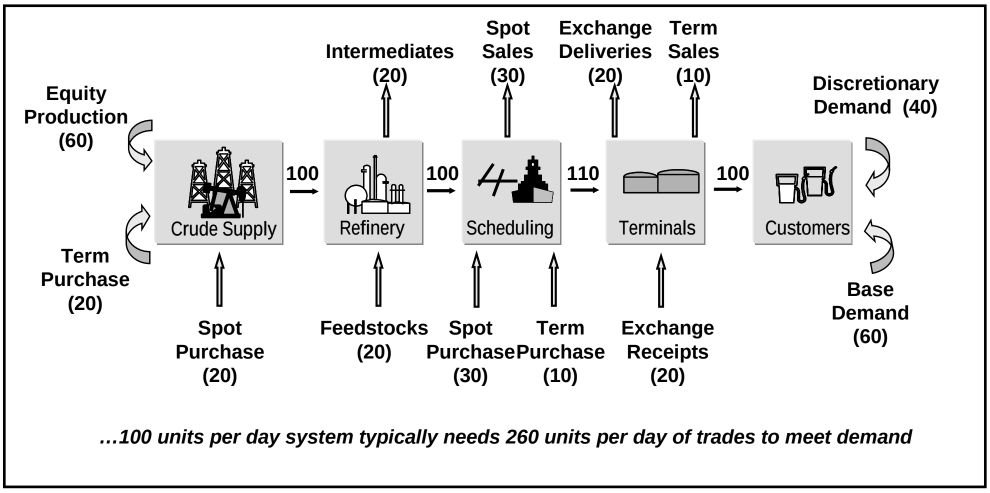


Figure 4.14 : Supply Chain Complexity
[Source: PWC, 2001:2]

4.1.6.1 Factors limiting supply chain success

There are a number of factors limiting supply chain success in petrochemical companies (Krenek, 1997:100). A few are:

- The petrochemical industry has a very conservative culture (corporate mentality discourages risk taking and speedy decision making)
- Direct competition for structural changes (mergers and acquisitions strain an organization's time and attention)
- Lack of top level supply chain management champions
- Inadequate understanding of the perceived importance of the supply chain
- Minimal attention to changed job requirements and responsibilities

4.1.6.2 Focus on margin management

In the downstream petroleum supply chain, cost-savings and margins are maximized when demand management (front end) and demand fulfilment (back end) processes are seamlessly linked (Petrolsoft, 2000:3). When demand management and demand fulfilment function as a single, unified process, effective margin management is enabled, maximizing the value extracted from the supply chain.

According to Gill (as quoted by Schwartz, 2000:54) margin management downstream of the refinery means realizing the greatest return from every unit of delivered product. This can be achieved by minimizing the costs of ownership while identifying and exploiting market value.

4.1.6.3 Supply chain planning business processes

Business processes around the oil supply chain involve a huge amount of communication and common understanding (Hanrahan, 2001:16). Major touch points occur at communication points (such as ship nominations), at agreement phases (such as contracts), at update events (such as pipeline "tickets") and at stages in the process where companies are trying to think about what the supply chain partners might want to do (such as demand planning).

"Industry analysts Cap Gemini, Ernst and Young estimate that an extra fifty US cents could be gained from each barrel of oil sold by improving downstream processes. In an industry with a daily production of seventy million barrels of oil worldwide, that's US$35mn wasted every single day." (Mani, 2003). The fifty US cents is an average value. This means that some companies may only be able to achieve twenty cents due to regulatory restrictions or a high level of existing efficiency. A small improvement in profitability per barrel does add up to considerable margin improvements. These value leakages relate to the fact that oil companies don't have a full picture of all network constraints across the entire supply chain. While oil companies are currently using planning tools to optimise production at a specific refinery, they realised that they were missing out on a huge opportunity to view and optimise the flow of oil and products all the way from the ground to the refineries and ultimately to the customer.

Mani (2003) also indicated that a number of factors hamper supply chain planning processes: Fragmented planning processes and applications that hamper business planning; Internal organizational boundaries prevented the flow of consistent and timely information; Conflicting objectives and poor interactive communication between departments and divisions also hamper planning; and The lack of information visibility and transparency across the business made timely decision making impossible. A complete supply chain transformation is essential. The oil industry is largely refinery-centric and production driven. It must become more customer-centric and, therefore, partly demand driven where appropriate in order to maximise margins. Refinery planning is currently separate from distribution planning and order fulfilment (a major opportunity to be integrated).

Regarding planning systems Mani (2003) believes there are currently too many multiple non-integrated planning and scheduling systems. They should be rationalized and integrated to move to the dream of one system of optimization and economic analysis. While a big traditional emphasis is on information gathering, the focus needs to shift to supporting decision makers. Truly integrated, modular and segmented solutions should be developed to encompass supply chain strategy and planning, demand management, transportation planning and refinery scheduling across one common and fully integrated technology platform. The advancement and change should be an evolutionary process, aimed at gradually adding extra cents of revenue per barrel with each incremental improvement in processes and technology.

4.1.6.4 Modelling and decision making

The oil industry has been a major source of applications of operations research (especially in vertically integrated oil companies), from exploration through production to distribution (Ronen, 1995:379). Several oil companies use linear programming and network models for product distribution planning to determine the shipping slate (Ronen, 1995:381). Determination of the shipping slate is usually separate from the dispatching decisions in oil companies because these decisions are vested in different departments, and their combined solution is difficult.

Market pricing play a big role in driving the relative value of crude oil, as does the physical makeup of the crude oil itself (for yield evaluation) (Trombley, as quoted by Schwartz, 2000:52). Models on crude oil are run at least monthly, sometimes weekly to optimize refinery yields (e.g. with optimizations software like PIMS). After economic modelling, scheduling takes over for sequencing the moving of the crude oil.

MRP is not well suited for the process industry (Rossouw, 1994:26). For planning, it was found that conventional MRP planning and control systems are not good enough. Different methods and philosophies are necessary because capacity is the determining factor of throughput.

The application of operations research techniques in Supply Chain Planning for the Process Industry has a long history of over 30 years (Shobrys, 2003:2). As the improvements occurred (techniques themselves as well as enabling technology), the barriers to entry reduced for companies seeking to improve their supply chain management functions.

1970's: In the late 1970's, solution techniques like linear programming were extended to address more difficult and long-term decisions (included the yes/no decisions associated with adding production capacity, selecting production technology, or picking sites for distribution centres). These applications often occurred in the process industries and at a planning level for large refining and chemical companies like Amoco, Chevron, Exxon, Marathon, and Shell.

1980's: In the mid 1980s many major chemical companies realized that they were becoming limited in their ability to offset decreasing margins with improvements to the manufacturing process, and started examining their supply chain activities. This gave birth to the start of initiatives related to planning and scheduling tools. Many of the tools were developed in-house, or purchased analytical products that they modified internally. The intent was to start following a true supply chain focus, rather than implement point solutions for functional silos like manufacturing or distribution. As artificial intelligence and expert systems started to emerge, petrochemical companies started initiative to use these capabilities in conjunction to optimization, simulation, and heuristics techniques. Expert systems were typically used in conjunction with heuristics to make planning outputs useful for scheduling. Artificial intelligence made subsequent contributions to techniques like constraint-based programming and genetic algorithms.

1990's: The early 1990's saw the introduction of imbedded Structured Query Language (SQL) capabilities, allowing Supply Chain Planning (SCP) tools to interact more dynamically with relational databases. The availability of increasing amounts of computer power at decreasing costs led to new solution methods, and expanded the size and complexity of the problems that were being addressed. Genetic algorithms and simulated annealing also became available.

These developments made Supply Chain Planning more accessible to supply chain managers Shobrys (2003:5). Computer power became much cheaper, data can be moved more readily, software products largely stop the need for internal development, and the supply of consulting resources continues to expand. However, companies seeking to play in this arena still have to address the major challenges associated with implementation:

- developing the infrastructure to provide integrated data of adequate quality,
- developing the internal skills to use these technologies effectively, and
- instilling the discipline to use these tools actively.

4.2 Level of advancement and areas for breakthrough improvement

Although slowly, the petrochemical industry has started to see the potential in using advanced supply chain planning processes and modelling in enhancing their decision making. There are also some positive signs in organization development to assist in the change process. The following paragraphs portray some of these developments.

4.2.1 Industry developments

Exceptionally rapid change is the order of the day in the oil business, and this change is impacting virtually all participants in the downstream value chain. This includes the fuel and lubricant employers and distributors (Fiala, 2002:23). These changes are mainly due to the merger and acquisition activity at the majors' level in the oil industry.

The chemical sector is also evolving (Boulanger & Eckstut, 2000:9). Business challenges including commoditization and crushing competition, exacerbated the industry's notorious cycle of peeks and valleys, creating extreme volatility and low earnings multiples, and limiting value-creating opportunities. Over the past decade chemical companies have made many large-scale changes to improve performance, including business process reengineering and consolidation by mergers, acquisitions and alliances. The most far reaching change, however, has been chemical companies' huge investments in enterprise resource planning (ERP) systems and other information technology in order to integrate internal supply chains. The quickly evolving chemical sector has created an array of innovations that will profitably affect all involved players.

The chemical industry, like other industrial sectors, must find new ways of competing with companies that have become part of the new business environment (AT Kearney, 1997:3). Until now, leading chemical companies have maintained a competitive edge through:

- Economies of scale
- Research and development to generate new products
- Meeting environmental restrictions
- Increased globalization

AT Kearney (1997:3) also indicated that success will depend on working in new and different ways. This requires setting up and becoming successful participants in supply chains that are really integrated networks of enterprises that can compete successfully with other such networks.

Although the chemical industry did not pursue supply chain improvements with the same vigour as other industries, it has started to address the supply chain potential available (AT Kearney, 1997:1). Overall, very few companies in the chemical industry are excelling in adopting the approach of total supply chain management. As indicated in paragraph 1.2, companies in the chemical industry that seize this opportunity could substantially improve their competitive position.

Based on the **Supply Chain Maturity Model** developed by PMG and PRTM, a supply chain practice assessment in 2002 provides the means of evaluating an organization's stage of operational and technological maturity (The Performance Measurement Group. 2003:1). This "Supply Chain Maturity Model" was used to assess the stage of capability for each of four processes defined by the Supply Chain Operations Reference model (SCOR) — Plan, Source, Make, and Deliver. Relative to the other industries, the chemical industry is still at a maturity stage 2 of internal integration (results of this assessment in Figure 4.15).The study further demonstrates the positive effect of advancing in supply chain maturity on driving both supply chain and financial performance. However, companies should select supply chain practices that are best aligned with their supply chain strategy and overall business.

The Supply Chain and Logistics Unit (part of Trade and Investment South Africa (TISA); division of the Department of Trade and Industry) conducted a key project in 2002 to identify supply chain opportunities that could enhance the competitiveness of export-orientated industries (Maree, 2002:3). A Supply Chain Excellence Model was developed to assess the supply chain maturity (assessing three themes of supply chain excellence) across four sectors selected for the study in South Africa; Agri-processing, Automotive and Components, Chemical Manufacturing, and Clothing and Textiles. The maturity assessment was designed in such a manner that respondents could achieve a score of 100% for maturity. Table 4.6 indicates the average scores for companies in the four sectors.

Average maturity by industry

Industry Segment	Average Dominant Score
Consumer Goods	2.5
Semiconductor	2.5
High Tech	2.2
Industrial & A&D **	2.2
Chemicals	***2.1***
Life Sciences	1.9

*** A&D – Airspace and Defence*

Supply chain maturity model stages

Stage 1- ***Functional*** departments within an organization focus on improving their own process steps and use of resources.

Stage 2 -***Division- or company-wide*** processes are now defined, allowing individual functions to understand their roles in complex supply chain processes.

Stage 3 - Stage 2 practices are now extended into the points of interface with ***customers and suppliers***.

Stage 4 - ***Customers and suppliers work strategically*** to define a mutually beneficial strategy and set real-time performance targets.

Figure 4.15 : Supply chain maturity by industry
[Source: The Performance Measurement Group. 2003:1]

Table 4.6 : High level supply chain maturity per selective sector
[Source: Maree, 2002:3]

Sector	**Customer orientation**	**Optimum Responsiveness**	**Maximum asset productivity**	**Average**
Agri-processing	58%	54%	49%	54%
Automotive	49%	54%	42%	49%
Chemical manufacturing	52%	50%	46%	49%
Clothing and textiles	55%	51%	40%	49%
Average	54%	52%	43%	

Resulting from the “Supply Chain Excellence in South Africa” project from TISA the following were identified as key challenges that South African companies are facing to improve their supply chain performance (Maree, 2002:8):

- Migrating the focus from individual to supply chain maturity. This implies focusing outwards instead of inwards, incorporating supply chain partners in ***planning and***

optimisation processes. Unless such a broadened view of supply chain excellence is adopted, it is impossible to start reaping the benefits of true (global versus local) optimisation.

- Manage ***technology*** investments and implementations in such a way that their effectiveness in contributing to strategic supply chain objectives is improved. Technology sophistication is high from a transactional perspective, yet, the effectiveness of technology rated surprisingly low. The respondents citing low technology effectiveness are also those without management practices in place. In other words, technology effectiveness is determined by the presence of a proper management systems and processes.
- Change the paradigm around ***collaboration***. Collaboration is still seen as an outcome driven by technology, which is often over-emphasized. In reality, the foundation is mutual trust and structures and processes around information sharing as a basis for co-operation. Unless the groundwork of relationship building is in place, the effectiveness of collaborative technologies to drive such processes will remain below expectations.
- Improve ***performance management*** practices to ensure that strategic objectives are achieved effectively and efficiently. Companies are aware of the issues and drivers of change their industries are faced with. However, the minority of companies are capable of effectively responding to such change. Implementing performance management processes throughout the supply chain will close the loop of strategic thinking, implementation of initiatives and its support through effective management practices.

The project also identified the following Supply Chain Planning and Optimization opportunities (Maree, 2002:8):

- More aggressive adoption of advanced supply chain management techniques and technologies, that is, advanced planning and scheduling and advanced distribution techniques.
- More aggressive adoption of outsourcing certain functions to strategic service providers. This will improve economies of scale and assist in reducing costs while increasing service levels.

4.2.2 Organizational development

Schwartz (2000:54) indicates that one of the major initiatives in the petroleum industry (for almost a decade) is to overcome the silo mentality. It is hoped to achieve improved efficiency through collaborative information sharing. Announcements by the oil majors regarding trade exchanges indicate that progress in industry collaboration is on the horizon.

4.2.3 Supply chain planning advancements

The supply chain planning group at Eastman Chemicals, known as Customer Service and Materials Management, includes all the activities involved with the supply chain planning and execution except production (Trent, 2002:32). This group reports to an executive who has responsibility for managing inventory investment. All incoming orders and outgoing purchase orders must pass through this group, which maintains specific targets for all major inventory categories. This group manages inventory as a company-wide number rather than as separate amounts spread across the supply chain. The customer service and materials management function have full responsibility and accountability for inventory management (With the aid of a developed information technology system called the “global business integrated information system”)

Transparency and agreement on all levels is the most important factor in laying the foundation towards successful integration and collaboration. Transparency within the chemical company itself is the first principle on which to hang the plan (HCB, 2002:30). The need for a complete service offering exists where the barriers between departments and business units must be removed to stop internal struggles.

BP Chemicals adopted innovative ways of simplifying and streamlining its business processes. The moves promised financial benefits in the region of $125 mil by year 2003 and positive results are already apparent across the business (BP Chemicals, 2001). BP has a number of on-going projects in their chemicals divisions looking at how IT and internet based tools can be applied to the chain operations from procurement and raw material supply, through manufacturing and distribution to the end customer. The goal is a set of simpler, less costly processes which help generate greater revenues. (The goal lies in terms of cost competitiveness, customer focus and revenue enhancement). The BPR process is also very much a program of learning what draws together expertise and experience. Ultimately it will lead to the much more widespread application of common work processes and practices.

The Integrated Demand Supply Planning (IDSP) project is a cornerstone of the BPR process in BP Chemicals. The IDSP blueprint is a combination of the following business processes:

- Demand management
- Supply planning
- Safety stock and inventory
- Shipment scheduling
- Plant scheduling
- Available to promise

In 2001 spreadsheets were used for integrating demand-, production and distribution planning. The IDSP group intended to run Distributed MIMI from AspenTech parallel to their existing planning system and planned to switch over completely by 1st Quarter 2002.

i2 Technologies Inc and Shell Global Solutions International BV planned to develop and pilot an integrated supply chain management (SCM) software package for the downstream oil industry (Computergram, 2002:3). They planned to combine i2's SCM applications with Shell's consultancy business and target downstream operations from crude oil selection to product storage at terminals and depots. According to Masson (2006), Shell changed this alliance to AspenTech.

4.2.4 Use of supply chain planning business processes and modelling for decision making

Many refining and chemical companies have used linear programming systems for planning for years (Bodington & Shobrys, 1996:58). Unfortunately many of these legacy systems are not easy to integrate with scheduling systems and database managers. Some only permit manual editing for input modification and do not lend themselves to automated updating or access to non-linear process models. This severely limits the user's ability to take advantage of the integration with scheduling and process control.

The oil industry is evolving rapidly, from the upstream to the downstream (Hanrahan, 2001:16). Outlined below are some step levels that can be applied to advance supply chain management in the oil industry. The required "*escape velocity*" required for moving from each step to the next is also suggested. Issues around internal politics and change management can often stifle progress but should be overcome in reaching the advancement objectives. The following are the proposed steps for building towards competitive advantage:

- ***Lay the foundations:*** know where you are or have been.

  Escaping upwards: Old business processes should be revisited, new ones determined and all challenged for their future-proofed capacity. Financial stability also provides confidence to invest in the future.

- ***Securing the foundations:*** executing the logistics processes effectively.

  Escaping upwards: Anything that is done need not rip the underlying solidity apart, smart supply chain management solutions work with the execution structure rather than fight against it.

- ***Managing your own supply chain processes:*** align planners and schedulers, schedulers and traders, operations people, and accountants all towards a common goal – managing your supply chain to begin minimizing costs and maximizing profits/margins/efficiencies. Breaking down internal functionality silos is also a key. Internal fighting can be very harmful and deflects attention from the real threats and opportunities that exist outside the company.

  Escaping upwards: Returns on the gradual tinkering within this stage becomes unproductive. Only by expanding beyond the boundaries of the business can the next real rewards be reaped. This means active dialog with partners, whilst maintaining the stable foundation built above.

- ***Go "collaborative":*** define and take advantage of c-business (collaborative business) market opportunities.

  <u>Escaping upwards:</u> The next steps require industry-wide advances that need a positive and consistent (universal) driver to bond the whole together and achieve the common goal of the interest group.

- ***Go Global and Unified:*** Look at a goal and a vision, something which requires a major driver to bring about what each oil company on its own does not possess. Strong supply chain partnerships are required to achieve this objective.

4.3 Trends and new developments (conduct and performance)

According to Masson (2004:1,4) profitable growth in the chemical industry requires **segmented services** through product and service innovation. Unfortunately, most companies in the chemical industry are still primarily focusing on cost reduction, not growth. Leaders in the chemical industry will also look outside of manufacturing for their next round of bottom-line improvements, thus lowering supply network costs by enhancing **collaboration with trading partners** to align manufacturing capability with demand. Serving both commodity chemical- and service-based segments will require different supply network strategies. The many challenges that still face the chemical industry are:

- The chemical industry cannot save its way to profitability
- Operational excellence is necessary, but not sufficient
- Profitable growth requires segmented services
- IT has a strategic role beyond provisioning shared services

SCM is growing in importance in the chemical industry (Whitfield, 2004). But, as the emphasis of SCM is on adding value rather than simply cutting costs, it looks as if **appropriate integration** is the only way ahead. **Highly integrated processes** all the way from the procurement of raw materials to the delivery of the final product should exist. Manufacturing efficiency alone does not ensure a competitive advantage any more. **SCM needs to become the backbone** of a business where logistics costs can be greater than manufacturing costs (excluding raw materials).

As indicated in Figure 4.16, petrochemical exports as ratio of production in South Africa has risen significantly over the last ten years (Department of Trade and Industry, 2004b). This directly contributes to the complexity of the petrochemical company's supply chains. With longer lead times, shipping reliability risks, international trade logistics and variability playing a much bigger role, planning over a longer time horizon becomes more crucial. Adding to the **complexity** of the business is the wide range of products, line items, and amount of role-players involved in the supply chain. Foreign investments in global manufacturing locations and businesses (through capital investments, joint ventures, and mergers/accusations) also add a new dimension to the petrochemical company's supply chains. A **global perspective** is required with superior integrated planning to realize the expectations in the justification of these ventures. It can't be business as usual and the synergies must be rigorously managed.

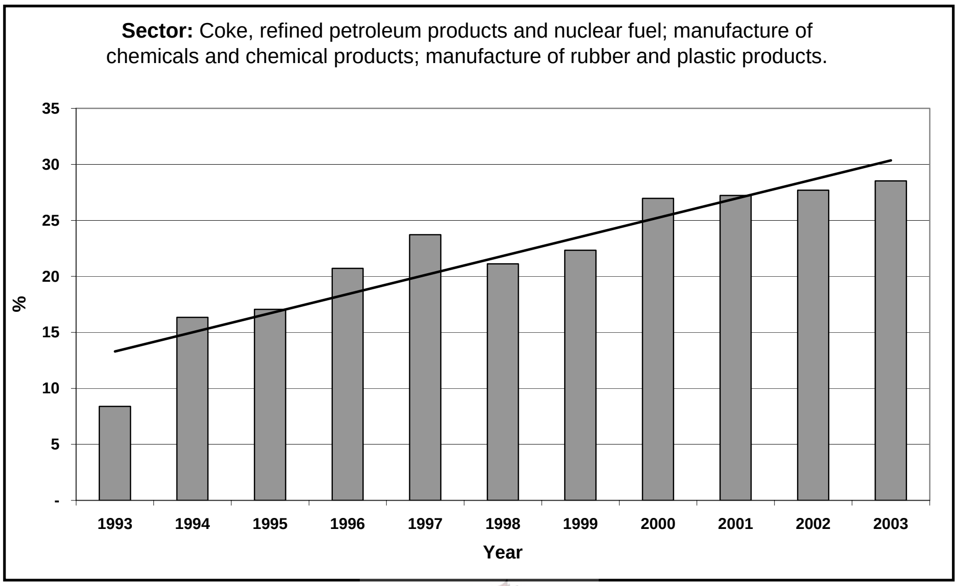


Figure 4.16 : RSA's petrochemical exports as ratio of production
[Source: Department of trade and industry, 2004b]

Based on the supply chain benchmarking studies conducted by AMR Research in 2004, it shows that the **Sales and Operations Planning (S&OP) process** is the critical best practice most widely adopted by **Demand Driven Supply Network (DDSN)** leaders across industries (Masson, 2005). The Chemicals industry is no exception. The more advanced chemical companies are using the S&OP processes to anticipate and profitably respond to demand. They typically prioritize the use of price optimization to develop price elasticity curves to outline price/volume tradeoffs, integrate with sell-side and raw material contract compliance to assess contract compliance risk, develop plans to sell excess capacity in lean times and profitably allocate capacity in boom times, and identify a trading plan.

4.3.1 Change pressures

Petrochemical companies are increasingly faced by **global competition** (Krenek, 1997:100). Confronted by the challenges of keen global competition, coupled with higher customer requirements and lowered working costs, chemical manufacturers are forced to seek new avenues to streamline operations and further tighten fiscal belts.

Flat growth, declining prices, accelerated product lifecycles, globalization/localization, regulatory pressures, and risk management are the major business challenges the chemical industry faces (AMR Research, 2004:3). The business goals of bulk chemical companies are geared toward mastering these issues and include:

- Operational excellence (lean manufacturing, rationalizing global operations, cost reductions)
- Expansion into new products, services, markets, and channels
- Consolidation/mergers and acquisitions
- **Extended supply chain** virtual operations and partnerships
- Supplier relationship management/strategic sourcing

The petroleum industry needs to change (Kafoglis, 1999:48). Faced with volatile prices, plentiful crude oil supplies, excess refining capacity, tight product inventories and a changing product/service mix, it is becoming increasingly necessary for downstream companies to **find new approaches to realize operational excellence** and increase profitability. One new approach is to fully integrate the supply chain across all functions and assets.

The chemical industry already started to address the supply chain approach challenges in the late 90s (AT Kearney, 1997:4). Throughout the nineties, chemical companies have made dramatic improvement in operational efficiency and cost reduction through business process reengineering. They have also invested in information technology (enterprise-wide systems) integrating all their data and information on a corporate-wide basis. But this has largely been internally focused. AT Kearney (1997:45) indicate that the following are typical **competitive issues** facing the chemical industry in the future:

- Satisfying the customer (understanding the position in the chemical value chains)
- Understanding the end users (not only the customer)
- Electronic linking (to ease the information availability about the end user)

Historically chemical logistics has played a supporting role within a volume-driven manufacturing environment (Garman, 2005:31). The focus has been on high production utilisation. In this context, logistics has traditionally been regarded as a cost to be minimized rather than a source of competitive advantage. Over-emphasizing chemical process management can be viewed as an incremental approach that rarely delivers anything ground-breaking (whether it be with regard to monetary savings, headcount reduction or percentage performance improvements). A more visionary leadership approach focuses on future needs, and instead, takes an analytical and holistic approach to supply chain management. Successful chemical supply chains will be those which avoid the separation of strategy and execution. **Supply chains will need to be an integral part of the business** in contrast to historical silo thinking. This will require that the supply chain function take its place at the boardroom table. Inevitably this will also alter the manufacturer and logistics service provider relationship to change from one of buying resource provision to strategic partnership. As indicated in Figure 4.17 chemical companies are now adopting new strategies to combat historically low returns and differ for the commodity and speciality chemicals.

Strategy 1: Commodity chemicals	**Strategy 2: Specialty chemicals**
• achieve absolute cost leadership through supply chain optimisation	• move up the value chain, often branded, specialty products
• production relocated to reduce cost	• requires increased investment in sales and marketing
• increases cost of logistics (esp. inventory and transportation)	• requires a very responsive supply chain delivering high levels of service
• may reduce customer service levels and supply chain responsiveness	• needs a change in organizational focus and mindset

Spectrum

Figure 4.17 : Chemical companies now adopting new strategies to combat historically low returns. [Source: Garman, 2005:31]

Lewis (2005:26) also indicates that the **supply chain has become the focal point** for change in Europe's powerful chemical industry. In many cases supply chain costs represent up to 37 per cent of net value. To stay competitive, the chemical sector will have to sharpen its act in order to react quickly to new challenges. Many chemical manufacturers throughout the world have overhauled their production over the past few years, and there are now only limited opportunities to realize major savings in this area. The focus has now changed to the **efficiency of the total supply chain**.

4.3.2 Supply chain advancement

Petrochemical companies responding strategically with an integrated supply chain approach are demonstrating dramatic cost savings (Krenek, 1997:97). By using effective supply chain management, a petrochemical company can reduce total production costs by 20% to 25%, plus cut product inventory by 20% to 30%.

Supply chain management has become the leading strategic concern in the chemical industry, with more than 90% of companies starting to plan supply chain initiatives in the late 90s (AT Kearney, 1997:11).

The following trends and findings were gathered from a survey regarding supply chain management in chemical businesses (PWC. 1999b:24):

- Mastering the supply chain is the key to future profitability
    - Companies are reengineering their supply chain in the hope of cutting costs and raising efficiencies.
    - 75% of a company's costs are in the supply chain.
    - The ability to gain price premiums has become very difficult. The key to profit growth lies in cost optimization.
- Globalization is changing the supply chain
    - Intensified price competition
    - Creeping commoditization of products
- Changing mindsets: customer focused
    - The demand chain orientation; customer pull rather than producer push
- Business processes must change first
    - Clearly the industry has fallen in love with enterprise resource planning (ERP) systems. About 80% of the companies surveyed either have installed or are installing ERP somewhere in their supply chain
    - The next big thing will be forecasting and planning systems which purport to coordinate the links in the chain
- Virtual organizational approach
    - Unconventional form of outsourcing: de-integration of manufacturing; Many companies are choosing to contract production of feedstock formally sourced internally.
- Non-financial management will gain acceptance
    - Management according to non-financial measures is the exception not the rule
    - KPIs are increasingly used, despite having been around for some years
- Behavioural change is the biggest challenge
    - Given the silo-like structure of many companies, the trend to demand revolutionary tactics (e.g. sharing of information), if change management is not done successfully, could lead to undesirable consequences.

Kafoglis (1999:50) indicate that an effective supply chain technical architecture must be able to:

- optimise production timing,
- perform on-the-fly adjustments,
- allow for easy scenario planning, and
- support all levels of planning.

In supporting planning at all levels, optimization must focus on the entire supply chain as a whole rather than optimizing each individual function. The tools that can enable these requirements are generally known as advanced planning and scheduling (APS) tools. No single tool can enable the vision and no single algorithm or optimization tool is the best for the full range of applications that constitutes an integrated planning architecture. The key is to determine the best mix of tools to address specific supply chain challenges. By implementing APS tools properly, in concert with LP tools and

ERP solutions, it should be able to manage all the industry complexities as indicated in Figure 4.18 and Figure 4.14.

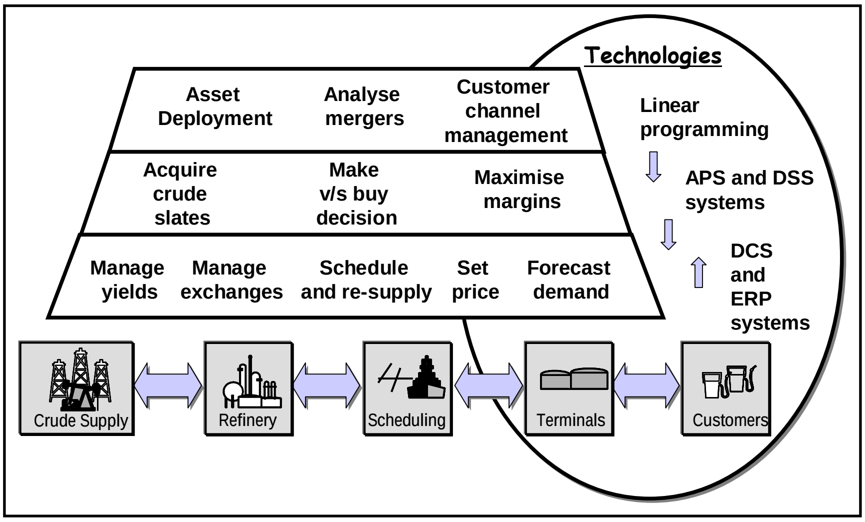


Figure 4.18 : APS tools can manage the petroleum industry complexities
[Source: Kafoglis, 1999:50]

The supply chain has become a forefront issue in the petrochemical industry (IBM, 1999:13). This is largely due to the changing environment (globalization, integrating acquisitions, industry regulations) and the dilemmas the petrochemical industry are facing (inadequate organizations structure, competitive positioning, process inefficiencies, supplier relationships, inventory problems). Possible remedies or solutions to these dilemmas include: cost control and supply chain, organizational design, change management, industry structure analysis, position analysis, production technology evaluations, overhead benchmarks, cost benchmarks, market forecasts, pricing issues, and raw material and sourcing studies.

The following were indicated as corporate initiatives planned by companies in the petrochemical industry (AT Kearney, 1997:28):

- Supplier/purchasing relationships
- Stronger customer relations
- Transportation/total cost reduction
- ***Cross functional integration for supply chain management***
- ***Planning and operations process***
- Cross functional integration for order fulfilment
- Information system upgrade
- Manufacturing effectiveness
- Product quality
- Economic value add measurement systems

Chemical businesses are faced with a challenging external environment. Continued pressure on margins and regulatory compliance has forced chemical companies to drive towards higher asset utilization and economies of scale (Supply Chain Consultants, 2003b). Managing supply chains in such an environment is difficult. In spite of this leading companies have managed to extract large savings by utilizing quantitative techniques to plan their supply chain operations. Some advanced chemical businesses now run their supply chain with less than half the inventory of their competitors, even though their manufacturing technology and assets are similar. The advantage comes from using all available information effectively to consistently make robust and "fact-based" decisions. This is made possible by using collaborative planning software and integrated processes that:

- Increase the visibility of available information
- Provide a solid framework for making robust decisions under uncertainty
- Use appropriate technology to optimize operations and reduce inefficiencies
- Break down organizational silos by providing and maintaining a consistent set of data to manage the supply chain.

As indicated in Figure 4.19, bulk chemical manufacturers outperform other industries in three of the five areas investigated by AMR Research (2004 Benchmark Analytix - AMR Research, 2004:4). These are: effectiveness, order quality, and efficiency. The big focus on process, plant, and delivery optimization are some of the major contributing factors. However, they pay more and take longer to deliver orders. Cost reduction is a focus for these manufacturers, forcing them to think out of the box, develop innovative processes, and seek alliances in investment spending. Given certification and transit cycle times, there is less opportunity to improve order cycle time. With the emphasis on asset utilization, the bulk chemical industry has the highest median plant utilization of industries surveyed, equalling 80.7%. Other industries with continuous processes, like consumer goods, tend to push utilization into the high sixties. Discrete industries average about 55% utilization.

Chemical industry leaders have started to widen their optimization scope from being predominantly plant-focused to becoming supply chain focused. They have entered the brave new world of supply networks, customer segmentation, and price management. This is happening in the midst of competitive pressures to become more customer focused, reduce high supply chain costs and improve margins (Connor & Souza, 2006). Focusing on the customer, new practices are evolving, and supply chain executives are launching these practices throughout the corporation. Some initiatives related to specific practices include: wrapping services around products to create an enhanced revenue opportunity, formalizing the Sales and Operations Planning (S&OP) processes to be more inclusive of all internal stakeholders, and redesigning the total supply network so that the enterprise can sense changes in demand as soon as possible.

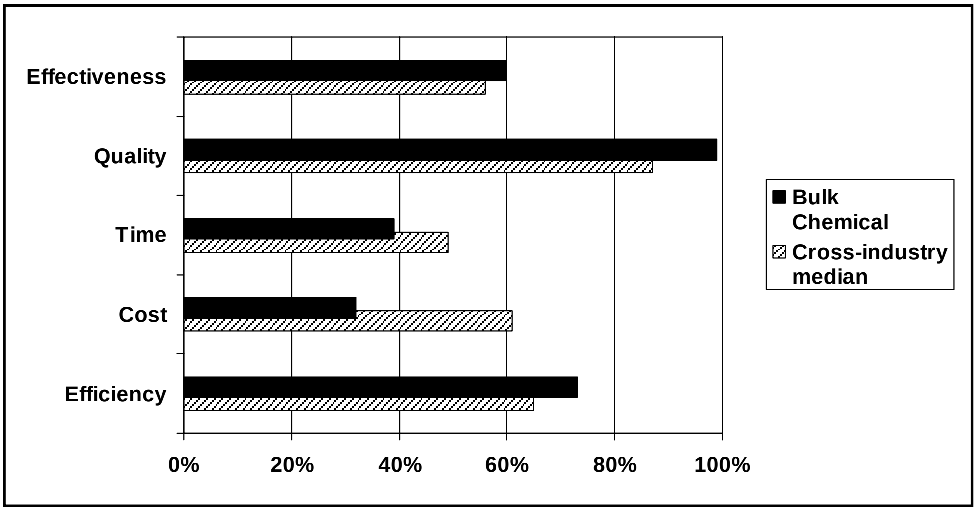


Figure 4.19 : Chemicals Businesses' Supply Chain Performance
[Source: AMR Research, 2004:4]

4.4 Summary of literature study related to petrochemical industry overview and supply chain planning challenges

Some fundamental differences exist between the process/petrochemical manufacturing businesses and discrete manufacturing businesses. Process industries add value to materials by mixing, separating, forming, purifying, or chemical reaction. Discrete manufacturing uses a bill of materials (with the supply chain convergent in nature) to make each finished product. The process industries often end up with a greater variety of products than raw materials, resulting in a bill of products (with the supply chain divergent in nature) as opposed to a bill of materials. Other differences relate to the type of technology employed, flexibility, product volume, capital required and unit cost. Petrochemical businesses have to deal with the associated divergent value chain. Upstream of the processing facilities relative few organic and inorganic raw materials need to be supplied. Securing and getting access to large volumes of these relatively low value materials is one of the key business drivers of large-scale petrochemical companies. Process industries typically account for half of all manufacturing, and this is growing. The petrochemical industry is highly complex and widely diversified, with end products and co-products often being composed of a number of chemicals which have been combined in various ways to provide the required properties and characteristics. The products being produced can typically be classified into primary products (feedstock and commodity chemicals), secondary products (intermediate chemicals) and tertiary products (specialty chemicals and processed goods).

The petrochemical industry is still a victim of silo mentality, something they have struggled to overcome for decades. While information technology systems are available to provide visibility into the supply chain, few are being used cross-functionally. Breaking down existing silos may be a tough job because the industry is organized around highly specialized business processes which encourage fragmentation. The petrochemical industry's business approach is however changing. Pacesetters in the petrochemical industry are replacing asset-driven approaches to business with a market focus and in some cases a trader mentality. Joint ventures, alliances and mergers are also significantly changing the competitive landscape. Although most companies continue efforts to reduce capital employed, a new trend is emerging where careful inventory management allows companies to take advantage of trading opportunities in a volatile market. Decision support systems for the petrochemical businesses should deal with three major business segments. These comprise:

- The supply segment (responsible for production, purchasing, and product exchange activities with other chemical corporations/co-producers)
- The storage and customer distribution segment (typical logistics activities of storage, packaging, handling and transportation)

- o The demand segment (responsible for customer demand, and locations where products have to be supplied to end markets and co-producers; due to product exchange agreements)

Supply chain business processes in petrochemical businesses are still very fragmented. These business processes involve a huge amount of communication and common understanding requiring sound and mutual beneficial relationships.

Over the last ten years petrochemical exports in South Africa (as ratio of production) has risen significantly. This directly contributes to the complexity of the petrochemical company's supply chains. With longer lead times, shipping reliability risks, international trade logistics and variability playing a much bigger role, planning over a longer time horizon becomes more crucial.

Although slowly, the petrochemical industry has started to believe in the potential of using advanced supply chain planning processes, as well as employing modelling to enhance their decision making. There are also some positive signs in organizational development to assist in the change process. Supply chain management is becoming the leading strategic concern in the petrochemical industry, with many companies planning or implementing major supply chain initiatives. Although numerous SC planning studies, pilots and proposals have been carried out to show the potential value, a relatively small portion has moved forward and taken the step to implementation. Supply chain leaders in the petrochemical industry follow an evolutionary (as opposed to revolutionary radical change) process to unlock value for their organizations. From the paragraphs in this chapter, it is evident that the petrochemical industry does differ significantly from other industries regarding the nature of planning decisions. This poses some unique challenges to overcome before these organizations will be willing to radically change their supply chain planning approaches.

Chapter 5: Findings and deductions from empirical research

Chapter 5 provides the results of the empirical research conducted. The findings and deductions from the interview questionnaires completed were analyzed, and are presented here. Semi-structured interviews (combined with a limited advancement questionnaire) were conducted with key stakeholders. The purpose of the interviews was to gain better industry understanding, assess appropriate supply chain planning practices and to determine the level of advancement in a number of supply chain planning related areas. Experts and credible participants from the petrochemical industry, consultancy, enabling technology suppliers and academia took part in this empirical research.

5.1 Approach and process followed to conduct the empirical research

Since the number of potential participants for this empirical research were relatively small (due to the field, scope and context of this study), a stakeholder (Participants) approach coupled with the Delphi technique was used to obtain general agreement on the findings among an informed audience. Experts and credible participants from the petrochemical industry consultancy, enabling technology suppliers, and academia's perspectives provided a balanced contribution, means of validation and assurance of consistency (Triangulation principle).

The process followed included:

- Drafting of interview questionnaire
- Screening interview questionnaire for coverage and intent with promoter
- Identify participants – selection criteria and perspectives (see paragraph 5.2)
- Invitation to participants and confirmation of willingness to contribute
- Introductory letter sent out and scheduling of interview
- Conducting of semi-structured interviews (combined with a limited assessment of advancement through the questionnaire)
- Analysis of interview questionnaires
- Summary of findings
- Distribute draft of summarized findings for review, comments to participants
- Receive and consolidate comments into summarized findings
- Compile chapter on Empirical Research Findings and Deductions for dissertation.

This process embodied the empirical research completed over the period July 2005 to December 2005. The interview questionnaire used is attached as Appendix A.

5.2 Participants (stakeholders)

Experts and credible participants from the petrochemical industry, consultancy, enabling technology suppliers and academia were identified and selected, based on some of the following criteria:

- Understanding of the petrochemical business challenges
- Knowledge and active involvement in the SCP and DSS disciplines
- Chemical/process engineering background
- Understanding and experience in large scale petrochemical companies (Upstream and downstream)
- Provided solutions that focus on petrochemical companies

In total 21 "one-on-one" interviews were conducted either through appointments or telephonically. Table 5.1 gives an overview of the participants that took part in the interviews.

Table 5.1 : Participants that took part in the interviews

Name	Company	Perspective/Discipline
Prof. Thokozani Majozi	University of Pretoria	Process Integration
Anton du Plooy	ETP	Petroleum Industry & Modelling
Cobus Rossouw	Volition	Supply Chain Strategy & Planning (from a FMCG Perspective)
Henry Lane	CMCS	Chemical Marketing and Consulting
Colin Masson	AMR	Chemical and Process Manufacturing
Willem Cilliers	Guqula	Supply Chain Strategy & Planning
Dr. Stephen Franks	Supply Chain Doctor Network	Supply Chain Planning
Andries Burger	Sapref	Operations Management
Andy Redman	Sasol Technology	Business Concept Development
Ben Human	Merisol (Sasol Joint Venture)	Global Strategic Supply Chain Management
Cyril Stevens	Engen	Supply Chain Planning
Dirk Uys	Sasol Ltd.	Marine Logistics Management
Humphrey Tedder	Sasol Polymers	Polymers Corporate Planning
Iloise Ras	Sasol Polymers	Supply Chain Planning Processes
Johann Venter	Sasol Ltd.	Group Planning
Vojta Svoboda	Total	Supply Chain Planning
Wayne Degnan	YARA	Supply Chain Management
Paul Schiller	BP Chemicals – Global	Project for Integrated Supply Chain Planning
Alex Algra	Sasol Oil	Manufacturing, Supply and Trading
Roch Gauthier	Aspentech	Supply Chain Planning & Modelling
Francis Gould-Marks	Private APS consultant	Supply Chain Planning & Modelling

5.3 Presentation of findings

The interview and questionnaire findings are presented in Section I and Section II respectively. In conducting the interviews and questionnaires, it soon became apparent that the nature, practices, and level of advancement in the liquid fuels and chemical domains sometimes differ. Companies or divisions focusing upstream in the macro petrochemical "pipeline" do follow different supply chain approaches and are faced with different decisions than those downstream. For this reason, where applicable in this synopsis, the participant's responses were separated and aggregated into the liquid fuels and chemical business. Since other process manufacturing businesses and fast moving consumer goods (FMCG) businesses were also briefly assessed, reference will be made where applicable.

Section I : Interview findings

5.4 Petrochemical companies in context

The following paragraphs provide an overview of the South African petrochemical companies' context (summarized from the interview findings). This includes a brief petrochemical value chain orientation, the basis businesses are structured on, and some business indicators related to the supply chain.

5.4.1 Nature of the petrochemical business and value chain orientation

The macro petrochemical value chain (pipeline) is characterized by a number of linked and successive interdependent transformation stages and processes. Starting with a relatively small number of raw materials, a large variety of different liquid fuel and chemical products (organic and inorganic) are produced in subsequent refining processes. These products are then either distributed and sold locally, or exported. Some products are made intentionally, while others are the result of the processing technology being used (co-products).

The manufacturing/transformation processes utilize very sophisticated refining and chemical conversion technology that predominantly operate 24 hours a day to convert feed material into value-added liquid fuel and chemical products. Petroleum distillates and chemical streams higher up in the macro petrochemical value chain are less stable and more dangerous to handle, compared to downstream liquid fuels and chemicals. This is one reason for closely linked manufacturing plants to be co-located on the same facility. Manufacturing plants could, however, also be geographically spread in a specific country, or globally. Logistics networks are then utilized to transfer the required feeds between facilities and ultimately to the various markets served. The various stages of the macro petrochemical "pipeline" (value chain) typically deal with raw material (e.g. coal, oil, gas), petroleum distillates and chemical feed streams (e.g. naphtha, ethylene), liquid fuels and bulk chemicals (e.g. petrol, diesel, methanol, ammonia), fine chemicals (e.g. reagents, surfactants, explosives, polymers & resins) and specialty chemicals (e.g. adhesives, films & fibres, paints & additives).

Along the various stages of feed and derivative transformation, opportunities exist to either sell/trade the petroleum and chemical products, or to further process them into higher valued products (progressing closer to the end consumer).

South Africa, because of its abundant access to low-grade coal and leading edge process technology, is currently the lowest-cost producer of ethylene and propylene in the world (two of the major chemical feed streams).

Chemical exports have increased as compared to import value from about 50% in 1996 to about 81% in 2001. Due to the substantial interdependency of the petrochemical value chain, nearly 60% of product trade is within the macro petrochemical pipeline. The revenue generated is the result of 50% product trade in the industrial markets (chemical, non-chemical and other related industries) with the other 50% to the end consumer markets. The two largest sub-sectors are liquid fuels (accounts for 32% of revenue) and plastics (accounts for 21% of revenue).

The Department of Trade and Industry (the DTI) has subdivided the South African chemical industry sector into 12 sub-sectors (as indicated in Table 4.4). Based on this subdivision, Table 5.2 gives an indication of the major players in each sub-sector.

Table 5.2 : Major players in each of the chemical industry's sub-sectors
[Source: Department of trade and industry, 2004]

Sub-sector	**Major Players**
Liquid fuels	Shell, BP, Total, Sasol and Caltex
Basic organic chemicals	Sasol, Dow, AECI, African Products, Degussa
Basic polymers and rubbers	Sasol, Dow
Basic Inorganic	AECI, Bayer, Dow, IOF, NECSA
Fine chemicals	Dow, AECI, FCC
Specialty and functional	Bayer, AECI, Plascon, Resinkem, Chemserve, Aventis
Bulk formulated	Sasol, Bayer, Omnia, AECI
Pharmaceuticals	Adcock Ingram, Aspen Phamacare, GSK, MSD, Novartis, Pfizer
Consumer formulated	Unilever, Colgate Palmolive, Plascon, Dulux
Plastics	Fenner SA, Goodyear, Dancor, SA Leisure
Rubber	Bridgestone/Firestone; Goodyear
Synthetic fibres (textiles)	SANS Fibers

Individual value chains typically exist within the various stages of the macro petrochemical value chain. Business units are structured around a specific product or product family and the related distribution, manufacturing and upstream sources of feedstock.

Taking a macro perspective, dominant petrochemical value chains are structured around those products that have high volume demand and high revenue, or are strategically important for a country/region. Major expansion projects also indicate dominant products (e.g. big Ethylene plants). The major volume driver/growth for synthetic materials and polymers are the replacement of more traditional materials such as steel, wood, wool etc.

Individual value chains (specifically those upstream in the petrochemical value chain) compete to secure adequate feed for their manufacturing processes. Companies could make a conscious decision to vertically integrate, and thus get control over availability and cost. Where multiple business units within a petrochemical enterprise internally rely on the same feed, a group perspective is needed to assure profitable allocation of these chemically rich feed streams (typically done by a group optimization group function). This highlights the need for clear downward visibility of demand and margins. Forecast accuracy is thus an important factor to assure reliable information. With the right demand information and mutual trust, very effective collaboration is possible in this allocation processes. Practices such as VMI and consignment stock can further enhance external visibility into downstream consumer demand.

Liquid fuels businesses

Crude oil feed for the South African based refineries are imported. From the large variety of crude oil grades imported, petroleum refineries produce a wide range of products from those with a very light, low boiling temperature, to the heavy, high boiling temperature ones. Typical products produced and marketed include liquid petroleum gas, propane, butane, naphtha, petrol (gasoline), jet fuel, illuminating paraffin, diesel, fuel oils, bitumen and sulphur. Other related products include lubricants, wax, solvents and chemical feedstock. To get these products to the market, primary distribution networks (to depots and commercial customers) and secondary distribution networks (to retail outlets) are used. Environmental pressures have initiated a major move towards unleaded and low sulphur containing fuels. The manufacturing technology and feedstock used, have a direct influence on whether or not, fuels produced could comply with the new environmental standards.

The petroleum products produced are mainly supplied to the South African local markets. Some petroleum products are also exported into near Africa countries. Oil companies will typically not have more than one or two refineries in a country and use supply agreements with the other oil companies to make up for its shortfall. Refineries are capital intensive and require vast numbers of utilities for production. Geographical product exchange (supply) agreements are commonly used between oil companies. An agreed volume of product will be supplied to a specific sales region of Company A from a nearby competing refinery (Company B). In exchange, the same volume of product will be supplied to a specific sales region of Company B from a nearby refinery (Company A). Both companies share in the benefits of not needing refineries in all regions, reduced logistics costs, balancing inventories and decreased working capital.

Derived from the interview findings, Table 5.3 indicates that, although most liquid fuel products are in a mature stage of their life cycle, the businesses structured around these products are still in a growth stage. This is evident by the increased demand for energy (fuel and gas) as well as the expanded scope of retail opportunities at petrol stations. Lubricants are viewed as growth products. Substantial research and development are continually coming up with lubricants that are more sophisticated. The development of gas-to-liquids (GTL) technology has provided new business opportunities to countries with "stranded" gas (e.g. Mozambique).

Table 5.3 : Product and business life cycle stage for "liquid fuels"

Life cycle stage - "liquid fuels"	***Products***	***Business***
Start-up/market development		○
Growth	○	●
Maturity	●	○
Decline	○	

Legend: Most replies ●
Some replies ○

Chemical businesses

Chemical companies predominantly rely on seven fundamental types of feedstock for the production of higher valued chemical products (agricultural and inorganic sources also play a significant role). These seven are: ethylene, propylene, C_4 Olefins (mixed butenes), benzene, toluene, xylenes and methane. Chemical feedstock is sourced almost exclusively from the energy sector (oil, naphtha, gas or coal). Most feedstock are available locally and only some process chemicals must be imported. The manufacturing facilities are predominantly located close to the major feedstock sources. Since chemical plants are relatively small when compared to refineries, multiple plants for the manufacturing of a specific chemical can exist in a country. Toll manufacturing and market swap are not as advanced as in the liquid fuels industry. During the manufacturing of the chemical feedstock and their associated derivatives, a number of other co-products (including inorganic chemicals) are also manufactured (e.g. ammonia). A number of successive chemical transformation processes are needed to transform chemical feedstock into intermediate derivatives and finally into chemicals for industrial or end users.

Chemical companies strive to backward integrate to gain control over feedstock. They also diversify downstream across a variety of chemical products to enhance their revenues, as well as reducing their financial risk due to the volatility and cyclical nature of chemical prices.

The major chemical products derived from the seven types of feedstock as well as some of the end uses of the final products are:

(a) **Ethylene – Polyethylene** production mainly drives ethylene usage. Other related products produced are HDPE, LDPE, LLDPE, ethylene oxide/glycol, ethylene dichloride/vinyl chloride monomer (for PVC), alpha olefins, ethylbenzene/styrene, vinyl acetate and some ethanol. Polyethylene products are soft and stretchable, and are typically used for wraps, plastic bags, milk bottles, packaging film, pipes, tubing and soft toys.

(b) **Propylene – Polypropylene** production mainly drives propylene usage. Other related products produced are propylene oxide, oxo alcohols, acrylonitrile, cumene, acrylic acid, oligomers, isopropanol, allyl chloride. Polypropylene products are hard, and are typically used for carpets, brushes, film sheeting, plastic bottles, rigid packaging and hard toys.

(c) **Butadiene –** The most important C_4 **Olefin** feedstock is butadiene which is produced from mixed butenes. Products produced from butadiene are styrene butadiene latexes and rubbers, polybutadiene rubber, hexamethylene diamine (Nylon 6,6 percursor), ABS, nitrile rubber, chloroprene. These products are typically used for paints, adhesives, footware, hoses & seals, tyres and tyre products.

(d) **Benzene –** Benzene is the third most important chemical feedstock after ethylene and propylene. Benzene is mainly used to produce Ethylbenzenes (EB) or **styrene**. Other Benzene derivatives are cumene (mostly converted to phenol and acetone), cyclohexane (feedstock for Nylon 6 via cyclohexanone to caprolactam and nylon 6,6 via adipic acid), nitrobenzene and linear alkylbenzene LAB. These products are typically used for ceiling tiles, disposable cups for hot drinks, packaging, transparent sheets/windows, solvents, epoxy resins, and protective packing and floor polish.

(e) **Toluene –** Toluene is produced in excess of its natural demand and much toluene is converted to benzene. The only important chemical derived from toluene is toluene di-isocyanate for **urethanes**. These products are typically used for flexible foams, ridged foams and coatings.

(f) **Xylenes –** There are three xylenes - ortho, meta and para xylenes. The most important is p-Xylene that is used to produce **Teraphthalic Acid** for polyesters.

(g) **Methane –** Natural gas and the uses of methane have received increased attention over the last number of years due to environmental and economic pressures. This has resulted in a huge demand for natural gas as a feedstock for power stations, as coal and nuclear power have become unpopular. The most important chemical application is that of **synthesis gas** as raw material for ammonia and methanol production. The development of gas-to-liquids (GTL) technology has provided an alternative to countries with “stranded” gas to convert methane to transportation fuels.

In some petrochemical plants, fertilizer and explosive plants also exist. Various transformation stages are involved in the manufacturing of finished fertilizer products, from raw materials preparation through intermediate products. The major feedstock to these plants is:

- Nitrogen (N). Typically provided though ammonia (NH_3) being manufactured as a co-product or deliberately from methane.
- Phosphates (P). Typically provided through “phosphate rock”. The reaction with sulphuric acid produces phosphoric acid.
- Potassium (K). Typically provided through Potash or Calcium Sulphate.
- Sulphur (S). Sulphur sources.

The intermediate products for the production of fertilizer and explosive products are ammonia, nitric acid, phosphoric acid and sulphuric acid. The finished fertilizer products produced include:

- Urea (N)
- Ammonium nitrate (N)
- Calcium ammonium nitrate (N)
- Nitrogen solutions (N)
- Ammonium sulphate (N & S)
- Ammonium phosphates (NP)
- Super phosphates - SSP & TSP (P)
- Compound fertilizers (NPK, NK, PK)

In South Africa, chemical producers serve both local and export markets (near Africa and international exports). Companies with a large local focus and that produce substantial volumes, often also have the major market share. When local markets are saturated with local supply, larger overflow volumes are exported. A number of factors influence the markets served by chemical producers. These include product value, domestic market size, and production volume.

Derived from the interview findings, Table 5.4 indicate that, although most chemical products are in a mature stage of their life cycle, the businesses structured around these products are still in a growth stage (some new ventures are in the start-up stage). This becomes evident in the increased demand for chemical products. The fertilizer industry also moved to new innovative bulk blending processing (from 3 x dominant N, P & K grades) compared to previous chemical plants manufacturing pure chemical grade products. There are however environmental pressure and black listing of some chemical products in certain countries (causing these products to go into a declining stage).

Table 5.4 : Product and business life cycle stage for "chemicals"

Life cycle stage - "chemicals"	***Products***	***Business***
Start-up/market development		○
Growth	○	●
Maturity	●	○
Decline	○	○

Legend: Most replies ●
Some replies ○

5.4.2 Business Structure

The South African chemical sector comprises of relatively few major integrated oil, gas and chemical companies involved in primary and intermediate manufacturing. These major integrated companies cover around three to four major stages in petrochemical stream and chemical beneficiation/transformation process. Small and medium-size enterprises are found mainly in downstream formulation and conversion processes.

Liquid fuels businesses

Throughout the participant's responses, it was found that most of the major integrated companies have corporate structures with some subsidiary businesses. In many cases oil companies (via joint ventures) jointly own refineries. Strong functional oriented structures exist based on the major stages of the value chain and major cost pockets:

- Exploration (Crude and Feedstock)
- Crude supply (Trading, Marine Shipping and Terminal Operations)
- Production (Refinery)
- Primary distribution (to Depots and Industrial Commercial)
- Secondary distribution (to Retail)

Marketing structures exist and are typically structured around agricultural, commercial, mining, aviation, and retail markets for the different fuels, product groupings (e.g. Gasoline, diesel, jet fuel, LPG, fuel oils, bitumen). Business support functions typically include finance, human resources, corporate affairs, audit, insurance and corporate planning. Internationally business and legal responsibility structures typically form around regional/political domain. The business structure also caters for major product groups: Fuels, lubricants, gas and non-fuels (e.g. wax, solvents, etc.).

Since crude sourcing form such a big cost driver in the liquid fuels businesses, crude trading functions and alliances are formed. They play a very important role in crude procurement and trading.

Very little direct interaction however exists between the functional structures. The functional areas typically result in deep silos of specialization and the management of the integrated supply chain does not resort under one functional entity. Semi-integrated manufacturing, supply, and trading structures are formed to deal with strategic and tactical value chain decisions. These holistic planning structures either form part of the supply structure, or part of corporate planning. These functions are mainly responsible for supply planning (sourcing, manufacturing, logistics) and demand planning. In some cases supply and demand planning functions also coordinate excess fuel exports. Each shareholder's refinery representative function normally does manufacturing planning. This typically includes supply planning, refinery planning and crude trading. Manufacturing planning (tactical and operational) is also done at the refinery to test for feasibility, refinery utilisation and yield optimization of the stakeholder's manufacturing plans. Inventory replenishment planning is done at the depots and logistics operations are decentralized on a regional basis.

Chemical businesses

From the participant's responses, it was found that most of the major chemical companies also have corporate structures with subsidiary businesses (divisions and business units). In some cases businesses are jointly owned by major chemical companies (via joint ventures) and either operate totally independent, or leverage some of their holding company's services.

Business entities are primarily structured in divisions or business units around product families and product application for value chain accountability (profit and loss) and customer focus. Sales offices are typically structured around geographical regions. Regional and country-specific structures also exist for legal operational responsibility (manufacturing facilities), managing support functions, and business administration. Depending on the nature of the business, structures can be single-site, regional, and global business unit orientated. Some cross-divisional-wide strategy, planning and shared support service functions are formed at the location where it makes business sense (e.g. finance, human resources and central planning).

Unfortunately, there is still a very strong functional and silo structure orientation, even within business units. The establishment of cross-functional processes are still relatively new and have a long road ahead to reach the required impact and contribution (e.g. planning). The process owners of these cross-functional processes also still have a tough challenge to initiate the behavioural changes required in functions, and to prevent the perpetuation of the past.

Note: The FMCG businesses have a strong value chain-oriented structure per product and regions.

5.4.3 Some business indicators

Liquid fuels businesses

Crude oil cost has a major impact on the value chain cost for liquid fuels businesses. Figure 5.1 indicates that crude oil costs amount to 80 - 90% of revenue. Up to 80% of oil companies' profit depends on the profitability of crude oil trading (Larger margins made upstream in the value chain). The crude oil trading prices have a major impact on margins. Margins can be as low as 0.5 -1% at crude oil trading prices of $35/pbl and could increase to 8 -10% at crude oil trading prices of $60/pbl. The direct supply chain cost as percentage of sales typically amounts to 90% and total direct inventory value as percentage of turnover amounts to 15%.

The level of awareness in terms of opportunity, benefits, and bottom line effect of supply chain improvements is increasing substantially.

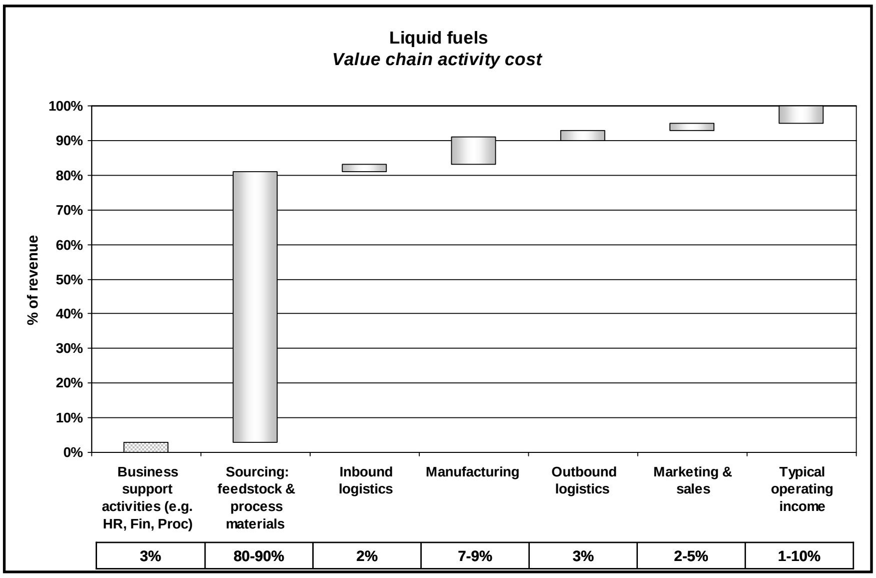


Figure 5.1 : Value chain cost build-up (Liquid fuels businesses)

Chemical businesses

Although feedstock cost for chemical businesses is at a lower percentage (20 - 40%) compared to that of liquid fuels businesses, it still has a major impact on the chemical value chain cost (as illustrated in Figure 5.2). Since there is a substantial growth in chemical exports and foreign revenue, outbound logistics cost is at a higher percentage than that of liquid fuels businesses. The direct supply chain cost as percentage of sales typically amounts to 70% and total direct inventory value as percentage of turnover amounts to 12 - 30%.

Note: FMCG businesses higher in marketing and sales cost (end consumer related).

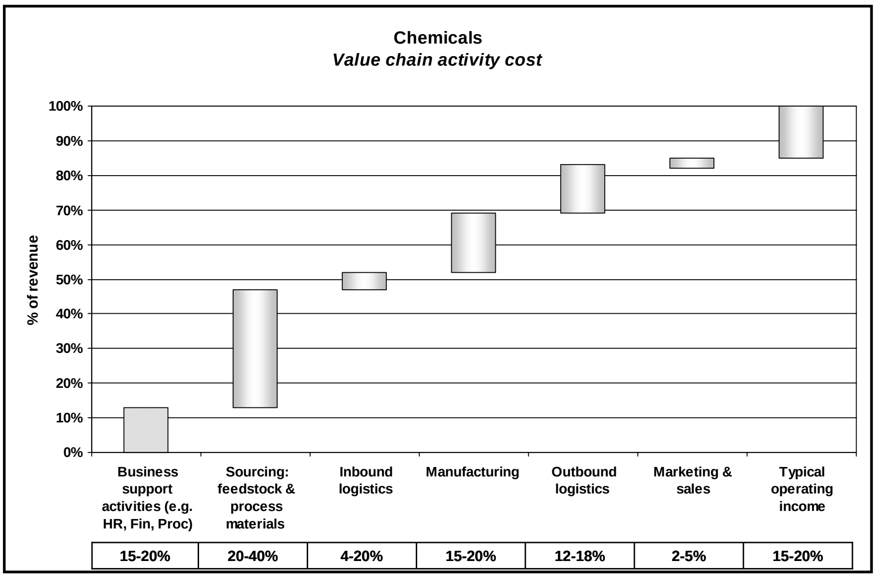


Figure 5.2 : Value chain cost build-up (Chemical businesses)

5.5 Supply chain approach/orientation followed in petrochemical companies

Most participants agreed that a relatively small number of petrochemical companies have adopted a full supply chain approach in managing their businesses along horizontal cross-functional processes reaching across upstream, refining and downstream supply chain stages. Where the adoption of a supply chain approach has been started, it is still in the early stages of development (2 to 3 years in existence). Planning processes are used as the main mechanism to interact and align across the functions directly involved in the supply chain.

Although some chemical businesses have adopted a supply chain approach in managing their businesses, processes are distributed among the business units and functions and not necessarily totally integrated from source and make, to sell and deliver processes (total process ownership). Inbound logistics, procurement and supply, manufacturing, and outbound logistics could still integrate closer on strategic and tactical levels.

In some cases shared services and hub-and-spoke approaches are followed for some functions within a division across the business units. In the direct supply chain environment, these shared services typically deal with the procurement and supply management of external feed material, process chemicals, and logistics services. Each business unit manages outbound supply chain operations. Integration with outbound logistics service providers varies from arm's length relationships to alliance partnering.

Some divisions do their feed stream allocation planning centrally to ensure profitable use of chemical streams. Monthly sales and operations planning (S&OP) processes assure tactical alignment and integration between business units. S&OP processes provide input into constrained production planning per business unit.

Where business units and business groups are structured to manage the value chain of a product family (or product application family), a supply chain approach almost comes as a natural next step. Sales and supply chain processes closely align to assure demand fulfilment and perfect orders. However, supply chain is still approached as a support function and not a core business process.

Major business benefits were achieved by means of demand and supply planning change initiatives. The business drivers for most of these types of initiatives were process integration and standardization (Internal, Downstream, Upstream, and External).

In FMCG businesses, a strong value- and supply chain structure approach already exists. A sound balance between functional and process structure is maintained. The level of advancement in adopting a supply chain approach also depends on the leadership approach, company size, complexity and turnover. The typical supply chain management structure employed includes:

- Procurement manager
- Supply manager (MPS & production scheduling)
- S&OP manager (SC strategy, S&OP process, forecasting)
- Customer operation (call centre, order management)
- Distribution manager (inventory replenishment)

Although the awareness has been kindled, very few petrochemical companies have sufficiently advanced to a point where pro-active influences and incorporation of supply chain considerations in the formulation of business strategies are formally structured and applied. This relates to the strategy formulation during the establishment of new businesses and long term planning of existing businesses. Where supply chain is still viewed as a support function, its influences on business strategies/scenarios are not always taken into account.

Where businesses have advanced in their adoption of a supply chain approach, typical supply chain design considerations taken into account with business strategy planning are:

- Market geographical and segmentation analysis
- Supply chain competitive requirements analysis
- Time, responsiveness and flexibility requirements
- Manufacturing site selection
- Sourcing evaluation
- Off-site facilities site selection
- Transportation requirements

Continuous strategic interventions are aimed at achieving world-class supply chain operations and to support business units and divisions in enhancing their competitive position.

A very limited amount of supply chain strategies, that has translated identified key business drivers into supply chain drivers and focus areas are properly documented. Some of the business units are well advanced in supply chain strategic thinking, setting cross-functional goals and using performance measures to track supply chain performance. Other business units still need to reach functional excellence before being able to step into supply chain integration.

The profile of supply chain related functions still do not get the same appreciation as other disciplines (e.g. marketing, finance, etc.). Adopting the supply chain approach in the chemical industry is relatively slow compared to other industries. Supply chain is still viewed as a function within the value chain, rather than the operational representation of the value chain's planning and execution activities related to inbound, manufacturing and outbound (excluding marketing and other business support functions). Although key positions are manned in the supply chain, they are either procurement and supply management or logistics biased. Limited executive representation exists and the full comprehension and understanding of a supply chain approach is lacking.

Upstream of the refineries, there is a good appreciation and awareness of the key role that the supply chain need to play (This relates to the major influence that crude feeds have on the Petroleum value chain). Unfortunately, this is not true for the supply chain stages downstream of the refineries.

As supply chains became more complex and costly, the awareness of and sensitivity to the supply chain's influence on the business have increased. Factors influencing Supply Chain complexity include:

- Number of supply chain stages
  (sources, inbound, plant, outbound [Primary and secondary], markets)
- Customer base (number of customers local and abroad)
- Range of products (with associated inventory distribution requirements)
- Nature of manufacturing processes (continuous, campaign or batch)
- Supplier base (no. of feedstock and process material suppliers)
- Logistics service providers (number of transport, facilities, support services contracts)
- SC length – geographical spread and reach
  (SC operation model; upstream and downstream)
  - 1st Tier (local – overland)
  - 2nd Tier (local and abroad – overland, marine)
  - 3rd Tier (local and abroad – overland, marine, overland)

As indicated in paragraph 5.4.3 (some business indicators) the materials, inbound supply, transformation processes and outbound supply covered in the supply chain (from suppliers to end customers) were found to represent anything from 70% to 90% of a typical petrochemical manufacturer's cost structure (expressed as a % of sales). Although the actual manufacturing activities of a company may be structured under a production operation managing function, the sales and operations planning processes (one of the key supply chain processes) have a major impact on the eventual production cost.

The following categories were confirmed to be a practical approach to categorise supply chain process:

-Physical and inventory flow processes	*(across the physical supply chain network)*
-Transactional processes	*(Workflow clearly defined ; tasks in succession)*
-Information processes	*(for sharing, exchanging information and collaboration)*
-Planning and decision making processes	*(to support and enable supply chain decisions)*

Supply chain planning and decision making processes intend to reach across multiple internal functional areas, as well as externally across the upstream and downstream supply chain stages (still an area for major development to reach the intended benefits). Information processes are typically required for the timeous availability of accurate supply chain information (still an area of major limitation).

As confirmed during the interviews, integrated planning could be approached from the following three dimensions:

-Functional integration	*(purchasing, manufacturing, transportation, and warehousing activities internal to an enterprise)*
-Spatial Integration	*(Integration of the supply chain stages; the extended enterprise reaching across company boundaries)*
-Hierarchical/Decision Integration	*(Three discrete levels of management control - strategic, tactical and operational)*

Although the Supply Chain Operations Reference model (SCOR) from the Supply Chain Council also provide a sound hierarchical basis for supply chain process and sub- processes, not many of the petrochemical companies interviewed have adopted or utilised it. SCOR could provide a platform for standardization, repository of best practices, metric benchmarking and using a common vocabulary. It is however viewed as too restricted and needs adaptation to become directly applicable in the petrochemical industry. One of the major reasons is that 80% of products handled in the petrochemical industry are liquid bulk. A large amount of terminology used in SCOR relates to discrete packaged products.

5.6 Supply chain planning and decision-making processes

5.6.1 Supply chain decisions (reason for sc planning processes)

For liquid fuels (Petrol, Diesel, IP, Jet Fuel, Fuel Oil, etc.), typical supply chain decisions were found to cover all stages supply chain (from crude supply from the various sources right through to final products for end consumers). However, for non-fuels and chemicals (Lubes, Solvents, Bitumen, etc), typical supply chain decisions only start at downstream feedstock from refineries for chemical plants through to product supply for end customers (Typical S&OP decisions). Although downstream supply chains are relatively independent of each other, some interdependencies however exist related to feed, infrastructure and alliance partners. The upstream and downstream drivers and variety of different system states also differ substantially.

Most supply chain decisions revolve around matching demand and supply. Most participants agreed that supply chain decisions need to be taken well in advance to keep actual supply chain operations running uninterrupted and meet consumer requirements. This is largely due to geographical separation, demand and supply uncertainties/variabilities, seasonal and cyclical demand patterns, operational capacity, flexibility and constraints, and different lead/cycle times for supply. Most manufacturing technology in the process industry is product-specific, making manufacturing processes less versatile. These are some of the reasons why supply chain decision need to be taken on different time horizons (long, medium and short term). The visibility of the real end user demand for final products is less in the process industry, compared to what is possible in the discrete industries (e.g. point of sale information). There is a trend for petrochemical supply chains to become more demand and pull oriented.

Higher upstream, supply chains are influenced by profitable and feasible allocation decisions related to bulk streams of scarce molecules to downstream producers for intermediate and derivative products (based on value adding potential and yield optimisation). Further downstream 60% to 80% of the petrochemical derivative products are still in bulk format, but decisions are more related to market allocation (based on margin enhancement potential). The supply chain decisions for products that are packaged and handled in mini-bulk containers, ISO containers, tank containers, pallets, bags and cartons, closer relate to the downstream supply chain decisions made in the discrete manufacturing industries.

Most participants highlighted the fact that long-, medium- and short-term decisions are typically iterative by nature and involve many parties along the supply chain to reach consensus (a number of passes are required before a final answer is produced). Long- and medium-term decisions relate to planning, while short-term decisions relate more to scheduling (Typically related to crude and petrochemical feed, production plants and units, products and logistics). Strategic supply chain location options are partially reduced in the petrochemical industry due to viable alternative feedstock locations and existing facilities with the required infrastructure and utilities.

Partly due to the specialized nature of petrochemical production processes and the products itself, decision domains and communities exist along the supply chain (e.g. R&D, strategy, trading, manufacturing, supply operations, marketing and sales). When these decision domains are not properly integrated and aligned, inefficiencies result that make the total enterprise less profitable. Another key challenge is to properly integrate strategic, tactical and operational decisions across the various decision domains. In many cases, value chain decisions are taken without incorporating/considering the supply chain's impact. A big problem that can also occur in long- to medium-term planning and projects is that during design stages, stable markets are assumed.

Participants also agreed that the outcome of long- and medium-term decisions should be used to guide the effective execution of the various supply chain activities. For example, the supply chain execution management activities at a depot would include:

store product properly; replenish and operate according to the tactical and operations supply chain plan; safe operation; accurate, reliable and transparent information about operations and transactions; and maintain the daily discipline.

It is critical to understand the different cycles of supply chain decision-making and the applicable time windows. If possible, decisions should not be taken too far in advance, and should be postponed up to the latest possible time. One major outcome of decisions should always be to determine the value of relaxing some constraints to supply chain throughput (e.g. by using advanced analytical processes). Constraints are typically related to feed material, markets, manufacturing and policies. Time horizon (forward looking), time buckets (granularity of data), and frequency of review (based on time buckets) are important parameters of supply chain decision-making.

Table 5.5 indicates the typical long (enterprise-wide and business unit specific), medium- and short-term supply chain decisions found through the interviews that need to be taken in petrochemical companies (key influence, questions to be answered, and typical considerations taken into account). An indication is also given of the interdependencies between these major long-, medium-, and short-term supply chain decisions.

<u>Note:</u> Rather than aggregating these decisions too much, a fair amount of detail is still listed (possible duplications could exist). These decisions will be categorized and related to what supply chain planning processes could be used in order to deal with these questions.

Table 5.5 : Typical long-, medium- and short-term supply chain decisions

Long-term **(A) Company wide/across multiple business units** **(B) External with other industry players**	
Decision/questions/key influences	**Typical issues & considerations**
(A) Internal to enterprise decisions New added ventures integration in the enterprise aggregate SC network SC due diligence evaluation of possible joint ventures, mergers or acquisitions (sound understanding of both businesses' SCs) Future market aspirations for different business units; Aggregate consensus view of on future volumes and geography of product family streams. Analyse new and existing business units' SC strategic plans for interdependencies & synergies to co-operate with other divisions & business units for group benefit and risk implications: - SC Logistics Network Synergies - Transportation Synergies (corridors of movement) - Freight densification (Economies of scale) - Shared facility opportunities - Aggregate SC & corridor risks - Consolidation of contracts - What products to be supplied from which plants/business units - Long term feed supply sources and agreements (internal and external) - Who to produce what amount of utilities and supply from where (e.g. Steam, Electricity) - Exchange of internally owned logistics infrastructure (e.g. pipeline and tank duty changes) Group Chemical Stream Directives: - Allocations alternatives of intermediate stream - Bulk Fuels and Non Fuels Interdependence (e.g. Use of Aliphatic & Aromatic Solvents for Octane booster) - Supply priorities (staircase of users and volumes) of chemical feedstock to downstream chemicals value chains (e.g. propylene) and use of chemicals in fuels - Wedge optimisation; optimise enterprise economics of upstream feed and stream allocation, and downstream derivatives across chemical businesses - Trade-offs required between asset/country managers (managing shared assets) business unit managers and group optimization manager - Directives on competition for the scares molecules - Group optimization management (profit management and providing group directives and required policies) **(B) External to enterprise decisions** Opportunities to co-operate with other oil companies: - Possible exchange agreements of like and unlike products with trading partners. - Cooperation between liquid fuels and gas companies in terms of supply agreements - Upstream economies of scale in shipping opportunities (joint chattering of VLCCs) - Freight consolidation - possible sharing of inventory in the "supply pipeline" - possible sharing of depot facilities Structural synergistic opportunities to share logistics network and infrastructure: - single buoy mooring (SBM) - terminal storage (coastal) - Inland depots - pipeline (crude, intermediate and final product) - trade lane/corridor freight densification - aggregate corridor risks - Infrastructure investment shared between petroleum companies (e.g. SBM, Depots, Terminals) Long term cooperation with government	_Business and chemical value chain_ Business scenarios and strategic alternatives Corporate strategy and business charter alignment Enterprise functional strategies (including SC) Industry scenarios & opportunities Corporate imperatives and core business Financial, value-add and economic considerations Chemical value chain interrelationships Look past individual business units (what's good for the company) New businesses, expanding of existing businesses and businesses being phased out Economic viability of new and existing businesses facilities Macro economic indicators Competitor reaction/cooperation _Marketing_ Target markets, size and market share aspirations Company product portfolio Brand awareness New product development Commodity pricing cycles _Agreements & Contracts_ Customers: - Base/contracted volumes - Discretionary volumes (Spot) Suppliers: - Bargaining power - Interdependency on suppliers - Commercial synergies - Leverage economy of scale - Current agreements in place - New ventures impact current contracts - Contracting strategy (supplier strategies & internal processes) - Crude Carriers (joint chattering) _Financial_ Business growth Financial targets (hurdle rates, gearing) Investments financing guidelines Rolling capital and operating budget Transfer pricing (internal) _Operations considerations (upstream, production and downstream)_ Capacity and utilisation Supply chain changes Aggregate volumes, distribution/trade lanes, nature of products. Overland transport options (modes and capacity available) Nature of manufacturing, products and processing technology options Willingness to share, cooperation and collaboration _Decision's interdependency with other timeframe:_ _Typically determines the boundaries for BU specific long term plans in terms of strategic objectives, investment, policies, directives, guidelines, etc. Investment decisions 3 to 10 years_

Long-term (per BU)	
Decision/questions/key influences	**Typical issues and considerations**
Translate business strategy into SC strategy and “strategize and prepare" Target market consensus 1 to 10 years out *(based on geographical and segmentation analysis)* Supply chain drivers from business strategy Supply chain strategy formulation (including supply chain competitive requirements analysis) Customer service and supply chain cost balancing (time, responsiveness and flexibility requirements) Setting and balancing of functional (logistics) objectives with Divisional (BU) objectives Handling fatal production and co-products from refineries and chemical plants Supply chain network structure and configuration - design for new or expansion/changes/optimise for existing businesses: - Capacity and flexibility - Network design & potential consolidation opportunities - Central vs. decentralized storage facilities - Allocating suppliers to plant, plant to DC, and DC to region and customers - Facility and site selection (chemical plants, bulk blending, distribution stores, depots, terminals) - Facility infrastructure and Investment - Establish transportation requirements - Choices in terms of. Transportation modes (Pipe, Rail, Road) and corridors of movement. - Transportation strategy and fleet sizing - Test supply chain dynamics (impact of supply and demand uncertainties) - Define Inventory Policy - Establishing organizational and governing structures, clarifying practices, policies, enablement Typical 70% of long term decisions in petroleum businesses are oil based decisions: - Which crude wells to exploit - Crude selection from available crude oil sources - Crude oil contracts and spot purchase balance Other Supply contracts/agreements: - Sourcing strategy - Trading and alliance partners choice - who will be the suppliers of feed and services (e.g. logistics) - Supplier selection for feedstock - Supply agreements (internal) - Sourcing contracts (external) Supply alternatives – trade-offs optimisation (Refinery is one source of supply; look for other sources as well e.g. imports, exchanges) Exchange and supply agreements within petroleum and chemical industry Energy supply choices (generate own/source external) Ownership strategy (own or contract service) Production, upstream and downstream supply philosophy Co-managed operation decisions (e.g. depot) Securing the right downstream supply capacity (including logistics capacity) Feed reservation to manufacturing operation and inventory reservation to sales regions Supply directives (strategic) supply chain goals setting (e.g. asset utilization and inventory targets) Communicate 1 Year firm & 4 Years indicative plans	***Business and chemical value chain*** Company growth path joint ventures, mergers, acquisitions or investments in new chemical plant capacity) Business charter Long-term decisions to make regarding what product to produce and what markets to serve. Business risks and uncertainties Competitive requirements Trade barriers Swap deals Level of vertical integration New product development ***Marketing*** Worldwide supply and demand imbalances Target market location, size and aspirations Product pricing Product slate/mix/characteristics Marketing dynamics Distribution channel to market strategies Customer segmentation ***Agreements and contracts*** Structures and agreements in place Trading and alliance partners available Contracting strategies Customers: - Base/contracted volumes - Discretionary volumes - Terms of sale Suppliers: - Available Trading and alliance partners - Costs, service requirements - MOUs & LOIs ***Financial*** Financial targets 5 - 10 yr budget (Yearly buckets) *(1st year Monthly, ,2nd year Quarterly, 3 + years Yearly)* ***Operations considerations (upstream, production and downstream)*** Crude oil and chemical feed sources (proximity, viability) Country logistics infrastructure Major trade lane and corridors Operational capacity and constraints (inbound, plant, outbound) Alternative site locations and utility availability Production technology and operating philosophy Product characteristics Environmental, legislative and regulatory Requirements Operations costs ***SC enablement*** What tools to be used to assist in decision making Structure, key roles, people competencies ***Decision’s interdependency with other timeframe:*** Decision on the umbrella of the corporate strategy decisions *Long-term decisions determine the SC network through which production, assembly and distribution serve the marketplace.* Looking 1 - 5 years ahead Monthly, quarterly, yearly time buckets Periods to cover at least multiple seasons and cycles

Medium-term (per BU)	
Decision questions/key influences	**Typical issues & considerations**
Translate SC strategy into SC operation plans and "structure and organize" Consensus demand and sales plan to use (1 month fixed, 3 firm and committed, 4 + indicative) Weekly and monthly sales campaign impact What orders should be committed on, and what planned or forecasted orders to use? New supply directives (tactical; what to supply from where) What rules, policies and guidelines to apply set from long term? Align S &OP process with budgeting process and quarterly reviews. Inventory allocation and deployment planning (chemicals): - Where to deploy and replenish inventory (centralized or distributed warehouses), - What material required from sources when? - What products need to move and where to customers - Indicative available to promise (ATP) Inventory allocation and deployment planning (liquid fuels): - Upstream: crude oil import planning and capacity balancing - Downstream: fuel product to various depots demand & supply balancing Transportation planning: - Primary & Secondary transport planning - Stock transfers planning - Transportation mode and carrier selections Production planning (Unit commitment, MPS, campaigns and lot sizing, component blending, macro sequencing) Feed stream allocation to manufacturing operation (staircase priority). General resource capacity availability and load allocation Workforce requirements (regular and overtime levels) Typical 20 - 30% of medium term decisions in petroleum businesses are oil based decisions: - Swapping and change of crude ownership to suit product slate - Speculation and trading with crude on water - Crude and LNG purchases on short supply - Crude oil spot purchase opportunities - VLCC Chartering with other oil comp. (Get economy of scale) and Shipment scheduling - What crude to buy & where to source from? Supply and demand balancing Cost and lead time trade-offs Procurement and supply scheduling of longer lead time materials Asset switching and utilization Imports or exchanges for short-term shortfalls Target setting based on longer-term plans Finalise the following plans (1 month fixed, 3 firm and committed, 4 + indicative): - Component supply plan - Crude + feed supply plan - Product exchange plan - Inventory deployment plan (primary distribution) - Monthly unit operations plans (refinery)	***Business and chemical value chain*** Scares molecule/stream allocation directives (Q1 fixed, Q2 directives, Q3/4 planning assumptions) Allocation decision from yield optimization (LP) Competitor reaction and tactics Margin optimization Required management controls ***Marketing and Sales*** Market commitments (committed/contract volumes) Market demand and segments Demand/sales forecasts/commitments Product shelf life Weather influence Market cycles and seasonal effect Major events (price changes) Expected price changes (cycles) ***Agreements and Contracts*** Operations agreements ***Financial*** Current Year and Quarterly budget figures ***Operations considerations (Upstream SC, production and downstream SC)*** Material and final products inventory (Location, Levels, reserved, cycles, lead time) Capacity constraint/Capacity available (assignments, plant shutdown, transport, tanks) Phase-in of large projects Optimal lot sizes Transport fleet allocation and utilisation Source availability and supply possible (compared to agreements) Export/import impact Petroleum exchanges much easier than chemical exchanges. 3 months lead time between crude purchasing and actual refining 3 months Short term Directives ***SC enablement*** Incentives and payment schemes Set operation and performance requirements ***Decisions interdependency with other timeframe:*** *Work under the umbrella of the long term decisions.* *Working according to the SC network; prescribes material flow management policies, including production levels at all plants, inventory levels and lot sizes. Optimised utilisation of resources.* Looking 3 to 6 months ahead Weekly and monthly time buckets

Short-term (per BU)	
Decision/questions/key influences	**Typical issues and considerations**
Translate SC operation plans into SC operation schedules and "commit and control" Monitoring performance of key execution activities that could have negative impact on total SC Given specific fill rate and fixed sales orders, how best can it be fulfilled (give supply processed) Best way to allocate demand/orders to delivery opportunities? When can committed orders be fulfilled? Logistics Scheduling (right product, right place, right time, right condition) Inventory availability for end customers (firm ATP) Distributions of inventory and scheduling of deliveries (customer delivery time window) Warehouse and tank farm transfers and replenishment Pipeline schedules (crude oil and final product) Sequencing and transportation routing Supplier and service provider firm commitments Primary and Secondary delivery (transport) schedules Finalize rail consignments Vessel arrival and shipment loading schedules Final capacity allocation and operations sequencing of production orders. (what volume to produce, where and when, on what plants and sections) Refinery and plant campaign scheduling (runs in typical 4 day campaigns) Scheduling related to feed, equipment and products Production schedules and plant availability match People/shift capacity scheduling Fuel component supply scheduling Process yield optimization Feed supply scheduling Procurement and supply scheduling of short lead time materials. Order and delivery scheduling of material and products. Finalize operational schedules of: - Receipts (inbound) - Production campaigns - Work force (People) - Stock transfers and deliveries (outbound) - Truck Routing - Load building	*Marketing and sales* Daily and weekly campaigns Demand fulfilment according to forecast or actual orders? Prior customer order commitments Committed off-takes Due dates of orders Order management Consumer behaviour before and after price changes *Agreements and contracts* Supplier reliability and service levels *Financial* Manage Cash to cash cycle *Operations considerations (upstream SC, production and downstream SC)* Inventory levels, replenishment plans and stock transfers Quality assurance and product testing requirements Controls and performance measures to stay within agreed plan (Visibility important) Orders linked to execution plan Inventory policy execution Day to day activities and events Plant capacity available and what's already committed Downtime of operations Feed availability and raw material commitments made Customs and excise requirements Transport fleet availability Tactical focus on operational constraints *1 - 2 weeks firm, 3 - 4 weeks indicative* Demurrage Intermediate tank space utilization Expected yields, qualities, cost and capacity for different crude grades *SC Enablement* People capabilities Adherence to plan and schedule v/s volume incentive conflict resolution *Decision's interdependency with other timeframe:* Take decisions conscious of the medium-term economics (e.g. product slate, crude slate) *Work under the umbrella of the medium-term decisions.* *When operations should be performed to meet given constraints; Feasible execution plan.* Looking 1 to 4 week ahead Hourly, daily and weekly time buckets

5.6.2 Supply chain planning processes used and stakeholder involved

Supply chain planning (SCP) processes should be used to translate the supply chain strategy into plans that direct the supply chain operations (to manage the flow of material, products, information and funds). Planning processes are utilized to explore, evaluate and make supply chain decisions. These SCP processes span long-, medium- and short- term time horizons. It balances the market demand requirements with supply resources (taking into account agreements, capacity, availability, efficiency, service level and profitability) and establish/communicate plans for the whole supply chain. Supply chain planning also support the drive for internal cross-functional co-operation (breaking silo mentality) as well as external decision integration (supply chain partners).

The use of planning processes (involving the relevant internal and external stakeholders), supported by appropriate analytical techniques, were found to be still fragmented along the various stages and sections of petrochemical businesses' supply chains. In some cases, decisions are still taken based on "gut feel" (or fixated on time-consuming procedures). This is opposed to using integrated planning processes and an iterative analytical approach. Very limited formal processes exist on the strategic level to explore, evaluate and make supply chain decisions (this applies to corporate as well as within divisions and business units). Medium- and short-term planning processes are more structured, but still rely heavily on people's roles and the relationships that have been established over time. People are still learning how to orient themselves around the hierarchy of constraints and follow an analytical approach. The evaluation of interdependencies is crucial in the process of developing feasible and optimal plans.

Liquid fuels businesses have a major focus on upstream supply chain activities (largely due to the large portion of value chain cost) and has made substantial advancements in formalizing planning processes and functions supported by appropriate analytical techniques. The medium term upstream crude related planning and decision-making processes are best documented and formalised. Refinery production planning processes are also well documented and formally executed. Limited focus and development is evident in advancing planning processes in the downstream supply chain activities (only now starting to get focused). Many of the downstream activities are still fairly reactive (and involve many role players).

Strategic and long-term supply chain network design and configuration are still mostly done on an ad-hoc (compared to regular review), informal and unsophisticated basis causing supply chains to evolve over time rather than to establish/optimise supply chains by intent.

Medium-term planning processes are now getting a lot of attention and are becoming a bit more formalized. The Sales and Operations Planning (S&OP) process is the one found to currently receive most attention. Although some has already utilized S&OP for a number of years, a number of petrochemical businesses are only just starting, or are still busy embedding these processes to support decision-making. This overarching S&OP process typically include the following processes:

- Demand planning and forecasting,
- Supply planning
- Supply chain balancing
- Formalise supply chain plan

The supply planning process then incorporate:

- Inventory planning
- Distribution planning
- Manufacturing planning
- Feed, component, external sourcing and exchange supply planning
- Procurement planning

Short-term planning was found, in many cases, to be done informally at each facility (these include distribution scheduling, feed procurement scheduling and production scheduling). Closed loop scheduling is becoming more important (i.e. updating status of schedules continuously and alerting relevant parties pro-actively regarding the extent and impact of changes; this relate to supply chain event management).

Table 5.6 indicate what supply chain planning processes were found to be applicable and the extent (span) of stakeholders involved in each.

Table 5.6 : Typical supply chain planning processes and span

Typical direct supply chain planning processes (for decision making)	External to company (Up- and downstream)	Across BU's in the same company	Within a specific business unit or subsidiary business				
			Marketing & sales	Outbound logistics	Manufacturing	Inbound logistics	Procurement *(For feedstock)*
Company wide (cross divisional) and across multiple enterprises							
Chemical feed clusters planning *(inventory flow dependencies)*	X	X	X		X		
Consolidated supply chain scenario evaluation (aggregate growth impact evaluation)	X	X	X	X	X	X	X
Macro logistics network synergy evaluation *(logistics synergies and interdependencies)*	X	X		X		X	
Sourcing consolidation and P&SM *(commercial synergies)*				X	X	X	X
Consolidated risk evaluation *(aggregate risk effect)*	X	X		X	X	X	X
Company wide technology governance *(standardising systems & data models)*		X	X	X	X	X	X
Company wide manpower planning *(critical jobs & cross BU succession)*		X	X	X	X	X	X
Cross-functional (within BUs)							
LONG-TERM							
Supply chain scenario and strategic planning	X	X	X	X	X	X	X
Supply chain network design	X		X	X	X	X	X
Supply chain configuration and functional design	X		X	X	X	X	X
Alliance and trading partner strategic planning	X	X	X	X		X	X
Long-term sales and operations planning *(quarterly, yearly - 3 to 10 years ahead)*			X	X	X	X	X
MEDIUM-TERM							
Medium-term sales and operations planning *(weekly, monthly - 6 to 12 months ahead)*			X	X	X	X	X
* Demand planning and forecasting			X				
* Supply planning				X	X	X	X
Inventory planning				X	X	X	
Distribution planning				X			
External supply and exchange planning			X	X	X		
Manufacturing planning				X	X		
Feed and component supply planning					X	X	
Trading and feed procurement planning					X	X	X
SHORT-TERM							
Short-term sales and operations scheduling *(hourly, daily & weekly - 1 to 4 week ahead)*			X	X	X	X	X
Order fulfilment scheduling			X	X			
Distribution scheduling			X	X			
Production scheduling					X		
Feed scheduling					X	X	
Procurement scheduling							X
Supply chain event management			X	X	X	X	X

Cross-divisional and cross-enterprise long- and medium-term planning are still in its infancy and only happen informally. The most prominent cross-divisional process relates to the procurement and supply management (P&SM) processes relating to external sourced feedstock, process material and services (including logistics). Procurement and supply management, establishing of company-wide strategic sourcing teams and supporting contracts (for goods and services) have developed significantly. Enterprise manpower planning is still in its infancy. Identifying cross-divisional critical supply chain jobs, succession planning and pro-active competency development are still left to fragmented individual divisional/business unit interventions.

Ad-hoc attempts are made to determine aggregate logistics network synergies and are limited to internal enterprise initiatives where corporate functions exist for supply chain optimization. Chemical feed clusters planning for wedge optimization (for allocating larger upstream chemical feed streams to smaller value add derivative producing units downstream) is also still in its infancy. Only where enterprise-wide global planning is done at corporate level, some formal processes are being established (still in early stages of maturing).

Although the SCOR model's processes have been developed to cover the supply chain for the process and discrete industries, the general impression indicates that potential users cannot apply these processes "as-is" – they need to be refined for the process industry. Participants in this empirical research however indicated that the prime focus should be on how to improve the supply chain rather than an overwhelming focus on the process methodology followed. This indicates that appropriate process reference models could be used up to a certain level of detail. Sub-processes and process activities are normally configured according to each business unit's unique requirements.

5.6.3 OR/MS used to support SC decision making processes

There is a huge lack of knowledge in the use of advanced analytical techniques for supply chain decision-support. Spreadsheets are still very popular for analysis purposes (simple mathematical calculation). People also still rely on their own brainpower and cognitive models (experience and judgement) for taking gut feel decisions.

In some cases, companies have developed to a level where more advanced analytical techniques are used. Analytical techniques are then used to construct model(s) representing the real world supply chains and indicate the effect of changes in certain parameters. Sophisticated models (using mathematical programming techniques) are also used to indicate the optimal solution to a specific problem. Long term and strategic analysis could typically utilize LP, MIP, and comparative economics analysis to provide decision support. For medium-term tactical decisions, predominantly LPs are used for sequencing and capacity balancing. Operational scheduling predominantly uses heuristics.

Mathematical tools should in future be utilized to prove what supply chain strategic and practice levers could have a positive impact on the company's financial objectives. Until now, too much focus was on cost- and local optimization (vs. profit- and global optimization). It is, however, important to realize that the approach/techniques used will determine the quality of the results achieved (important to use the right technique for solving the right problem).

In many cases, one model could be used with a variation in time horizon and level of detail to answer multiple questions. In cases where more than one model exists for interdependent systems, these models should preferably be linked.

Table 5.7 gives an indication of what OR/MS/analytical techniques that could be used to support the various supply chain planning processes.

Table 5.7 : OR/MS/analytical techniques that could be used

Supply Chain planning processes	OR/MS/analytical techniques
Company-wide (cross-divisional) and across multiple enterprises	
Chemical feed clusters planning *(Inventory flow dependencies)*	Mathematical programming (LP, IP or MIP)
Consolidated supply chain scenario evaluation (Aggregate growth impact evaluation)	GIS NPV comparative analysis
Macro logistics network synergy evaluation *(Logistics synergies and interdependencies)*	GIS NPV comparative analysis
Sourcing consolidation and P&SM *(Commercial synergies)*	Simple mathematical calculation
Consolidated risk evaluation *(Aggregate risk effect)*	Simple mathematical calculation
Company-wide technology governance *(Standardizing systems & data models)*	-
Company wide manpower planning *(Critical jobs & cross BU succession)*	Systems Theory and Simulation Modelling
Cross-Functional (Within BUs)	
LONG-TERM	
Supply chain scenario and strategic planning	Mathematical programming (LP, IP or MIP) NPV comparative analysis
Supply chain network design	Mathematical programming (LP, IP or MIP)
Supply chain configuration and functional design	Simulation (test dynamic behaviour, policy capacity) Stochastic Modelling
Alliance and trading partner strategic planning	Simple mathematical calculation
Long term sales and operations planning *(quarterly, yearly - 3 to 10 years ahead)*	Mathematical programming (LP, IP or MIP) Simple algorithmic methods (Based on TOC)
MEDIUM-TERM	
Medium-term sales and operations planning *(weekly, monthly - 6 to 12 months ahead)*	Mathematical programming (LP, IP or MIP) Simple algorithmic methods (Based on TOC)
* Demand planning and forecasting	Statistical forecasting techniques, Neural Networks
* Supply planning	Mathematical programming (LP, IP or MIP) Simple algorithmic methods (Based on TOC)
Inventory planning	
Distribution planning	
External supply and exchange planning	
Manufacturing planning	
Feed and component supply planning	
Trading and feed procurement planning	
SHORT-TERM	
Short-term sales and operations scheduling *(hourly, daily & weekly - 1 to 4 week ahead)*	Simple mathematical calculation Scheduling heuristics Algorithmic methods Genetic algorithm Simulated annealing
Order fulfilment scheduling	
Distribution scheduling	
Production scheduling	
Feed scheduling	
Procurement scheduling	
Supply chain event management	

5.6.4 Performance measures used to assess the effectiveness of supply chain decision-making processes

Supply chain planning performance measures should reach across the whole supply chain. These performance measures can then be used as the means of measuring how some of the agreed upon supply chain objectives are achieved. It is important to construct and measure performance indicators in such a way to assure unbiased results. Some performance measures must be compulsory and the application thereof governed for the good of the whole supply chain. Not just the absolute value of performance measures must be used, but also the variance during a review period (e.g. 1 month out, 3 months out). The level of granularity is also important for different timeframes (e.g. not only time buckets, but also product family level, product level and SKU level). The confidence in using and applying supply chain planning processes for decision-making can also be used as a qualitative indicator. The accuracy of models used for supply chain planning could contribute to the confident use of these models. A good plan could thus be characterized by confidence in the planning process and having an accurate model (including all requirements, constraints and supported by the correct information). Performance measures applicable for supply chain planning can also be categorized into operational and financial performance measures. Failure to perform in one operational performance/metric will require corrective action. This corrective action/compensation will normally have a negative financial impact. It is thus important to measure the cost of these corrective actions (e.g. expediting).

Since the typical supply chain decisions and objectives differ for long-, medium-, and short-term, the correct planning metric should be used for each. Long-term performance measures are closely related to a firm's financial performance measures (Nett operating profit, return on investment, cash flow). An indication of the forecasting error and total supply chain cost are also found quite relevant. Medium-term performance measures become more operational and relate to throughput for the whole supply chain, inventory and relevant operational expenses that will realize. Since supply chain plans direct the actual operations, planning accuracy is an important metric. The information used in supply chain planning models must be reliable. For this reason data accuracy is an appropriate metric to use and make visible to supply chain members. Short-term performance measures relate more to schedule achievement (adherence), performance and service levels (measured daily, weekly, monthly), and perfect orders. Performance measures do not stand in isolation and the inter-relationships should be understood in order to evaluate properly how well supply chain planning is done.

There are huge differences between the levels of performance measurement along the petroleum value- and supply chain. Proper information systems are also required to make the required supply chain decision information visible. Limited evidence was found of properly configured and fully operational information systems for this purpose. A healthy level of communication and fast propagation of information along the supply chain is also needed, but still lacking. High levels of trust and honesty along the whole supply chain is important to share the correct information for calculating the required performance measures.

Participants indicated that it is also important to link a specific supply chain planning and decision performance measures to a company's important financial and related performance measures used on senior management's scorecards. By indicating the positive effect of specific supply chain planning practices and levers on a specific supply chain planning metric, the benefit contribution can then be used as input for the motivation for required changes.

The remuneration of people should in some way or other also be linked to appropriate supply chain performance measures. This could assure the appropriate behaviour and drive for continuous improvement.

Derived from the interviews, the appropriate planning performance measures that can be used for supply chain planning are indicated in Table 5.8. Typical supply chain practices and leavers are also included to indicate how to effect improvements to the supply chain. Not all these performance measures have to be used by a specific company. A company should use this list as a guide and choose the ones most applicable to the challenges currently being faced.

Table 5.8 : Appropriate supply chain planning performance measures

Performance measures and focus	Supply chain practice and levers
Planning accuracy - *Forecast vs. Actual* - *Plan vs. Actual* - *Schedule vs. Actual* *(Comparing planned demand and sales, and actual supply operations [source, make and deliver]. Not only focusing on the accuracy, but the target and variance as well – e.g. actual figures within 5% of those planned)*	A result of both demand (and forecast) and supply planning accuracy. This relates to the applicable review period, volume and products. Collaborative forecasting assures consistent and transparent forecasts into a single repository available for all supply chain stakeholders to see. One demand and supply plan aligning all stakeholders in the supply chain towards a common goal and provide the required directives for focused execution (execution to plan). *Forecast vs. Plan* Compared M+3 forecasts (indicative) with plan M+1 plans. *Plan vs. Actual* Compared M+1 plan with actual figures. *Schedule vs. Actual* Compare Schedule with actual operational execution.
Model accuracy *(Is the model a true representation of the real world situation)*	Model should include all requirements, constraints and be supported by the correct information. Use of model verification and validation processes to assure true representation of the real world situation. By constraining the model used (e.g. LP) with actual condition, and comparing it to the plan generated (back casting), the planner gets an indication how good the plan was. This is a process of refining planning models and basis for assumptions to use.

Adherence to plan and Schedule achievement (adherence) *(To what degree has the supply chain plan been implemented and followed)*	A good plan can be established, but if not followed it is actually useless. The required management controls should exist to implement supply chain plans and monitor that they are followed.
Inventory Levels and Value *(Assess the raw material, process material, intermediate product, and final product inventory profiles trends)*	Surplus inventory is sometimes an indication of poor synchronization of material and product flow in a supply chain. By reducing uncertainty (via forward visibility) and balancing with instantaneous capacity constraints, only the appropriate level of inventory is needed to buffer variability and provide for cycle stock requirements. Aligning inventory and location policies with service level requirements, and consolidating unnecessary stock location via supply chain network optimization, could assist in optimizing inventory levels. This can also relate to impact of the supply chain and inventory strategies.
Capacity utilization *(Measure of how intensively a resource is being used; usage compared to capacity available)*	Since the petrochemical industry is very capital intensive, capacity utilization is also a very appropriate measure used for planning. Long term planning (network design and infrastructure configuration) typically creates and establishes the capacity required for future supply chain operations. These capacities then become part of the potential constraining resources used in tactical planning and scheduling. Capacity utilization indicates how effective planning was done in providing for future requirements. Taking a long-term perspective and harnessing cross-divisional and cross-enterprise synergistic opportunities, capital avoidance could result for all stakeholders involved.
Total supply chain cost *(direct and related supply chain cost of raw materials, procurement, inbound, manufacturing outbound, return and planning)*	The direct supply chain cost has a significant impact on a company's bottom line. Supply chain planning allows for focused and more cost effective operations. By analyzing the cost elements (making up the total supply chain cost) non-value adding activities can be identified and eliminated though supply chain design, optimization, process improvements, etc.
Actual takeoff vs. committed takeoff *(Apply to JVs and exchange agreements)*	This gives an indication of how well all the stakeholders have committed to a supply chain plan. If the committed take-off does not realize, inventory capacity problems can have a negative impact on upstream activities in a production plant.
Throughput for whole supply chain *(Correct total tonnage delivered at consumers with the minimum amount of losses and hold-ups in the supply chain)*	A key focus of the supply chain is to increase its speed and throughput. Tonnage produced should pass through the supply chain to the correct destinations and not unnecessarily be held up in inventory (TOC principles). This is also a sound indication of how well inventory location points and policies are used to manage constraints in the supply chain. Petrochemicals are predominantly handled in bulk format and many products are volatile by nature. Unnecessary and incorrect handling, storage and trans-shipments all lead to product losses and

	potential contamination problems. The correct design of networks, facilities, controls and operating procedures could contribute in reducing product losses (eliminating non-value-adding activities).
Cash-to-cash cycle *(Tracking Inventory days of supply, days sales outstanding and days payable outstanding)*	The longer the cash-to-cash cycle, the more current assets are needed (relative to current liabilities) since it takes longer to convert inventories and receivables into cash. Increasing the speed and throughput in the supply chain and superior performance in perfect orders can make a positive contribution to the Cash-to-cash cycle metric.
Planning and re-planning cycle time *(Planning Flexibility)*	Reduced Planning Cycle Time for planning, re-planning and scheduling makes supply chain more responsive to change and unforeseen events.
Data accuracy *(trusted sources and consistency of date)*	Plans are only as good at the data used.
Profitability *(In total and per customer)*	Profitability can improve through aligned, reliable and cost effective supply operations, and increased sales due to supply reliability. Reliability of supply indicates that the required inventory is available at the right locations at the right time according to a consensus demand plan and confirmed orders.
Perfect orders *(Total perfect orders compared to total number of orders)*	Having the correct product, in the correct quantity and quality, at the right place at the right time, to the correct specified entity, with all supporting documentation for the order accurate, complete, and on time. Analyzing each of these elements would give an indication of where the supply chain demand fulfilment performance is still not meeting customer expectations and where planning could contribute in improvements.
Unallocated orders (from Planning systems) *(Number of orders still unallocated and un-scheduled for fulfilment)*	This metric typically applies when using an order book. At the end of a planning cycle and model run, feasible and optimal plans are produced to match the requirements (demand) with the available resources (supply). Should too much unallocated orders still exist, it indicates that either the constrained demand or sales plan were not done properly, or that not all supply constraints and realities were not considered during finalizing the aggregate plans.

5.6.5 Critical people competencies required for supply chain planning

Distinction should be made between the competencies required for the end users of advanced planning processes, planning model developers and support personnel.

For the purpose of this research, the focus is on the competencies required for end users of advanced planning processes. Derived from the responses of the participants, Table 5.9 provides a summary of the skills, attributes and knowledge, and general competencies required for advanced supply chain planners (end users).

Table 5.9 : Planner's skills, attributes and knowledge, and general competencies

General Skills	Holistic integrative thinking (big picture person) Systems approach in analyzing problems Cause and effect comprehension (systems concept) Analytical ability *(e.g. making sense from vast volumes of information and interpretation results)* Ability to work within overlapping responsibility Demonstrating expertise Networking/creating relationships Conflict resolution Business mindset Systematic/Logical thinking "Feet on the ground" and "fit-for-purpose" approach Proficient in the use of information technology
Functional/ technical skills	Supply chain optimization Business process design and optimisation Problem solving Facilitation of decision-making Developed sound judgement Detail conscious DSS application Project Management Good communication and business writing skills Convincing and selling skill (coupled with presentation skills) Conflict management and resolution
Attributes	Goal/achievement orientation Inherent inquisitiveness Openness to continuous learning Self-discipline Creativity Resilience Tenacity Integrity Fair minder Approachable Patience Balanced temperament Interpersonal relationships – comfortable to interface with people
Knowledge and experience	Supply chain processes and procedures Knowledge of computer-based design and analysis tools Mathematical or scientific background Analytical, optimization and risk management appreciation Knowledge of management science and operations research Understanding basic statistics and variability Basic understanding of economics Understanding of multiple functions; appreciation for cross functional dilemmas *(Had broad exposure to different line functions)* Understanding the basic execution process in a supply chain and unique challenges *(Important to understand the operational supply chain activities)* Comprehension of the petrochemical business context *(Needs a broad view of business)*

	Comprehension of petrochemical manufacturing processes and technology used *(Has a large impact on supply chain decisions)* Production planning, business planning/analyst background/experience
Other general competencies	Credibility amongst stakeholders Respect for personal knowledge Should preferably not be an execution oriented person A person preferring to avoid problems rather than fire fighting MBA type people that understand the business language (Business school background) Typically people that are following an executive development path

5.6.6 Big opportunities and potential value-adding benefits

Most participants indicated that substantial supply chain improvements in specific focus areas are still possible in the petrochemical industry (20% - 40%). To justify any supply chain intervention and get the attention and interests of senior managers, supply chain levers should be linked (as far as possible) to financial benefits and key company performance measures. The analysis of these opportunities should be conducted by applying a system analysis approach (looking for how to improve the total system).

Balancing the applicable supply chain trade-offs can bring huge financial benefits. Advanced supply chain planning processes can aid in providing a better understanding (mental model) of the inter-relationships of the key supply chain operational activities. The knowledge that advanced supply chain planning processes are aimed at doing what is best for the whole company, contribute to more informed instantaneous decisions making when all key players are not always available.

Typical direct benefits achievable relate to:

- Increased Revenues (demand management, customer segmentation and service differentiation)
- Optimised Manufacturing Costs (materials, conversion, cross-plant optimization)
- Optimised Transportation and Distribution Costs (sourcing, distribution planning)
- Inventory Reductions (raw materials, WIP, finished goods)
- Reduced working Capital and Fixed Capital avoidance
- Reduced Administrative Costs (efficiency, headcount reductions)

The Related indirect benefits include:

- Facilitates fundamental changes in organization from functional-based to process-driven
- Improve customer service at lower total cost
- Improve production throughput
- Allow demand driven synchronization
- Key enabler for efficient customer response
- Improves available to promise (ATP) and capable to promise (CTP) capability
- Better handling of unplanned emergency orders
- Reduction in error costs (Enabled by local level of work in progress)

Leverage the planner's knowledge to make better decisions – Planner don't need to spend so much non-value adding time in mechanistic routine activities

Faster adaptation to changing customer requirements

Reduced planning workload

Fewer crises to handle

5.7 Supply chain planning challenges

5.7.1 Process vs. discrete businesses (major differences)

Process manufacturing businesses are generally less flexible than discrete manufacturing businesses. Most transformation processes of material into higher valued products are irreversible. Process manufacturing businesses still have a push orientation for transforming feedstock into commodities and derivatives compared to a demand pull orientation. This is partly due to the nature of 24-hour production processes with limited flexibility and huge interdependencies between successive processes. Discrete manufacturing businesses on the other hand sometimes have major difficulty in establishing integration between units. In discrete manufacturing industries, the product demand can easily be related back to the required component level BOM's, which makes the application of the MRP methodology very appropriate (but not that appropriate for Process manufacturing businesses).

The divergent progression of petrochemical value chain segments are complex, tightly interconnected, and large in scope. There is not always a clear and direct one-to-one relationship between final products and feed streams (i.e. recipe driven v/s BOM driven), resulting in significant variability in feed material demand over time. Pressure for high process occupancy (to assure cost effective operations) result in upstream supply flexibility and buffer requirements (relatively high feed material inventory buffers). Long lead times and variability in lead times also relate to higher inventory. Since the petrochemical industry is very utility intensive and requires large amounts of mission critical utilities (Continual availability of power, cooling water, steam, etc.) the potential manufacturing site selection options are significantly reduced compared to discrete manufacturing industries.

The following are some of the influences found that would affect the manufacturing process and feed stream balancing. These factors have a major influence in supply and demand balancing:

- Process yield differences for variety of feedstock (e.g. crude grades)
- Yield variance based on process efficiencies
- Drive for economy of scale to have cost-effective operations (high capital and fixed cost requires process occupancy of above 75% - 80% for profitable operations).

Within manufacturing sites, four different linkage and storage combinations were found that exist between successive process plants, causing varying degrees of flexibility:

- Unlimited storage available between processes
- Finite storage capacity available
- Zero storage capacity available (Stability very important)
- No wait (no space)

Derived from the interviews, supply chain can also take up various forms. “V” type businesses typically relate to the process industry, whereas “A” type businesses typically relate to the discrete industry. “T” type businesses are typically a combination of “V” and “A” type businesses. A brief description of these business types follow:

Supply Chain “Complexitors” (V type businesses; typical for **process industry**)

- *Diverging flow*
- *Process bound, capital intensive business*
- *Multi-purpose plant*
- *Capacity driven*
- *Product allocation complexity*
- *Throughput focus*
- *Large product range, large customer profile*
- *Downstream production and distribution complexity*
- *Significant data issues, limited exposure to ERP*

Supply Chain Inhibitors (A type businesses; Typical for **discrete industry**)

- *Converging flow*
- *Order or customer driven (Service)*
- *Material focus*
- *Synchronization complexity*
- *Lead time reduction pressures*
- *Upstream supply complexity*

Supply Chain Modifiers (T type businesses)

- *Converging and diverging flow*
- *Order , customer and forecast driven (service)*
- *Process influenced*
- *Multi-purpose plant*
- *Synchronization complexity*
- *Lead time reduction pressures(lean manufacturing)*
- *Supply and Upstream supply complexity*
- *Build to forecast/assemble to order*

5.7.2 South African petrochemical industry vs. global petrochemical industry; supply chain challenges

Derived from the interviews, a number of key competitive challenges that petrochemical businesses in South Africa face are (some of these are also faced by large scale global petrochemical companies):

- The volatility of the rand
- Limited and deteriorating logistics infrastructure (roads, rails, some ports)
- South Africa's costs to manufacture are relatively high, although we have access to relatively low cost feedstock
- South Africa's physical location in the world relative to other big economies
- The foreign market's perception of South Africa
- Incentive/support and government policies to grow industry (trade barriers)
- South Africa's price-to-quality ratio is too high
- A strong culture and emphasis on autonomous/decentralized businesses focussing on their own objectives and vested interests. This need to change to maintaining the required level of BU autonomy but is subject to the enterprise's benefit
- Feedstock and chemical stream transfer prices not always driving the right behaviour. Transfer pricing policies to reflect the alternative value of molecules still in its infancy (not only fuel alternative value)
- Chemicals are sometimes at the mercy of liquid fuel considerations - "Master/slave" dependency well established but not always accepted.
- Limited "birds eye view" approach; Optimisation across business units/value chains
- Some businesses are manufacturing driven, while other are starting to become value chain or supply chain driven
- Market and business intelligence not always transparent across business unit boundaries
- More and changing nature of future joint ventures, mergers, and acquisitions. Joint ventures create more formal relationships between two interdependent but legally separated manufacturing processes.
- Molecule and component balances will become more tightly balanced in future resulting in:
    - Production more closely coupled to markets
    - Less flexibility
    - Higher level of interdependence/influence resulting in tighter integration
- Tighter future fuel specifications will further reduce flexibility
- Logistics operations will be under more strain due to capacity availability and increased supply chain complexity
- Global competitive landscape is changing, demanding global intelligence and pro-active way of adapting to changes

Some specific supply chain challenges that the liquid fuels and chemical industries currently face in South Africa are:

Liquid fuels businesses

The South African liquid fuels industry differ in a number of ways from global liquid fuels industries (e.g. in Europe and USA). Following is a number of distinct differences that bring their own supply chain challenges:

- Liquid fuel markets are more structured and regulated in South Africa, compared to Europe being very open (South African prices are more regulated). There is however, a trend in the oil industry to become more open and less regulated.

- Level of fuel component trading is much higher globally than in South Africa (in South Africa trading and exchanges are largely limited to crude oil and final product)
- South African petroleum companies are relatively small compared to overseas.
- The number of product grades are typically less than 5 - 6 grades of petrol vs. 23 grades in USA.
- Tightening of specifications (sulphur) reduces refinery flexibility (world-wide)
- South Africa's geographic distances and availability, and scale of logistics infrastructure
- The geographical location of South Africa's refineries and distance from petroleum sources also differ relative to global liquid fuels industries.
- Large number of merges and acquisitions happening abroad

A number of factors also limit the success of advancing in supply chain approach adoption in the liquid fuels industry and unlocking the benefits. These include:

- Lack of applying supply chain-wide performance measures and measurement (opportunities lost at interface/de-coupling points)
- Assign responsibility to a single organizational entity for total supply chain alignment
- Lack of alignment on shared supply chain objectives (getting stakeholders together on a regular basis to assure information transparency and indicate effects of decisions)

Chemical businesses

The South African chemical industry also differs in a number of ways from global chemical industries (e.g. in Europe and USA). A number of distinct differences that also bring its own supply chain challenges are:

- Proximity to feedstock, but relatively further away from end consumers
- Located on less dense petrochemical trade/shipping routes
- Highly regulated fuel industry having influence on chemical product alternative prices
- Fluctuating exchange rate makes investment decisions more difficult
- Skill level available and required for world class petrochemical operations
- Logistics flow imbalances on major routes (Trade imbalances; Freight opportunistic opportunities)
- Availability of adequate logistics infrastructure
- South Africa's unique geographical position
- No waterways available for barging
- Comparative rates for road and rail (South Africa more expensive compared globally)

A number of factors also limit the success in advancing in adopting supply chain approach in the liquid fuels industry, and unlocking the benefits. These include:

- Physical challenges in dealing with hazardous goods
- Safety and Risk in dealing with hazardous goods
- Service provider maturity and readiness for medium- to long-term decision integration
- Advancement in full understanding of the supply chain concept

- Holding on to previous schools of thought
- Complexity and Function focus
- Risk averse to paradigm shifts
- Secrecy and hesitation to become transparent
- Distrust and fear for loss of control
- Uneasiness with less clear responsibility lines

5.7.3 How to break down the functional silo and secrecy mentality

The functional silo and secrecy mentality within business units, divisions and petrochemical enterprises is a major problem to overcome in an attempt to follow an integrative supply and demand planning approach. A number of ways found in which the functional silo and secrecy mentality can be reduced are:

- Via increased awareness/transparency
- Showing the potential value (business benefits and business case)
- Change from competition to a co-operation debate approach
- Group bottom line vs. overemphasizing individual business unit's bottom line (Drive for Group and BU performance measures harmonization)
- Make key performance areas and charters of business units cross-"accountable"
- Care needs to be taken in the performance measures used for rewards (perhaps people should be rewarded on the performance of all divisions, not only on their own one's performance)
- Possibly governance, policies to manage interdependencies
- Embed a holistic integrative systems approach
- Start with better understanding of SC at the top; cross-functional influence
- Create a compelling business case actively supported by a passionate executive
- Set common goals that can pull cross-functional and cross-company co-operation
- Get into the company's top 10 focus area radar screen
- Foster a process thinking philosophy and establish guiding principles
- Implement in "bite size chunks" and follow a staged advancement approach
- Education, learning, awareness of impact of decisions
- Performance measurement (bonus structure; bring in total system/enterprise benefit)
- Move from "insecure and distrust" world to a team-orientated world
- Increase the level of communication and common understanding
- The drive for co-operation is much bigger upstream (many dependants) than for those downstream. Onus for co-operation lies with the upstream/macro planner
- The career structure of an organization should encourage people to have a number of jobs in a number of divisions that in their very nature have conflict.
- Dealing with the power play/balance between the resource owners (typically manufacturing) and market owners (typically marketing) is critical. The fear for loss of control/power in changing to "horizontal" process management (vs. vertical) must be

eradicated by a clear understanding of the benefits to all, and the following of a proper change management approach.

5.8 Supply chain planning intervention approach

Due to the major impact that supply chain planning initiatives have on a business, a combined program and project approach should be followed. Key enablers that were found to help in the justification and implementation of SC Planning interventions include; understand the potential reward (business case), vision clarity, management support, cultivate internal ownership, training, communication, and a formal change management program.

The participants also indicated that unfortunately, in many cases, when supply chain planning initiatives are justified, lots of attention is given to selling the potential value it will generate (basic economic benefits estimated). At that stage, it is not yet clarified how the value will be unlocked. This relates to the organizational and process change that would be required (included in the marketing & sales departments).

When these projects get approval and implementation starts, there is sometimes an exaggerated focus on cost and deadlines for the technology implementation, and not enough focus on the business transformation that should happen. This could have a severe negative impact on the ultimate unlocked value. An acceptable guideline for the project focus is 50% organizational change, 40% process definition, and 10% technology enablement. A balanced set of key roles and responsibilities should be established (Project Manager, with a project leader, technical leader and business/organizational change leader). Organizational change includes such items as:

- Culture
- Motivation
- Maturity
- Skills development
- Performance measures and key performance indicators
- Process Design

The following should also be taken into account:

- Identifying the value and selling the project
    - Assess the value and verify with stakeholders
    - Determine how success will be measured
- Selling the project
    - High-level sponsorship is important
    - Commitment to resources (money and people)
    - Business/stakeholder buy-in is critical
    - Address alignment and interfaces with other initiatives (set priorities)
- Recognizing that process issues will be at least as important as tool development
- Selecting enabling technology (technology that has been applied in your industry)
- Selecting the technical partners (quantity and quality of resources is critical)

- Addressing change management
  - Stakeholder identification
  - Change readiness assessments
  - Organization impacts (roles & responsibilities, organizational design changes)
  - Risk assessments
  - Communication plans
  - Training plans
  - Performance measures
- Determining project approach
  - Schedule-driven or value-driven
  - Degree of standardization desired
  - One “central” project or a set of individual ones
- Following good project management basics

Post implementation audits were found to be essential mechanisms to determine how successful the project was in delivering on the anticipated benefits (on which the initiative was originally justified).

During implementation the business lead must make sure that the planning processes are clarified before the functional requirements and software development scope are finalized (not the other way around). Relative good understanding of OR techniques are required for more complex solutions (not to be seen as a black box).

A number of key requirements for sustainable change are:

- Need to change culture/orientation (cross functional/process thinking)
- Holistic integrative thinking required
- Measure and report benefits
- Show small benefits as soon as possible
- Break the big project into small business releases
- Ensure all processes have owners.
- The new processes must become the normal practice on a day to day basis
- Recognize processes are “living” and will continuously evolve and improve
- Provide for on-going support and enhancements
- Reward champions
- Publicize successes and share learnings

5.9 Supply chain planning and selecting enabling technology solutions

Through the development of a business case, the contribution of decision support systems to enable supply chain decision-making processes are justified. The contribution is recognized to the extent that the decision support systems can affect identified performance measures through supply chain levers.

The first step should be to carry out a “master plan for supply chain planning” to identify the real planning issues and opportunities, the location of planning within the organisation, the organisation of the planning group(s), and a functional definition of the planning capabilities required. The needs identified through this approach might not necessarily be the same as the initial thoughts. This study should be undertaken by knowledgeable experts in planning, together with the support and participation of relevant stakeholders. It is at the end of this study that the technology requirements and the priority for development are clarified.

Once the “master plan for the supply chain planning practice” is clarified and completed, it will serve as a guide for screening the types of software required and the associated potential technology providers. Some crucial aspects to be considered in screening the potential technology vendor(s) are; their business understanding, their petrochemical industry experience, their willingness to learn the business and their capability to enhance and grow their products during the course of any project.

Other key considerations to take into account when selecting the appropriate supply chain planning enabling technology include:

- Hierarchical planning approach
  (Aggregation and disaggregating, and linking of planning models)
- True optimization techniques used
- Must support cross-functional integration
- Experience of similar decision problem tackled in the petrochemical industry
- Software Application itself; proof of application in other petrochemical companies
- Vendor’s vision and approaches followed
- Vendor’s financial viability
- Using proof of concepts and bake-offs of the vendors’ solutions to clarify suitability
- Integration capability (masses of data; capture data at source)
- Infrastructure architecture
- Principles on which the software operate

Section II : Questionnaire findings

A questionnaire was used (and completed during the interviews) to assess the level of advancement in the identified planning business processes along relevant different supply chain dimensions.

The responses to the questionnaires are summarized in tables, and comments added to assist with interpretation. For comparative reasons, the level of advancement for liquid fuel and chemical businesses are indicated on the same table. Clarifying comments are used to explain the differences in advancement between these types of businesses.

5.10 Supply chain adoption and approach

Petrochemical businesses are still aspiring to advance to a point where the firm's strategic/competitive advantages are associated with the way it can leverage it's integrated supply chain activities.

Table 5.10 provides an aggregate view of the differences in the supply chain approach followed by petrochemical companies. From the responses, it is clear that most liquid fuel and chemical businesses have advanced to a stage where they have adopted a market focus/orientation. Since more than half of the commodity products are traded between the major players in the petrochemical value chain, a strong cost focus is maintained related to direct supply chain expenditure (to support cost containment/leadership strategies). Not many businesses have advanced to the stage where customer and market differentiation strategies are followed. In these cases, the supply chain design, configuration and management practices were geared to differentiate the business from its competitors.

Table 5.10 : Supply chain approach followed

Focus	Indicators	Approach	
Cost focus	Supply chain is only viewed as area for cost control	Liquid fuels	○
		Chemicals	○
Market focus	The company recognizes that adopting a supply chain approach could have a revenue enhancing impact on sales	Liquid fuels	●
		Chemicals	●
Customer & market differentiating focus	A supply chain approach is one of the key aspects in which a firm can differentiate itself from its competitors	Liquid fuels	○
		Chemicals	○
Strategic focus	One of the firm's strategic/competitive advantages is centered around its integrated supply chain activities.	Liquid fuels	
		Chemicals	

Legend: Most replies ●
Some replies ○

Some supply chain approaches might not be applicable to certain businesses, purely due to the specific business drivers, state regulation of commodities, the company's market capitalization, and scope of the extended supply chain. On the other hand, a customer focus might be a competitive necessity. Where a customer-differentiating focus could provide superior customer service, a price premium could enhance margins. Following a customer-focused approach also lead to pricing and revenue optimization.

The supply chain approach followed also depends on the relative position of the focus company in the global petrochemical value chain. The advancement is also based on the recognition received and the profile of supply chain within the business. Upstream and wholesale/industrial market players are further away from end user customers and have a strong supply, throughput and asset utilization focus. Downstream and retail focused players having a much closer interaction with end consumers requiring a customer satisfaction, service and segmentation focus.

Although fuel-related products continue to evolve (e.g. unleaded fuel introduction), the oil industry is very mature, and characterized by relatively low margins. There still exist huge opportunities to advance and improve the industry's business conduct (applying appropriate supply chain practices). Due to huge volume throughputs, small improvements can make a big contribution. Although the industry deals with highly regulated commodities, some liquid fuels businesses have created unique customer focused solutions to differentiate itself from its competitors. These include:

- Consignment stock
- Telemetry and automated stock replenishment
- Extranet linkages
- Forecourt offerings (convenience stores)

In some cases the oil companies have advanced further than the chemical industry, by using their supply chain as an entry barrier to competitors (e.g. use location advantages, customer-focused solutions).

5.11 Advancement in supply chain decision integration

Four dimensions of supply chain integration were assessed to get an indication of the level of advancement reached in petrochemical companies. These dimensions are:

- Horizontal integration *(supply chain partners involved along the supply chain stages)*
- Hierarchical decision integration *(decision level involved - decision impact and time scale)*
- Petrochemical value chain cluster decisions and supply chain decision integration
- Logistics network integration *(cross business unit, cross company, cross industry)*

5.11.1 Horizontal (SC stages) and hierarchical (SC decision impact) integration

Table 5.11 indicates the current extent of internal and external integration of petrochemical business units (supply chain partners involved along the supply chain stages upstream and downstream). This is cross-mapped with the level of supply chain decision integrations achieved.

Although many petrochemical companies are actively busy with external supply chain integration, huge scope exists for bedding down internal integration within each business unit (within function as well as cross-functional/departmental). Unfortunately, many companies still find it easier to integrate externally as opposed to integrating internally across functions. Some business units still need to reach functional excellence before being able to step up to supply chain integration. The decision-making levels involved (hierarchical decision integration), still need to extend properly to medium and long-term integration. The decision integration for short-term supply chain operations in liquid fuel businesses has advanced further than that of chemical businesses. Upstream supply chain integration has also advanced further than downstream supply chain integration (based on feed stream dependencies).

Table 5.11 : Extent of internal and external supply chain integration

(A) Horizontal SC integration advancement: supply chain reach ***(supply chain partners involved)***		**(B) Hierarchical decision integration decision making level involved** ***(decision impact & time scale)*** **For a business unit**		
		Short-term *Execution & local operational processes (e.g short- term scheduling)*	Medium-term *Tactical planning (e.g material requirement & distribution planning)*	Long-term *Strategic planning (e.g. supply chain network design)*
Internal BU integration: ***within each department/function/facility*** of the business unit (e.g. logistics - vehicle loading & dispatch)	Liquid fuels	●	◉	◉
	Chemicals	●	◉	◉
Internal BU Integration: ***across department facilities of a business unit*** (e.g. procurement, production, logistics, marketing, R&D)	Liquid fuels	◉	◉	◉
	Chemicals	◉	◉	◉
External/***backwards integration: BU with its own upstream SC partners -*** *BU* with its own 1st tier suppliers & logistics service providers	Liquid fuels	●	◉	◉
	Chemicals	◉	◉	◉
External/***forward integration: BU with its own downstream SC partners -*** with its own logistics service providers & 1st tier customers	Liquid fuels	●	◉	◉
	Chemicals	◉	◉	◉
External integration ***(upstream and downstream)***: ***BU with its own SC Partners*** (e.g. suppliers, plant, customers, logistics service providers, logistics management)	Liquid fuels	◉	○	
	Chemicals	◉	○	

Legend: Mastered ●; Maturing ◉; Still Developing ○

One factor limiting downstream supply chain integration for chemical businesses is the smaller downstream customers that do not always have the capability and infrastructure to collaborate. Many stakeholders along the supply chain still fall into the trap of local optimization. Even multiple-staged production processes internal to an enterprise are very silo oriented. Some of the other process industries and FMCG businesses have advanced further with internal supply chain decision integration (mastered cross-departmental integration – short-term) than in the petrochemical industry. This is most probably related to the business imperatives of fast moving consumer goods.

5.11.2 Petrochemical value chain clusters and supply chain decision Integration

The successive chemical transformation processes that convert feed material into a variety of derivatives, commodities and ultimately into end consumer products is the main reason for the divergent nature of petrochemical value chains. These chemical transformation processes can be spread across multiple geographically dispersed facilities. Interdependencies amongst the individual value chains exist and can take any of the following forms:

- Sequential *(linear dependency where one chemical is produced from one feed stream)*
- Pooled *(many chemicals can be produced from one feed stream)*
- Reciprocating *(backward and forward use of chemicals)*

Individual petrochemical value chains exist around a specific product or product family and forms the basis for business unit structures in this industry. Tightly interdependent value chains form value chain clusters. These value chain clusters then closely cooperate in balancing their interrelationships, collaboratively allocating scarce molecules and reaching of shared objectives. Value chain business decisions relate to long-, medium- and short-term decisions and typically include: market selection; processing technology and licensing; site selection; processing facility investment; further refining a chemical derivative or selling it; intermediate blending; and inventory allocation for region/customer.

The supply chain forms a critical part of a petrochemical business's value chain (refer to Chapter 1). Supply chain realities, constraints and costs should thus be considered because they influence value chain decisions to ensure feasibility and optimality.

Value chain decisions, however, form the background for supply chain decisions. These two sets of decisions should closely integrate with one another. Some value chain and supply chain decision parameters derived during the interviews are:

Chemical Value Chain Decision Parameters (largely determined by petrochemical production technology and marketing considerations):

- *Business strategy / drivers*
- *Market opportunity (supply and demand imbalances)*
- *Creation of market demand and agreeing on sales terms*
- *Available/new petrochemical facilities/hubs (utility requirements)*
- *Chemical reactions based on technology used and feed properties*

- *Alternative value of processing product at different stages in the downstream Petrochemical value chain (e.g. petroleum use v/s chemical use)*
- *Feed dependencies and allocation priorities*
- *"Static" analyses of activity's value add and cost*
- *Tax influences, Trade incentives and Business incentives*
- *Full business economic context and financial considerations (EVA)*

Supply Chain Decision Parameters (relate to extended list in par 3.1)*:*

- *Consensus demand plans with associated resource requirements*
- *Supply chain structure, configuration and capacity*
- *Geographical dispersed supply facilities and transportation activities (creating "dis-link")*
- *Dealing with throughput constraints and finite capacity*
- *Maintaining inventory availability*
- *Upstream inventory dependency and availability; feasible buffering, sequencing, discrete and continuous flow process effects, assuring continuous operation*
- *Downstream inventory dependencies, influences and availability; customer requirements, lead time, supply variability, buffers*
- *"Dynamic" operability and feasibility evaluation (tactical plan formulation)*
- *Required business processes to enable plan, execute and control*
- *Resource trade-offs and supply chain economic context*
- *Customer demand fulfilment "accountability"*

Liquid fuels businesses, by its very nature, closely co-operate with upstream crude oil suppliers. In South Africa, all refineries are far away from crude sources requiring large scale inbound logistics operations to supply crude oil (including marine shipping, terminal and overland transportation). Short and medium term supply chain decisions are well integrated with the crude value chain supply segment. To a large extent the successive petroleum transformation and refining processes that convert crude into intermediate distillate streams and finally into final products, take place within a single refinery's battery limits. The refining processes constitute a large portion of a liquid fuels business's value chain and do not require major supply chain decision integration except for production planning and scheduling. Manufacturing processes are closely linked via pipelines and production managers manage the operational execution. Where downstream derivative consumer(s) are located on different facilities, short- and medium-term supply chain decisions are fairly well integrated with the component's value chain supply segment. Exchange/supply agreements are also used for alternative source(s) of liquid fuels.

Table 5.12 indicates what progress has been made in petrochemical companies in integrating value chain and supply chain decisions (Long, Medium and Short term). This is an indication of what level of supply chain decision considerations is being incorporated when taking chemical value chain- and value chain cluster decisions.

Table 5.12 : Progress in integrating value chain and supply chain decisions

(C) Extent of petrochemical value chain clusters decision integration *(Could be: - Vertical integration, - JV contract, or - Term Contract)*		**Level of supply chain decisions considered**		
		Short term *(e.g. Production scheduling & order promising)*	**Medium term** *(e.g. Inventory distribution & allocation)*	**Long term** *(e.g. Site selection & SC network design)*
Single BU value chain integration with 1st **upstream** chemical feed sources	Liquid fuels	●	◉	◉
	Chemicals	●	◉	◉
Single value chain integration with **upstream** feed source(s) **and downstream** derivative consumer(s) *(Including external exchange/supply agreements)*	Liquid fuels	●	◉	
	Chemicals	●	◉	
Multiple BUs & JVs that **collaborate in a specific feedstock or product value chain** and take a "profitable volume" allocation approach. *"value chain cluster approach"*	Liquid fuels	●	◉	
	Chemicals	●	◉	◉
Multiple BUs & JVs that **collaborate across feedstock product value chains** and take a "profitable volume" allocation approach. *"value chain cluster approach"*	Liquid fuels	◉	○	
	Chemicals	◉	◉	○

Legend: Mastered ● Maturing ◉ Still Developing ○

From this table it is clear that the advancement of petrochemical value chain cluster and supply chain decision integration has not advanced further than short-term decisions. Some of the petrochemical companies with many successive value chains and multi-stage supply chains are starting to advance in integrating value chain and supply chain decisions.

Only a few liquid fuels businesses have established organizational entities for the total supply chain alignment for a specific product and cluster of related products (feed supply, manufacturing and product supply to consumer). These products relate to crude oil supply, and upstream crude distillation process streams to downstream final liquid fuels and derivative products. These value chain segments are managed within functional domains and only certain areas are managed cross-functional (e.g. joint venture partners managing their share in a refinery via manufacturing, supply and trading groups). However, not enough interaction exists between these functions, and this typically results in deep silos of specialization. This is partly the reason why very limited long and medium term supply chain decision influences are considered in collaboration across feedstock value chains.

Chemical businesses deal with a large variety of feed streams (from onsite refineries or overland/international sources) and interrelated successive chemical transformation processes *(upstream chemical process streams, midstream chemical feedstock and derivatives, to downstream polymers, commodity chemicals, fine chemicals, and specialty and functional chemicals)*. The inbound supply chain segments have a major logistics scope to manage the supply of feed inventory. On site, chemical operations are closely linked with chemical process technology (multiple successive chemical transformation processes) and operationally managed by process coordination functions. The supply chain scope would require the upfront assurance of adequate buffers required for inter-process flow variability during facility design stages (long term capacity decisions). Production planning and scheduling needs close interaction with the outbound supply chain segments, marketing and sales.

Compared to the liquid fuels businesses, toll manufacturing and market swap are not as advanced in chemical businesses in South Africa.

A number of internal chemical value chain clusters have formed, and are sometimes formally structured. Two examples of chemical value chain clusters are:

- A polymer division with business unit clusters for Olefins (ethylene, propylene), derivative polyolefins and plastics
- A nitro division with business unit clusters of nitrogenous products (ammonia, fertilizer, explosives)

The petrochemical supply chain practitioners are still developing in totally understanding the fully integrated nature of petrochemical businesses. They form part of the macro oil and gas and chemical value chain, individual value chain decision domains (value chain structures) as well as possible petroleum and chemical clusters that closely relate to one another and have the potential for increased co-operation. (chemical dependency). Many value chain decisions are thus made without taking the required supply chain considerations into account. Ultimately these decisions result in operational inefficiencies, and sometimes in not meeting consumer requirements (huge profit enhancing opportunities lost).

Integration processes to conduct objective trade-off analysis between the decision domains of asset/production managers (managing shared assets) business unit managers (managing product value chains), supply chain managers, and cluster and group optimization managers are still developing.

5.11.3 Cross-business unit, company or industry logistics network integration

Table 5.13 indicate what progress has been made in logistics network integration for large scale petrochemical companies (cross-business unit, cross-company, cross-industry).

Table 5.13 : Progress in logistics network decision integration

(D) Extent of logistics network integration		**Level of Supply Chain decisions considered**		
		Short-term *(e.g. Shipment consolidation)*	**Medium-term** *(e.g. Freight consolidation on corridors)*	**Long-term** *(e.g. Shared infrastructure investment)*
Same enterprise: corporate unity in upstream/backwards integration with first tier suppliers & logistics service providers	Liquid fuels	●	◉	◉
	Chemicals	●	◉	○
Same enterprise: corporate unity in downstream / forward integration with logistics service providers and first tier customers	Liquid fuels	●	◉	○
	Chemicals	◉	◉	○
Same enterprise: corporate unity in downstream and upstream integration cooperation of the corporate entity (e.g. shared infrastructure & economies of scale)	Liquid fuels	◉	◉	○
	Chemicals	◉	○	○
Petrochemical industry: upstream of multi-enterprises - backwards integration with first tier suppliers & logistics service providers	Liquid fuels	●	◉	◉
	Chemicals	◉	◉	○
Petrochemical industry: downstream of multi-enterprises - forwards integration with logistics service providers & possible market swap out agreements	Liquid fuels	●	◉	○
	Chemicals	◉	◉	○
Petrochemical Industry: Downstream and Upstream integration/cooperation for the Corporate entities (e.g. Shared infrastructure & Economies of Scale)	Liquid fuels	●	◉	○
	Chemicals	◉	○	○
Multiple industry: downstream and upstream cooperation for the synergistic cluster (e.g. shared infrastructure & economies of scale)	Liquid fuels	○	○	○
	Chemicals	○	○	○

Legend:	Mastered	●
	Maturing	◉
	Still Developing	○

Liquid fuel companies have matured as an industry and have a long history of co-operation and exchange agreements. They also share some of their operations and logistics infrastructure. With competition becoming fierce, collaboration between supply managers has reduced, but is still present amongst the shipping managers. Petroleum companies co-operate on a number of upstream and downstream logistics activities (e.g. sharing cargo space on VLCC vessels to get the economy of scale advantages and reduced cycle stock).

Chemical businesses have not yet reached the same level of logistics cooperation as liquid fuel companies. In South Africa, the logistics activities of chemical businesses still operate relatively independent from one another (Limited sharing and co-management of infrastructure, e.g. Ammonia Imports). Some advancement is also evident in Europe where multiple enterprises draw from a network of propylene pipelines. Opportunities do exist for multiple industries to cooperate. Early stages of co-operational development have started in the South African agricultural industry (e.g. Corn from coast and fertilizer to coast on a backhaul basis). There are also possible opportunities for co-operation with the motor manufacturing industry (containers) on rail along certain trade corridors.

Petrochemical businesses continually take many commercial decisions related to logistics. Formal integrating processes unfortunately do not yet exist for taking these decisions and harnessing the commercial and operational synergies.

Huge opportunities exist for the chemical companies to work closer within the industry itself, as well as with related industries (e.g. chemical, paper and pulp, and paints). Closer collaboration and gradual sharing of increasing relevant supply information is the key. There is also a gradual move in the chemical industry to outsource their logistics operations further, and to allow 4PLs to leverage synergistic opportunities with other related players across the types of logistics networks that exist.

Compared to the FMCG industry, limited evidence of close co-operation between FMCG product value chains and supply chains exist (partly due to branding and pride). Limited evidence exists of close co-operation between competitor value chains.

5.12 Supply chain planning processes and analytical techniques used

Table 5.14 indicates which categories (levels) of analytical methods are used for the different supply chain planning processes (time frame and scope):

Level 1: *Rule of thumb and gut feel*

Level 2: *Rule based methods (e.g. heuristics and artificial intelligence)*

Level 3: *Descriptive, Advanced heuristics and local optimality models (e.g. forecasting models, simulation models, simulated annealing or genetic algorithms)*

Level 4: *Global optimization algorithms and mathematical programming models (e.g. Linear Programming (LP), Mixed Integer Programming (MIP))*

Although there seem to be a fair amount of advancement in the level of analytical techniques used, the knowledge of management science and operations research are still lacking at end users. In many cases these analytical techniques are embedded into decision support systems and the user view them as “black boxes”.

Only certain companies have advanced to a point where level 4 analytical methods (Global Optimization Algorithms) are used. This is an indication of the huge scope advance planning and scheduling techniques still have to cover in order to reach its full potential in the supply chain management domain.

Table 5.14 : Advancement in analytical techniques used

SC Planning Processes		**Advancement in Level of analytical techniques used**			
		Level 1	Level 2	Level 3	Level 4
Long-term (macro-/company-wide)	Liquid fuels	○	●		
	Chemicals	●			
Long-term (per BU) Strategic planning processes	Liquid fuels	○	○	●	
	Chemicals		●	○	
Medium-term (per BU) Tactical planning processes	Liquid fuels			●	○
	Chemicals			●	○
Short-term (per BU) Operational scheduling processes	Liquid fuels	○	●	○	
	Chemicals	○	●	○	

Legend: Most replies ●

Some replies ○

5.13 Decision Support Systems (DSS) used/applied

Table 5.15 indicates the implementation status of the major categories of supply chain management tools.

Table 5.15 : Implementation status of supply chain management tools

Major categories of supply chain management tools		Implementation status			
		No plans to install	Planning to install	Busy installing	Has installed; system in use
Supply chain configuration tools *(strategic, network design)*	Liquid fuels	●	○		
	Chemicals	●			
Demand planning tools *(to predict future demand)*	Liquid fuels		●	○	○
	Chemicals		○	○	●
Supply planning tools *(to match supply and demand)*	Liquid fuels		○	○	●
	Chemicals		○		●
Inventory distribution planning tools *(to plan the deployment of inventory)*	Liquid fuels		○	○	●
	Chemicals		○		●
Production planning & Scheduling *(plan and schedule processing units and equipment duties)*	Liquid fuels		○	○	●
	Chemicals		○	○	●
Transportation planning and management tools *(transportation selection, sequencing and tracking)*	Liquid fuels			○	●
	Chemicals		●	○	○
Warehouse/Tank farm management tools *(transactional, managerial activities between the four walls)*	Liquid fuels		●	○	○
	Chemicals		●	○	○
ERP tools *(the single data model; transactional backbone)*	Liquid fuels			○	●
	Chemicals				●

Legend: Most replies ●
Some replies ○

Most petrochemical companies have installed some form of supply planning (for S&OP), Inventory distribution planning, production planning and scheduling, transportation planning, and management tools. Not all of these systems implemented fully provide advanced planning and scheduling (APS) capability, but at least provide some of the functionality required to support decisions in the different decision domains (also relate to par 5.6: Section I).

Warehouse and tank farm management tools are still evaluated for installing.

In most cases, no plans were found to install supply chain configuration tools for strategic supply chain network design. In many cases these tools are supplied as part of product suites. Supply chain network design initiatives are also done on an ad hoc basis through projects or external consultants.

ERP tools were installed in most petrochemical companies as the transactional backbone and the enterprise's date repository. APS tools are used as the analytical engine for planning decision analysis. Spreadsheets and flat files, and some data warehouses are also used to keep data, which has not been included in EPR systems, for decision making.

5.14 Advancement in supply chain information management systems for decision support

Table 5.16 indicates the level of advancement in supply chain information management systems for decision support.

Table 5.16 : Advancement in supply chain information management systems used

Advancement in information management systems		Advancement
Data in distributed disparate repositories; no shared master data model *(difficult to share and aggregate data to information)*	Liquid fuels	
Data in distributed disparate repositories; no shared master data model *(difficult to share and aggregate data to information)*	Chemicals	
Data kept in decentralized repositories but structured according to a master data model *(databases organized according to supply chain structural elements; e.g. transport, facilities, customers)*	Liquid fuels	◉
Data kept in decentralized repositories but structured according to a master data model *(databases organized according to supply chain structural elements; e.g. transport, facilities, customers)*	Chemicals	◉
Data abstracted from transactional repositories to form supply chain information according to a master data model	Liquid fuels	◉
Data abstracted from transactional repositories to form supply chain information according to a master data model	Chemicals	○
A central shared data warehouse exits and is integrated with the supply chain decision support tools	Liquid fuels	
A central shared data warehouse exits and is integrated with the supply chain decision support tools	Chemicals	

Legend: Mastered ● Maturing ◉ Still Developing ○

Although not indicated on this table, distinction should be made between internal and external data, and structured and unstructured data. Many petrochemical companies are still in the early stages of advancement related to external data integration. This would provide for releasing more transparent decision-making information to a selected community of supply chain partners. Structured transactional data is typically kept internally to petrochemical companies according to some master data model. Unstructured data (e.g. Demand Forecasts) are still mostly kept in decentralized repositories and sometimes structured according to a master data model. There is a huge need to structure and standardize the way of keeping decision making information and making it available for supply chain planning.

5.15 Deductions from empirical research

The nature, practices followed and level of advancement related to advanced supply chain planning processes differ between the liquid fuels and chemical domains. Companies or divisions focusing upstream in the macro petrochemical "pipeline" follow different supply chain approaches and are faced with different decisions than those downstream.

The macro petrochemical value chain (pipeline) is characterised by a number of linked and successive interdependent transformation stages and processes. Starting with a relative small number of raw materials, a large variety of different liquid fuel and chemical products (organic and inorganic) are produced in subsequent refining processes. Along the various stages of feed and derivative transformation, opportunities exist to either sell/trade the petroleum and chemical products, or to process them further into higher valued products (progressing closer to the end consumer).

The South African chemical sector comprises of relatively few major integrated oil, gas and chemical companies involved in primary and intermediate manufacturing. Each of these major integrated companies covers around three to four major stages in the upstream petrochemical value chain (focusing on optimizing stream and chemical beneficiation/transformation profitability). Most of these major integrated companies have corporate structures with some subsidiary businesses focusing on specific products, product families or petrochemical value clusters. Small and medium-size enterprises are found mainly in downstream formulation and conversion processes.

A relatively small number of petrochemical companies have adopted a full supply chain approach (including planning) in managing their businesses along horizontal cross-functional processes reaching across upstream-, refining- and downstream supply chain stages. Where the adoption of an integrated supply chain planning approach has started, it is still in the early stages of development (2 to 3 years in existence). Value chain and supply chain planning processes provide the main mechanism to integrate and align the enterprise cross-functionally, cross-divisionally and with all related external parties directly involved in the applicable segments of the macro petrochemical value chain.

Materials, inbound supply, transformation processes and outbound supply covered by the supply chain (from suppliers to end customers) were found to represent anything from 70% to 90% of a typical petrochemical manufacturer's cost structure (expressed as a percentage of sales). Although the actual manufacturing activities of a company may be structured under a production operation managing function, the sales and operations planning processes (one of the key supply chain processes) have a major impact on the eventual production cost. Petrochemical businesses are still aspiring to advance to a point where the firm's strategic/competitive advantages are associated with the way in which it can leverage its integrated supply chain activities.

Supply chain decisions must be taken well in advance to keep actual supply chain operations running uninterrupted and to meet consumer requirements. The very nature of the South African macro petrochemical value chain results in a number of supply chain decision characteristics. These decision characteristics relate to geographical separation, demand and supply uncertainties/variability, seasonal and cyclical demand patterns, operational capacity, flexibility and constraints, and different lead/cycle times. An extended list of typical long- (enterprise-wide and business unit specific), medium- and short-term supply chain decisions taken in petrochemical companies were derived from the interviews. It could form a sound basis of what the supply chain planning processes in petrochemical companies should aim for (key influences, questions to be answered, and typical considerations taken into account as listed in Table 5.5). An indication is also given of the interdependencies between these major long-, medium-, and short-term supply chain decisions.

Supply chain planning (SCP) processes can provide a logical and structured approach for supply chain decision making. SCP processes are intended to translate the supply chain strategy into plans that direct the supply chain operations (to manage the flow of material, products, information and funds). These SCP processes span long-, medium- and short-term time horizons. It aims to balance the market demand requirements with supply resources (taking into account agreements, capacity, availability, efficiency, service level and profitability) and establish/communicate plans for the whole supply chain. Supply chain planning support the drive for internal cross-functional co-operation (breaking silo mentality), as well as external decision integration with supply chain partners. The major supply chain planning processes and the indication of their span, deducted from the interviews, form the basis for the proposed framework in Chapter 6 (summarised in Table 5.6).

A brief indication of the typical interdependencies found for the different supply chain decisions are:

Long-term corporate decisions ("*Mindset:* Focus and alignment"): These decisions have a long lasting effect and typically determine the boundaries for business unit specific long term plans in terms of strategic objectives, investment, policies, directives, guidelines, etc. Corporate priorities, enterprise functional strategies and business charters are established. Long-term financing and aggregate capital investment decisions are also determined.
Investment decisions typically are taken 3 to 10 years in advance.

Long term business unit supply chain decisions ("*Mindset*: Strategize and Prepare"): These decisions work under the umbrella of the corporate strategy decisions (also having a long lasting effect). The business strategy is translated into a supply chain strategy. Long term supply chain decisions determine the supply chain network that provide the configuration and inventory flow capacity for feed supply, production conversion of feed into value added products and distribution to the marketplace served. Strategic supply chain objectives and targets are also determined.
Looking 1 to 5 years ahead in monthly, quarterly, yearly time buckets.

Medium term supply chain decisions ("*Mindset*: Structure and Organize"): These decisions work under the umbrella of the long term decisions and work according to the supply chain network, prescribed material flow management policies, production levels set at all plants, inventory levels and lot sizes. The prime focus is on converting the supply chain strategy into supply chain operation plans. Medium term decisions also focus on optimizing supply to the market within the supply chain resource capability available.

Looking 3 to 6 months ahead in weekly and monthly time buckets.

Short term supply chain decisions ("*Mindset:* Commit and Control"): These decisions are conscious of the medium term economics (e.g. profitable product allocations, crude slate decisions already taken) and work under the umbrella of the medium term decisions. The prime focus is on converting the supply chain operation plans into supply chain operation schedules. Monitoring processes for execution control are also utilised.

Looking 1 to 4 week ahead in hourly, daily and weekly time buckets.

The use of planning processes (involving the relevant internal and external stakeholders), supported by appropriate analytical techniques, are still fragmented along the various stages and segments of petrochemical businesses' supply chains. Very limited formal processes exist on the strategic level to explore, evaluate and make supply chain decisions (this applies to both corporate and within divisions and business units). Medium- and short-term planning processes are more structured but still rely heavily on people's roles and the relationships that have been established over time. People in the petrochemical businesses are still learning how to orient themselves around the hierarchy of constraints and following an analytical approach. The evaluation of interdependencies is crucial in the process of developing feasible and optimal plans. An indication of what supply chain planning processes are used for, and which stakeholders are typically involved, is provided in this chapter.

There is a huge lack of understanding and experience in the use of advance analytical techniques for supply chain decision support. Spreadsheets are still very popular for analysis purposes (simple mathematical calculation) but are normally focused on local optimization. Spreadsheet models are normally very difficult to integrate, have very restricted scalability and changes in model configuration are not easy to manage. People also still rely on their own brainpower and cognitive models (experience and judgement) for taking "gut feel" decisions (or fixated on following time consuming procedures). This is opposed to using integrated planning processes and an iterative analytical approach for large complex supply chain decision making.

Supply chain planning performance measures should reach across the whole supply chain. These performance measures should then be used in parallel to other operational and financial performance measures to measure how some of the agreed upon supply chain objectives are achieved. Although not all the supply chain planning performance measures derived from the interviews (as indicated in Table 5.8) are used by all participants, they were found to be consistent in their definition. A selection of these performance measures is made, given a specific business units' requirements. Given these performance measures, substantial supply chain improvements in specific focus areas are still possible in the petrochemical industry (20% - 40%). These benefits relate to direct and indirect benefits achievable (quantitative and qualitative as indicated in paragraph 5.6.6).

The functional silo and secrecy mentality within business units, divisions and petrochemical enterprises is still a major problem to overcome in an attempt to follow an integrative supply and demand planning approach. A number of ways, in which the functional silo and secrecy mentality can be reduced, were deducted from the interviews and is one of the key inputs to the roadmap for process advancement and application in chapter 7.

Unfortunately, in many cases, when supply chain planning initiatives are currently justified, lots of attention is given to selling the potential value it will generate (basic economic benefits estimated). It is not yet clarified how the value will be unlocked. This relates to what would be required for organizational and process change (included in the marketing and sales departments). When these projects get approval and start with implementation, there is sometimes a too big focus on cost and deadlines for the technology implementation and not enough focus on the business transformation that should happen.

The following four dimensions of supply chain integration were assessed to get an indication of the level of advancement reached in petrochemical companies (Deductions from this assessment are discussed in the paragraphs following):

- Horizontal integration *(Supply chain partners involved along the supply chain stages)*
- Hierarchical decision integration *(Decision level Involved - Decision impact and time scale)*
- Petrochemical value chain cluster decisions and supply chain decision Integration
- Logistics network integration *(Cross-business unit, Cross-company, Cross-Industry)*

Although many petrochemical companies are actively busy with external supply chain integration, huge scope still exists for internal integration for each business unit (within function as well as cross-functional/departmental). Unfortunately, many companies still find it easier to integrate externally as opposed to integrating internally across functions. Some business units still need to reach functional excellence and stability in supply chain operation before being able to step up to supply chain integration (internal and external). The decision making levels involved (hierarchical decision integration), still need to extend properly to medium- and long-term integration. The decision integration for short-term supply chain operations in liquid fuel businesses has advanced further than that of chemical businesses. Upstream supply chain integration has also advanced further than downstream (based on feed stream dependencies).

Integration processes to conduct objective trade-off analysis between the decision domains of asset/production managers (managing shared assets), business unit managers (managing product value chains), supply chain managers and cluster and group optimization managers are still developing. Planning process frameworks that can assist in evaluating these opportunities should be developed.

Huge opportunities exist for the chemical companies to work closer within the industry as well as with related industries to leverage logistics network synergies for mutual benefit (e.g. Chemical, paper and pulp, and paints). Planning process frameworks that can assist in conducting objective trade-off analysis should be developed.

Although there seem to be a fair amount of advancement in the level of analytical techniques used, the knowledge of management science and operations research are still lacking at end users. In a number of cases these analytical techniques are embedded into decision support systems and many users view them as “black boxes”.

Most petrochemical companies have installed some form of supply planning (for S&OP), inventory distribution planning, production planning and scheduling, and transportation planning and management tools. Not all of these systems provide advanced planning and scheduling (APS) capability when fully implemented, but at least they provide some of the functionality required to support decisions. Although these tools are installed there are still huge opportunities to utilize their capability, which are not currently being exploited and integrated with other relevant systems, to its full capacity. There is also a huge need to structure and standardize the way of keeping decision-making information and making it available for supply chain planning.

Chapter 6: Synthesis and recommended advance supply chain planning framework

6.1 Introduction

A supply chain structure and configuration, the relevant customers, and related supply chain partners, for a focal business in concert with the supply chain drivers and supply chain objectives, form the basis along which supply chain processes are created. Planning processes comprise one of the important categories of supply chain processes. These planning processes support decision making and guide the cost effective execution of supply chain activities aligned with customer's requirements. Planning processes exist for individual supply chains (for a specific product or product family) but should also extend to interlinked supply chains (or elements thereof) which are typically found between related businesses in the petrochemical industry.

This chapter concludes on what is believed to be an appropriate supply chain planning approach/framework for the decisions faced in large-scale, integrated petrochemical companies. The structure of the framework consists of an appropriate philosophy, concept, guiding principles, typical petrochemical supply chain decisions, the supply chain planning processes themselves and the way in which planning processes should be enabled.

6.2 Synthesis from literature study and empirical research

From the literature reviewed and empirical research conducted, abundant research studies are available and many approaches were developed on how to plan and manage supply chains for individual products or product families. Although these approaches create a sound basis for managing individual supply chains, they lack in two aspects to provide appropriate solutions for the supply chain challenges faced by large-scale integrated petrochemical companies. ***Firstly***, with reference to the nature of supply chain processes utilized in petrochemical- compare to discrete manufacturing companies. Liquid and discrete products differ in relation to the supply chain practices applicable. Supply chain networks for liquid products have some specific attributes (e.g. continuous vs. discrete flow dynamics) and require specific supply chain processes not applicable to discrete manufacturing companies. ***Secondly***, with reference to the interdependencies that exist within and across supply chains for petrochemical manufacturing companies. These interdependencies relate to upstream feed clusters (sequential, pooled and reciprocal), logistics networks (infrastructure, facilities and corridors) and downstream product clusters (related to regions, markets and customers) (refer to Paragraphs 4.1.1, 4.1.4.3, 5.6.1 & 5.7.1)

The opportunity exists to establish advanced supply chain planning processes that leverage synergies, and deal with the interdependencies that typically exist between supply chains in large-scale companies. Given the demarcation of this dissertation, in this instance, the focus is on large-scale petrochemical companies. Taking a holistic perspective, the focus should be on what is best for the whole enterprise—thus reducing the risk of only optimizing locally within each subsidiary business unit's supply chain (and for its related supply chain partners).

Given the current level of advancement, there exists an opportunity to expand the chemical supply chain scope and planning horizon (to support supply chain decisions). A well established supply chain principle followed is that long-term decisions will guide medium- and short-term decisions, and ultimately actual operations. There are, however, few petrochemical companies that have expanded their supply chain thinking to include additional value-add dimensions of supply chain scope and supply chain planning in their interdependent chemical supply chains and logistics networks. These areas of improvement is indicated in Figure 6.1 (also refer to Paragraph 5.11). The well-established supply chain planning approach is covered in the ***intra-supply chain*** scope (refer to Paragraphs 2.2.2 & 4.2.1). The ***inter-supply chain*** scope would aim to harness benefits both internal and external to a firm by leveraging off synergies and interdependencies found between chemical supply chains and logistics network. This calls for network management of the related interdependencies. Pro-active planning and alignment of all relevant supply chain partners will create the opportunity to optimally synchronize horizontal and sequential inventory flow. Where logistics interdependencies exist, cooperation on strategic, tactical and operational level can assure supply chain feasibility and holistic optimization.

The supply chain focus and planning can thus extend its reach/span across any of the following seven domains (categorized into intra- and inter-supply chain scope):

Intra-supply chain scope (for an individual supply chain):

- Across activities within a function/department (internally focused)
- Across functions within a business unit (internally focused)
- Across a complete supply chain: backwards integration with suppliers, and forward integration with customers and other supply chain partners (externally focused)

Inter-supply chain scope (for multiple supply chains or cross-segments):

- Across business units in a division (internally and externally focused)
- Across divisions in an enterprise (internally and externally focused)
- Across enterprises in the same industry (internally and externally focused)
- Across enterprises in different industries (internally and externally focused)

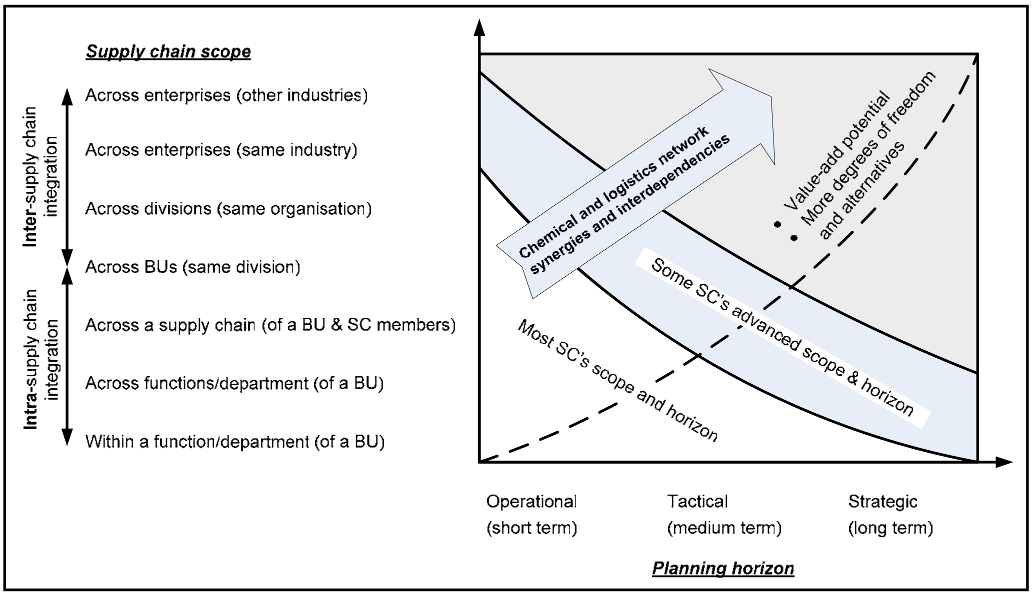


Figure 6.1 : Potential expanded chemical supply chain scope and planning horizon

Organizationally most supply chain planning processes are structured within business units and focus on the intra-supply chain scope (extending to their own suppliers and customers). There are however still some major challenges to overcome related to cross-functional integration (largely due to silo-oriented functional approaches within business units). Not many enterprises have properly structured themselves to cater for the planning processes required for the inter-supply chain scope (refer to Paragraphs 5.7.3 & 5.11.2). The competencies required for people responsible for supply chain planning are also not fully appreciated and are constantly underestimated/underappreciated. With the globalization of businesses and facing of global competitive pressures, supply chain complexity has increased dramatically (refer to Paragraphs 1.2.1 & 5.7.2). This has started the elevation and appreciation of the role that supply chain planning can play in dealing with increased complexity.

The use of OR/MS techniques within appropriate supply chain planning processes in order to support sound decision making, still has major room for improvement. OR/MS techniques can provide the proper analytical basis to assure sound decision making for complex supply chain problems based on facts, rather than perception and gut feel alone. Many supply chain managers still lack a basic understanding of the OR/MS techniques applicable to the supply chain discipline (refer to Paragraphs 1.2.3 & 5.6.3). Decision support systems that incorporate OR/MS techniques have developed satisfactorily and their application are growing. Although the functionality provided by these systems are not yet fully utilized, they at least support the basic decisions and provide objective answers to the questions at hand. The proper understanding and appreciation of the capabilities of these systems, and the correct application thereof, are fortunately increasing.

6.3 Petrochemical supply chain philosophy

A **supply chain approach** forms the basic orientation and complements the chemical value chain approach in that it assures not only optimality, but also feasibility (by taking into account all the relevant constraints and operational realities). An applicable and complete supply chain approach is however required to secure a competitive advantage for a business and its supply chain partners. In future, supply chain leaders will leverage their supply chain approach and capability to distinguish themselves from their competitors. Leaders in the chemical industry will look outside their own manufacturing operation for bottom-line improvements (and not primarily focus on manufacturing-cost reduction) (refer to Paragraph 4.3). In focusing on lowering the total supply chain network's cost, **collaboration with trading partners** becomes a prerequisite to align procurement, manufacturing and logistics capabilities with the customers' demand. Each individual supply chain, however, needs to take account of the enterprise-wide synergies and interdependencies in which it operates.

To focus only on the functional excellence of individual functions in the supply chain will not suffice. In becoming customer-focused and demand driven, a company needs to adapt **a process approach** in managing its business across all relevant internal functions and external partners. The appropriate integration of business processes is the key—not just interfacing. **Highly integrated processes**, all the way from the procurement of raw materials up to the delivery of the final product, should exist. Fostering a supply chain culture will drive the correct values and required behaviours for a true supply chain approach (refer to Paragraphs 1.2.6 & 2.2.3).

The correct supply chain and planning performance indicators, linked to key business measures will secure senior management's awareness, attention and support. Without **senior management's complete support** and active participation in using a supply chain management approach to manage their business, the full potential and benefits of superior competitiveness will not materialize (refer to Paragraphs 3.2.2.2 & 3.3.2.2).

By evaluating future demand requirements and constraints, **supply chain planning processes assure a pro-active approach** and enough time to prepare supply chain operations properly for synchronized execution (refer to Paragraph 1.2.3). Supply chain planning will play the key role in aligning all the supply chain partners to a common goal on strategic, tactical and operational levels. These objectives focus on:

Senior management (strategic): strategic objective

Middle management (tactical): process and functional objectives

Lower management (operational): sub-process/activity objectives

By following a holistic integrative approach and removing organizational barriers (silos) between interdependent chemical value chains, global optimality can be achieved that is far better than the local optimization of the individual value chains. This philosophy can also be applied to a supply chain approach. The internal and external integration within individual supply chains (structured around the value chain of an individual product or product family) is the first plateau reached by following a conventional supply chain approach in a petrochemical company. This can be viewed as **intra-supply chain integration**. Due to the highly integrated nature of petrochemical value chains, related supply chains should also be integrated by taking account of enterprise-/industry-wide synergies and interdependencies (refer to Paragraph 5.11). This scope moves past the first plateau indicated and can be viewed as **inter-supply chain integration**. Inter-supply chain integration can typically develop along three dimensions:

- Upstream chemical feed interdependencies/synergies (upstream in chemical value chain)
- Downstream product interdependencies/synergies (downstream in chemical value chain)
- Macro Logistics network interdependencies/synergies (within and across enterprises related logistics networks for liquid bulk, dry bulk, packaged goods and gasses)

6.4 Concept of extended supply chain management and advanced supply chain planning

A Supply Chain Management (SCM) orientation forms the basis in any business for advancing it's supply chain planning processes. Long-, medium- and short-term decisions are made (with the help of supply chain planning processes), followed by the required actions to direct the activities of organizations, functions and people within the supply chain toward common objectives. The constituent parts of SCM are: (a) the **supply chain** itself, that is; the supply chain operational activities related to the storage, flow and transformation of raw materials into products from suppliers through production and distribution facilities to the ultimate consumer, and (b) **management**; the process of developing decisions and taking actions to direct the activities of organizations and people within the supply chain (focusing on planning, organizing, staffing, leading, and controlling) (refer to Paragraph 1.2.3). A SCM approach provide for the systemic, strategic co-ordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. Managers in companies across the supply chain should work together to make the entire supply chain more competitive.

Supply chain planning supports the SCM objectives to minimize the total supply chain cost (capital, fixed and variable), maximize net revenues (gross revenues less total cost) and achieving non-monetary objectives, such as customer service, availability, reliability, product variety, quality, and time. A key point in supply chain management is that the entire supply chain must be viewed as one system (refer to Paragraphs 1.1.1 & 1.1.2). The performance of each member of the supply chain affects the overall performance of the whole supply chain. With supply chain planning also following a systems approach, it makes the most of resource inter-changeability opportunities in the supply chain (e.g. modes of transport). A global integrative systems approach looks for the contribution/optimization of individual activities/functions/ processes related to the bigger picture (inter-changeability amongst resources and optimal resource balancing/trade-offs of people, material, capital, equipment, information and energy).

Supply chain planning processes become more advanced as the supply chain scope covered increases, the time horizon extends, more sophisticated techniques are used and decisions become more complex. As petrochemical companies develop their sources and markets globally, their supply chains become lengthier, more divergent, increasingly complex and more costly. Figure 6.2 indicates the expanded chemical supply chain operations and decision domains that supply chain planning processes can cover in large-scale petrochemical companies. The features of the two distinct stages in advanced supply chain planning can be articulated as:

First stage advanced supply chain planning (intra-supply chain)

- Planning process integration to cover an organization's functional silo and corporate barriers across the partners in each supply chain (reach)
- Planning covers strategic, tactical, and operational decision layers (level)
- The use of enabling OR/MS techniques, relevant decision information databases and IT
- Concurrent- and constraint based planning with fast propagation of change (considering all relevant constraints simultaneously)

Second stage advanced supply chain planning (inter-supply chain)

- Chemical feed-stream interdependencies/synergies (upstream in chemical value chain)
- Product interdependencies/synergies (downstream in chemical value chain)
- Macro logistics network interdependencies/synergies within and across enterprises related to liquid bulk, dry bulk, packaged goods and gases

Supply chain **process enablers** provide the means for processes to function and meet the intended performance targets. Related to planning processes, the enablers include (also indicated in Figure 6.3):

- People (with critical competencies) playing specific roles (organizational design)
- Analytical techniques (OR/MS)
- Key performance measures and related benchmarking
- Key information and sources thereof
- Communication infrastructure

- Decision support systems
- Management components (*physical and technical, and managerial and behavioural)*

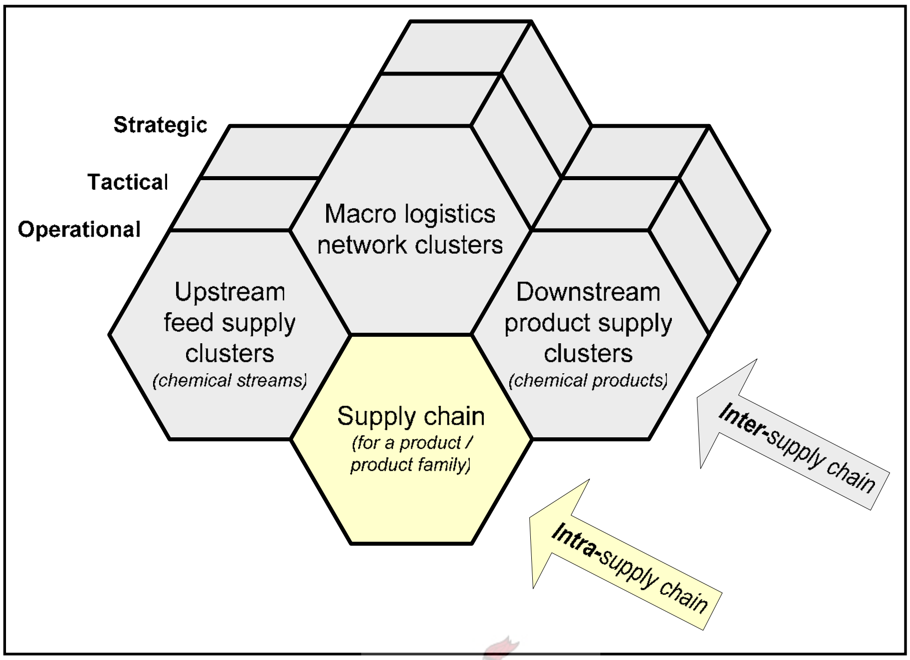


Figure 6.2 : Expanded chemical supply chain operations and decision domains

Supply chain planning uses time-phased planning and different time horizons to establish a single consistent plan for each supply chain. As indicated in Figure 6.4, different moving time horizons and time buckets are used for the different levels of planning. Through aggregation and de-aggregation, the different levels of planning are integrated to form a single consistent plan.

Individual petrochemical **value chains** and their associated supply chains exist for a specific product or product family and form the basis for business unit structures in this industry (as indicated in Figure 6.5). Sources for chemical feedstock supply could either be internal or external to business. The demand for final product supply could also be internal or external to business. The external demand is typically viewed as a independent demand (external consumers' demand driven by their own business dynamics). On the other hand, internal demand is viewed as a dependant demand since the downstream consumptions can be derived from known drivers (e.g. downstream production plan/schedule).

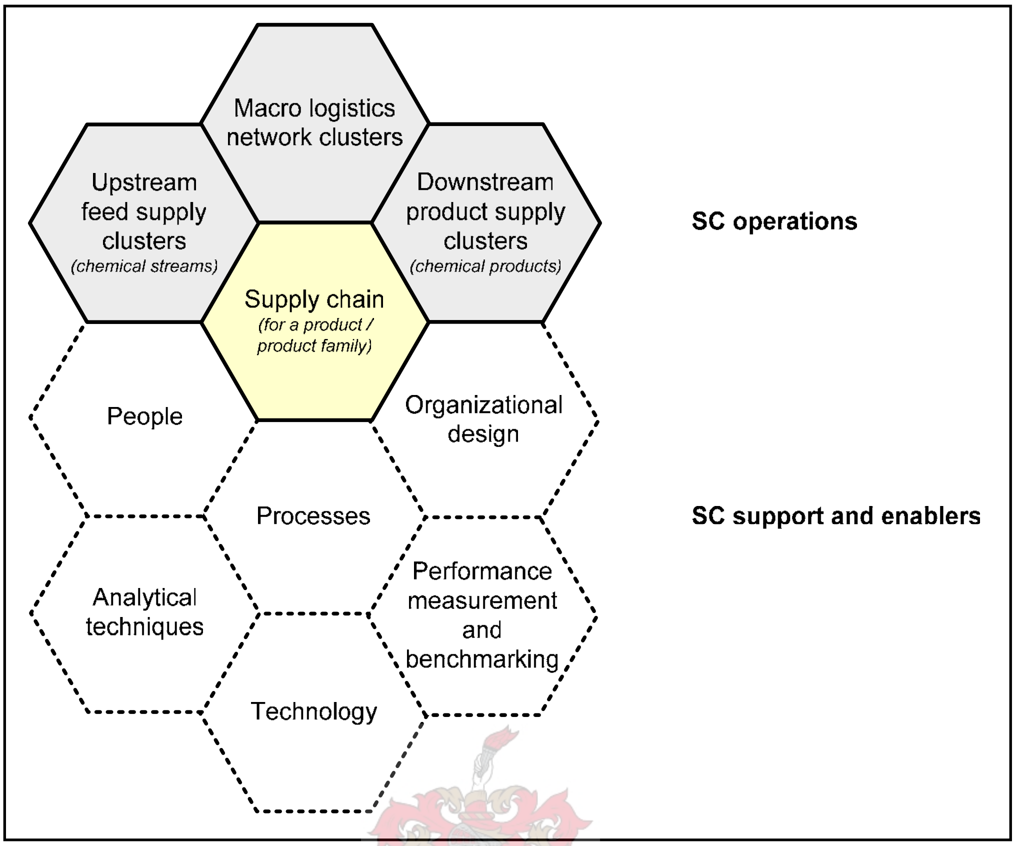


Figure 6.3 : Expanded chemical supply chain operations domains with enablers

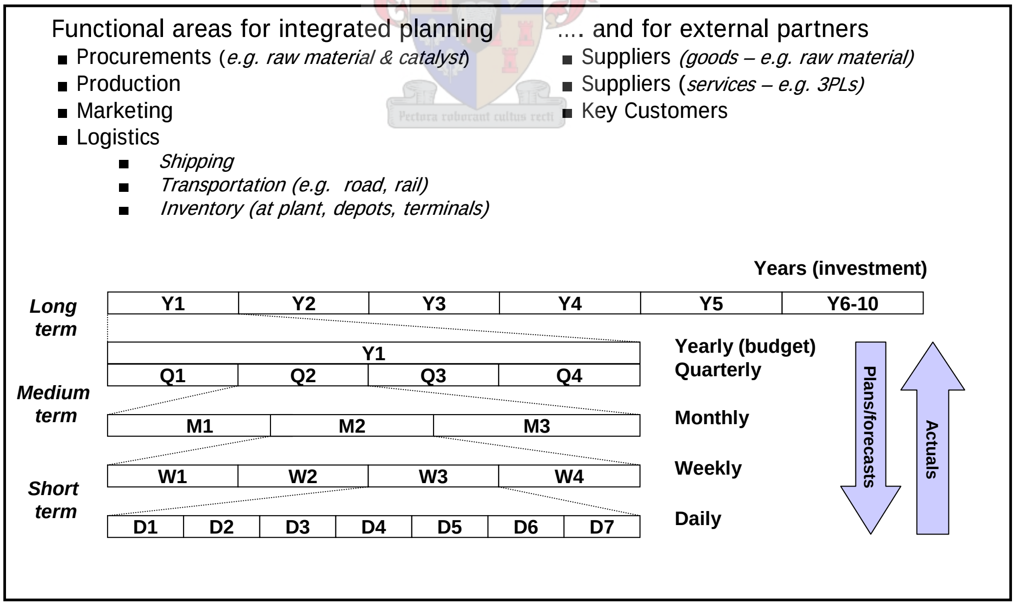


Figure 6.4 : Integrated planning process time horizon and windows

The successive chemical transformation processes that convert feed material into a variety of derivatives, commodities, and ultimately into end consumer products, result in the divergent nature of petrochemical value chains. A specific focus is on integrating horizontal interdependent supply chain processes spanning from suppliers through manufacturing to end customers. Value is created by tight feed stream allocation, integration, visibility and alignment towards market segments. The variety of chemical manufacturing processes and technology available provides a fair amount of flexibility in the allocation and utilization of feedstock and commodity chemicals to produce a wide range of more refined and value adding chemical products. Process yield, split factors, feed availability, chemical product prices and profitability are some of the factors taken into account in these allocation decisions.

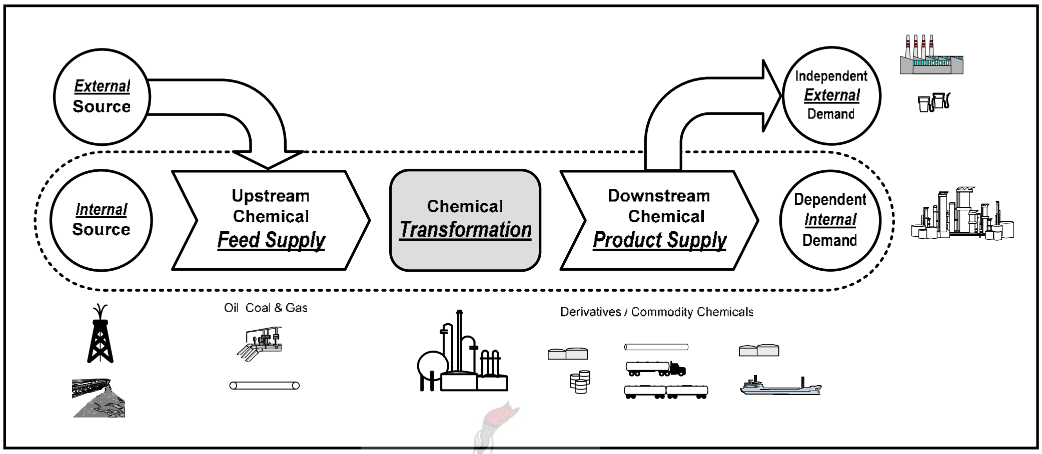


Figure 6.5 : A petrochemical value chain with its associated supply chain elements

Tightly interdependent value chains form value chain clusters (upstream and downstream in the macro petrochemical value chain). These **chemical value chain clusters** then closely cooperate in balancing their interrelationships and align to reach shared objectives. It also forms the basis for the "wedge optimization" of the macro petrochemical value chain (relate to figure 4.7). Upstream, the focus is on collaboratively allocating scarce molecules profitably to downstream consumers, that is **upstream feed supply clusters** (refer to Paragraphs 5.6.1 & 5.11.2). Chemical transformation processes can be spread across multiple geographically dispersed facilities and therefore logistics considerations should be taken into account when taking these allocation decisions (considering capacity, cost, risk and lead time). Interdependencies amongst the individual chemical value chains exist and can take any of the following forms (relate to Figure 6.6):

- Sequential *(linear dependency where one chemical is produced from one feed stream)*
- Pooled *(many chemicals can be produced from one feed stream)*
- Reciprocating *(backward and forward use of chemicals in the chemical value chain)*

Downstream, the focus is more on collaborative inventory allocation to regions/customers and swaps with other industry competitors (**downstream product supply clusters**) Where more than one business unit from the same enterprise serves the same customer, interdependencies and synergistic opportunities should be evaluated to assure that their own individual actions do not compromise their own enterprise's strategic intent.

From a **logistics** perspective, large-scale petrochemical companies can work closer within themselves, within the chemical industry, and also with related industries (e.g. chemical, paper and pulp, and chemicals and paints). The lack of integrated planning between industry players by sharing common infrastructure, leads to sub-optimal utilization (e.g. transportation corridors, storage facilities). The logistics synergies and interdependencies could be used for mutual benefit. **Firstly**, commercial synergies can be derived through consolidation processes (strategic service sourcing practices). Economies of scale and commercial synergies can be leveraged through the logistics service providers that serve a number of business units within a corporation. **Secondly**, synergistic opportunities with other related players across the types of logistics networks could also exist and can be leveraged for mutual benefit. Related to logistics networks, the network types (basis for logistics value clusters) depend on the handling and packaging characteristics of the product (liquid bulk, dry bulk, packaged goods and gasses). Interdependencies can exist related to infrastructure on facilities and transportation along specific corridors. Closer collaboration and gradual sharing of increasing relevant supply information is the key to making these synergies and interdependencies transparent (refer to Paragraphs 4.1.5 & 5.11.3).

Typical opportunities that could exist, and where leveraging is possible, include:

- front haul/back haul balance,
- moving from road to rail transportation and vice versa, plus corridor densification,
- achieving economies of scale along major corridors,
- hub- and spoke best practices,
- exploiting differences in transport tariffs between origins and destinations, and
- modification to tariff structures based on economies of scale.

6.5 Guiding Principles *(Related to the petrochemical industry)*

6.5.1 Supply chain approach principles

A supply chain exists for each product/product family

A supply chain is the physical representation of a business's value chain. It forms a critical part of a business's value chain since it covers three of the five primary value chain activities (i.e. inbound logistics, manufacturing and outbound logistics). Companies have traditionally grouped customers by industry, product, or trade channel and then provided the same level of service to everyone within a segment. Effective supply chain management, instead, groups customers by distinct service needs, regardless of industry, product, or trade channel, and then tailors services to those particular segments. Companies need to design a logistics network based on the service requirements and profitability for each identified customer segment. The conventional approach of creating a large, monumental logistics network providing the same service to all customers, runs counter to successful supply chain management.

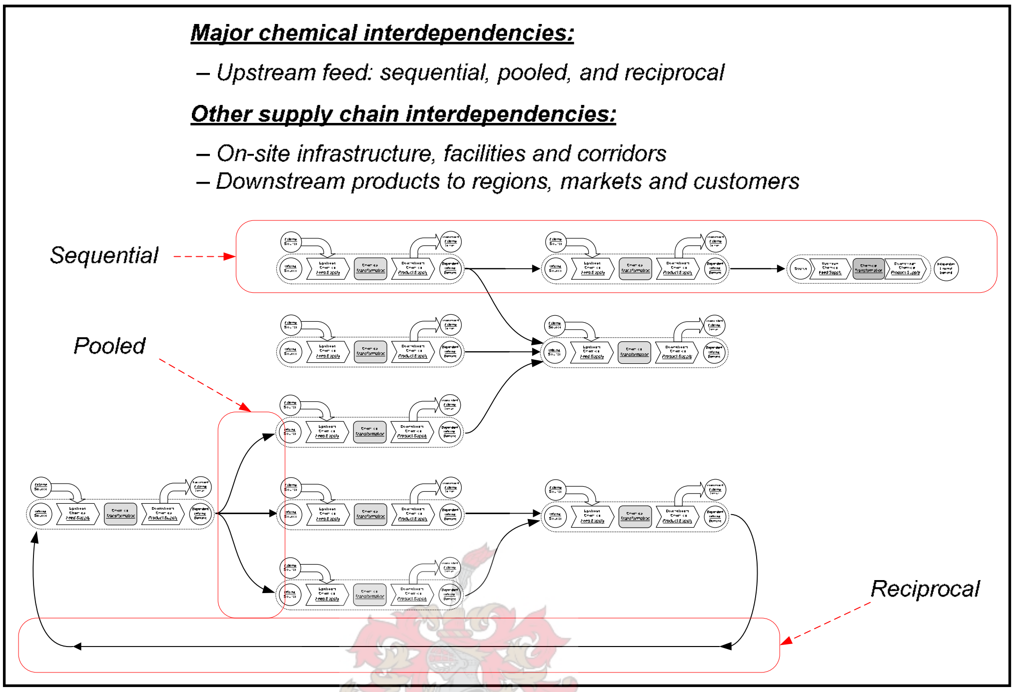


Figure 6.6 : Supply and demand balance (integrated chemical enterprise)

A supply chain is made up of interlinked segments/threads

The supply chain segments/threads within and outside an organization represent all the operations and activities taking place within a supply chain from original supplier, through manufacturing and distribution, to the end customer. The segments/threads also represent the different partners fulfilling a specific role, based on the supply chain design and operations model (refer to Paragraph 2.1.2.1). The challenge of integrated advanced planning lies with process integration. The greatest challenge is to ensure that the supply chain parts cooperate with each other and stay focused on a single objective. Advanced planning has to cross not only the functional silos within one enterprise, but also the corporate barriers across the supply chain. Supply chain partners are guided by either agreements (internal–governance driven) or contracts (external between legal entities–legal driven). These contracts and agreements typically relate to feed-stock suppliers, contract manufacturer, logistics service providers and customers.

Supply chains in process manufacturing industries are fundamentally different compared to discrete manufacturing industries

The macro petrochemical value chain (pipeline) is characterized by a number of interlinked and successive interdependent transformation stages and manufacturing processes. Starting with a relatively small number of raw materials, a large variety of different liquid fuel and chemical products (organic and inorganic) are produced in subsequent refining processes. Some products are made intentionally, while others (co-products) are the result of the processing technology being used. Since many of the products produced are commodities with standard specifications (e.g. fuel), exchange/swap supply agreements are used as an alternative source of supply. Close to 80% of products are handled in liquid bulk format. Liquid and discrete products differ in relation to the logistics and supply chain practices applicable. A liquid product supply chain network (when properly designed) has some specific attributes and requirements (refer to Table 4.3 for more detail).

There are also some fundamental differences within the petrochemical supply chain. Most on-site chemical operations run according to steady state objectives (flow, temperature and pressure). However, this assumption cannot be made for off-site facilities and logistics (refer to Paragraph 4.1.3.2). These processes are discontinuous, time-variable and unsteady-state by nature, necessitating applicable controls and management.

The level of product sophistication also determines the logistics approach. In the consumer product environment and utility products, the main emphasis is on business logistics (Effective movement and service level focus). With more sophisticated products (like equipment and machinery), the main emphasis is on engineering logistics (Support of systems; availability focus). By its very nature, with chemical product supply chains, the main emphasis is on business logistics.

Progressing from intra- to inter-supply chain thinking will become a competitive requirement in the petrochemical industry

A supply chain approach will help companies to become competitive and extend their processes to beyond the four walls of the company (linking the focal company to its supply chain partners). This competitive paradigm places the firm at the centre of an interdependent network–a confederation of mutual complimentary competencies and capabilities–which competes as an integrated supply chain against other supply chains. The key focus is on network management and integrated processes. This requires collective strategy development, win-win thinking and open communication.

In the petrochemical industry, the level of interdependencies is such that individual supply chains must work together in value clusters to assure optimal and feasible plans for each related supply chain. This requires the next level of advancement in taking an inter-supply chain integration approach. Although the optimization of individual supply chains and reaching operational excellence form an important basis, large-scale petrochemical companies need to integrate interdependent supply chains and constantly screen for synergistic opportunities to maintain a competitive advantage over their competitors. Their competitive advantage can be enhanced through more cost-effective supply chain solutions than what would have been individually developed (refer to Paragraph 5.15).

Hubbing provide mechanism for shared services and corporate guidance

Hubbing is one of the mechanisms that can assist with integration and making processes more cost effective. The concept of hubbing brings work that had been spread across multiple departments and functions together at one point (could also relate to shared services). Hubbing is particularly important to large-scale enterprises. It is best suited to, and can even transform, decision-centred customer-service processes in which each unit traditionally handles only parts of the decision. Hubbing also puts the entire decision in the hands of one employee (or key stakeholder group) (refer to Paragraph 2.1.1.2).

6.5.2 Supply chain planning approach principles

Supply chain planning processes enable supply chain decision making and ultimately guide supply chain execution activities

Supply chain planning processes enable supply chain decision-making across the three decision layers in organizations. These planning processes relate to the decision time frames of strategic (long-term), tactical (medium-term) and operational (short-term) (refer to Paragraph 2.2.2). Effective supply chain planning processes will direct the three major supply chain execution/operational processes: sourcing, production and logistics (inbound and outbound).

Supply chain planning processes aim to drive integration across the following three dimensions:

Functional integration	*(purchasing, manufacturing, transportation, and warehousing activities internal to an enterprise)*
Spatial integration	*(Integration of the supply chain stages; the extended enterprise reaching across company boundaries)*
Hierarchical/decision integration	*(Three discrete levels of management control: strategic, tactical and operational)*

From a systems perspective, the strategic, tactical and operational supply chain decisions cascade into a hierarchy of interrelated decision layers:

Strategic (Long-term)	Provide the overall strategy, drivers, objectives and secure long term capacity
Tactical (Medium-term)	Works under the umbrella of Long-term: throughput and capacity balancing
Operational (Short-term)	Works under the umbrella of Medium-term: finite capacity scheduling and sequencing of operational activities

Supply chain decisions should be based on sound facts

Transparency and timely access to key planning information across all supply chain segments is vital for effective supply chain planning. Supply chain decisions should be based on facts and proper analysis (not on perception and gut feel alone) to assure the required credibility (refer to Paragraph 1.2.3).

Breaking down functional silos/walls between internal (cross-functional and cross-divisional) and external supply chain stages (cross-enterprise), plays an important role in making the supply chain more transparent, reducing uncertainties and providing the needed information for sound decision-making (getting sharing and a “team approach”/“unity of effort” going) (refer to Paragraph 3.3.2).

Decision domains exist along and between individual supply chains

Many decision domains exist along individual supply chains. These decision domains are typically found in some of the segments/elements that a supply chain comprise of. Decision domains also exist between individual supply chains or segments/elements thereof (refer to paragraph 6.4 – inter-supply chain concept). The more decision domains in a supply chain, the bigger the challenge for integration (due to delays, local optimization, silo mentality, power play, poor transparency, slow reaction time, slow propagation of change). Inappropriate organizational structures and power distribution also bring about many decision domains that are not always easy to integrate.

Proper Supply chain planning will counteract the "Industrial dynamics" effect (Bullwhip effect)

The main reasons for demand amplification and distortion in a supply chain are the flywheel effect of shortage, over-ordering and unreliable delivery. The law of industrial dynamics is a well-known phenomenon which leads to significant swings in demand as orders are passed down a supply chain. Proper supply chain planning will counteract the "Industrial dynamics" effect (Bullwhip effect of inventory shortages or over supply). This is done through the availability of a single transparent demand plan and a supply plan executed in a synchronized fashion.

The balancing of future demand and supply capacity requirements on a rolling, telescopic time horizon is required to proactively identify and resolve future constraints before they materialize. (e.g. Build-up of inventory buffers in advance of high demand periods that would be in excess of instantaneous production and supply capacity). Managing constraints across a supply chain would involve matching two variables (supply and demand) at each node. Supply side constraints typically include capacity, capital, space, people and equipment (across the inbound, manufacturing and outbound stages of a supply chain). On the demand side, the best is to start with true demand from the final consumer. It is normally difficult to get the true demand due to noise factors (i.e. promotions, forward buys, end-of-quarter or end-of-year inventory pushes, price wars and new product introduction). Suppliers should thus try and get as close as possible to visibility of true customer demand.

Planning and optimization must focus on the entire supply chain

In supporting planning at all levels, optimization must focus on the entire supply chain as a whole, rather than optimizing each individual function. The tools that can enable these requirements are generally known as advanced planning and scheduling (APS) tools. Some advanced chemical businesses run their supply chain with less than half the inventory of their competitors, even though their manufacturing technology and assets are similar. The advantage comes from using all available information effectively to consistently make robust and "fact-based" decisions. This is made possible by using collaborative planning software and integrated processes that:

- Increase the visibility of available information
- Provide a solid framework for making robust decisions under uncertain conditions
- Use appropriate technology to optimize operations and reduce inefficiencies
- Break down organizational silos by providing and maintaining a consistent set of data to manage the supply chain.

The correct planning performance measure should be used for each supply chain planning timeframe

Supply chain planning performance measures should reach across the whole supply chain. These performance measures can then be used as the means of measuring how some of the agreed upon supply chain objectives are achieved (refer to Paragraph 3.2.1.1). It is important to construct performance measures in such a way as to eliminate bias. Since the typical supply chain decisions and objectives differ for long-, medium-, and short-term, the correct planning performance measures should be used for each .

Long-term performance measures are closely related to a firm's financial performance measures (Nett operating profit, return on investment, cash flow). An indication of the forecasting error and total supply chain cost are quite relevant.

Medium-term performance measures become operational and relate to throughput for the whole supply chain, inventory and relevant operational expenses that will realize. Since supply chain plans direct the actual operations, planning accuracy is an important performance measure. The information used in supply chain planning models must be reliable. For this reason data accuracy is an appropriate performance measure to use and made visible to supply chain members.

Short-term performance measures relate more to schedule achievement (adherence), performance and service levels (measured daily, weekly, monthly), and perfect orders. Performance measures do not stand in isolation and the inter-relationships should be understood in order to properly evaluate how well supply chain planning is done.

Independent demand to drive dependent demand (causal relationship)

When considering future demand, there is the difference between dependent and independent demand. Forecasts refer to independent demand. On the other hand, the projected off-take of raw material is dependent on the expected sales against the finished goods (refer to Paragraph 2.2.4). Distribution requirements to a branch network are dependent not only on the forecasted sales of a specific branch, but also on the stock on hand and target stockholding of a specific product in the branch. Independent demand thus drives dependent demand and can be calculated via the causal relationships that exist. It is thus always best to rather derive/calculate demand when specific causal relationships exist, rather than to forecast/estimate demand based on historic demand patterns.

Inventory can also be classified based on its dependency. Independent inventory includes those products that are not dependent on the demand of other products (refer to Paragraph 2.2.2.3). This means that they are the ultimate finished products destined for the final consumer. Managing the inventory of these products requires forecast information based on consumer needs. Dependent inventory includes items that are usually feedstock, catalyst or process material used in the manufacture of the final consumer product. This martial represents a typical bill of material used in material requirements planning.

Hierarchical Production Planning systems typically plan for "independent demands" while Material Requirement Planning systems plan for "dependent demands" (i.e., independent demand for finished goods drives the dependant demand for materials and components).

Supply chain planning involves collaboration and coordination

Collaboration requires a climate of trust and cooperation (for information sharing and visibility of the activities). Collaboration is a key approach to break down secrecy and silo mentality along the supply chain. Collaboration can also take place at three levels: transactional, process, strategic. Cross-enterprise collaboration in a supply chain will allow for sharing key information, joint strategic planning and synchronizing operations (coordinated efforts in reaching goals). Collaboration relies on:

- Right processes (leadership, planning and control, and operational processes)

- Right competencies (skills)
- Right capabilities (experience)

6.6 Petrochemical supply chain decisions

Supply chain decisions should be guided by the overarching corporate and business decisions. The competitive environment an enterprise and its subsidiary businesses face, could require and pre-determine specific supply chain designs and configurations. A business strategy and the associated marketing strategy create a number of supply chain challenges that need to be addressed. This provides the basis for the resulting supply chain decisions that, on their own, can again influence the marketing and business strategy.

Typical business decisions include:

- Corporate positioning (Alternative long-range business definitions, purpose and missions)
- Corporate purpose and direction; corporate alignment
- Positioning and grouping of subsidiary businesses (composite mission per business unit)
- Positioning in each diversified market segment
- Corporate portfolio and product category portfolio decisions
- Investment decisions
- Product portfolio decisions
- Business structure
- Major business unit drivers, strategic goals and imperatives
- Budget allocations and yearly volumes
- Alternative long-range functional strategies
- Resource allocation and control
- Functional area policies
- Functional area details
- Budget details

Intra-supply chain decisions typically cover a number of decision areas across the long-, medium- and short-term time frames for a specific supply chain. These supply chain decisions relate to those derived during the empirical research of this dissertation (refer to Paragraph 5.6.1).

Table 6.1 to Table 6.3 presents a consolidated version of these decisions and is grouped according to the following decision areas:

- Customer demand
- Integrated supply chain
- Downstream product supply segment (inventory, facilities and transportation)
- Manufacturing
- Upstream feed supply segment (inventory, facilities and transportation)
- Sourcing (material and services)

A brief abstract of the different supply chain decisions timeframes are:

Long-term supply chain decisions ("*Mindset*: Strategise and prepare"):

These decisions work under the umbrella of the corporate and business strategic decisions (having a long lasting effect). The business strategy is translated into a supply chain strategy. Long-term supply chain decisions determine the supply chain network that provide the configuration and inventory flow capacity for feed supply, production conversion of feed into value added products, and distribution to the marketplace served. Strategic supply chain objectives and targets are also determined.

Looking 1 to 5 years ahead in monthly, quarterly, yearly time buckets.

Medium-term supply chain decisions ("*Mindset*: Structure and organize"):

These decisions work under the umbrella of the long-term decisions, and according to the supply chain network, prescribed material flow management policies, production levels set at all plants, inventory levels, and lot sizes. The prime focus is on converting the supply chain strategy into supply chain operation plans. Medium-term decisions also focus on optimizing supply to the market within the supply chain resource capability available.

Looking 3 to 6 months ahead in weekly & monthly time buckets.

Short-term supply chain decisions ("*Mindset:* Commit and control"):

These decisions are conscious of the medium-term economics (e.g. profitable product allocations, crude slate decisions already taken) and work under the umbrella of the medium-term decisions. The prime focus is on converting the supply chain operation plans into supply chain operation schedules. Monitoring processes for execution control are also utilized.

Looking 1 to 4 weeks ahead in hourly, daily & weekly time buckets.

Table 6.1 : Long-term BU supply chain decisions

(Intra-supply chain decision areas within each supply chain)

(a) Customer demand:

Marketing scenarios to consider.
Consensus target market; 1-10 years out (geographical and segmentation analysis).
Product range and specification.
Customer service requirements; contract vs. spot sales balance; selling terms.
Product prices and volume expectations (profitability staircase)

(b) Integrated supply chain:

Business scenarios to consider and supply chain strategy.
Supply chain network structure and configuration.
Supply chain risk tolerance and contingencies.
Optimizing operational margin.
Supply chain directives (strategic); supply chain goals.
Organizational and governing structures.
Planning and execution practices to follow, broad policies, performance measures and enablement of supply chain processes.

(c) Downstream product supply segment:

Inventory and Facilities:	**Transportation:**
Product supply buffering required (impact of supply and demand Variability). Product inventory policy. Facility requirements (Capacity and flexibility). Alternative facility locations and site selections (terminals, distribution centres, depots, drumming, packaging). Ownership/contract strategy. Capacity reservation.	Transportation requirements (capacity and flexibility). Alternative transportation modes and corridors of movement selection. Ownership/co-managed strategy (own or contract service). Preliminary fleet sizing. Capacity reservation.

(d) Manufacturing:

Alternatives manufacturing locations and site selection (chemical plants, bulk blending).
Toll manufacturing options/choice.
Production technology and Production philosophy.
Production capacity and flexibility.

(e) Upstream feed supply segment:

Inventory and facilities:	**Transportation:**
Available crude wells/chemical sources? Feed supply buffering (impact of supply and consumption Variability). Internal vs. external supply balance. Feed inventory policy. Feed capacity reservation. Facility requirements (Capacity and flexibility). Alternative facility locations and site selections (terminals, depots, warehouses). Ownership/contract strategy. Capacity reservation.	Transportation requirements (capacity and flexibility). Alternative transportation modes and corridors of movement selection. Ownership/co-managed strategy (own or contract service). Preliminary fleet sizing. Capacity reservation.

(f) Sourcing (material and services):

Sourcing strategy to follow (if external sources – related feed stock and logistics service suppliers).
Contracts and spot purchase balance.
Exchange and supply agreements within petroleum and chemical industry.
Trading and alliance partner choices (related feed stock and logistics service suppliers).
Energy supply choices (generate own/source external).

Table 6.2 : Medium-term BU supply chain decisions

(Intra-supply chain decision areas within each supply chain)

<table>
<tr><td colspan="2">(a) Customer demand:
Consensus demand and sales plan to use (1 month fixed, 3 months firm and committed, 4 months+ indicative).
Weekly and monthly product introduction/phase-out impact.</td></tr>
<tr><td colspan="2">(b) Integrated supply chain:
Translate supply chain strategy into operation plans; “structure and organize”.
Outline the regular operations; rough resources quantities and time requirements; inventory flow across the supply chain.
Supply directives (tactical; what to supply from where).
Align S&OP process with budgeting process and quarterly reviews.
Supply and demand balancing (define supply operations plans).
Cost and lead time trade-offs.</td></tr>
<tr><td colspan="2">(c) Downstream Product Supply Segment:</td></tr>
<tr><td>Inventory and facilities:
Deployment strategies (pull vs. push), control policies (order quantities, re-orders point and safety stock levels).
Inter-facility/stock transfers.
Inventory allocation, investment and deployment plans.</td><td>Transportation:
Primary and Secondary transport requirements.
Shipment nominations and commitments for marine vessel preliminary schedules.
Inter-facility/stock transfers shipment requirements.
Transportation mode, rough cut capacity plan and provisional carrier selections.</td></tr>
<tr><td colspan="2">(d) Manufacturing:
Feed stream allocation to manufacturing operation (staircase priority).
Production capacity availability and load allocation.
Production planning (unit commitment, master production plan, campaigns and lot sizing, component blending, macro sequencing).
Assignment of production capacity to product families, by plant (and often) by medium size time periods (e.g., monthly and quarters).
Workforce requirements (regular and overtime levels)</td></tr>
<tr><td colspan="2">(e) Upstream feed supply segment:</td></tr>
<tr><td>Inventory and facilities:
Deployment strategies (pull vs. push), control policies (order quantities, re-orders point and safety stock levels)
Inventory allocation, investment and deployment plans.
Supply scheduling of longer lead time materials.</td><td>Transportation:
Upstream transport requirements.
Shipment nominations and commitments for marine vessel preliminary schedules.
Inter-facility/stock transfers shipment requirements.
Transportation mode, rough cut capacity plan and provisional carrier selections.</td></tr>
<tr><td colspan="2">(f) Sourcing (material and services):
Procurement and supply scheduling of longer lead time materials.
Commitment to exchange and supply agreements.
Contract call offs from term agreements.</td></tr>
</table>

Table 6.3 : Short-term BU supply chain decisions

(Intra-supply chain decision areas within each supply chain)

(a) Customer demand:

Given specific fill rate and fixed sales orders, how best can it be fulfilled (give supply processed)

Best way to allocate demand/orders to delivery opportunities?

When can committed orders be fulfilled?

(b) Integrated supply chain:

Translate SC operation plans into SC operation schedules and "commit and control".

Consolidated logistics schedule (right product, right place, right time, right condition).

What key execution activities to track that could have negative impact on the total SC.

Customer order processing and scheduling.

(c) Downstream product supply segment:

Inventory and facilities:	**Transportation:**
Inventory availability for end customers (Firm ATP). Operational Schedules for Stock transfers and deliveries (outbound). Distributions of inventory and scheduling of deliveries (customer delivery time window). Product certification scheduling. Short-term inventory balancing and reconciliation. Facility operations scheduling (e.g. Warehouse picking, tank farm rundowns, packaging). Reservation and provision.	Vessel arrival and shipment loading schedules. Pipeline schedules (final product). Primary and secondary delivery (transport) schedules. operational schedules for truck routing and load builds. consignment scheduling. final mode, routing, carrier selections for individual loads and vehicle scheduling.

(d) Manufacturing:

Daily and weekly production scheduling at the product level; including product sequencing decisions

Feed, refinery, plant campaign & unit scheduling (runs in typical 4 day campaigns), maintenance scheduling and plant availability matching

Final capacity allocation and operations sequencing of production orders. (what volume to produce, where and when, on what plants and unit)

Process yield optimization planning

Warehouse and tank farm transfers and replenishment

Operational schedules for work force (people)

Replenishment and reconciliation scheduling

Labour scheduling for manufacturing and warehouse operations

(e) Upstream feed supply segment:

Inventory and facilities:	**Transportation:**
Stock replenishment schedules. Tank farm and warehouse operations schedules. Product certification scheduling. Labour schedules.	Truck, train arrival and shipment receiving schedules. Pipeline schedules (crude and components).

(f) Sourcing (material and services):

Supplier and service provider firm commitments

Feed, fuel component process material supply scheduling

Procurement and supply scheduling of short lead time materials.

Order and delivery scheduling of material and products.

Operational schedules for receipts (inbound)

The **inter-supply chain decisions** typically deal with synergies and interdependencies between supply chains within an enterprise and closely relate to the overarching corporate and business decisions. These supply chain decisions can also extend to interdependencies and synergies between related enterprises within the same or various industry sectors. These decisions also relate to those derived during the empirical research of this dissertation (refer to Paragraph 5.6.1) The focus is on long-term decisions that will have a long-lasting effect on all parties involved (typical issues include strategic objectives, investment, policies, directives, guidelines, etc). The typically timeframe is 3 to 10 years in advance. Table 6.4 and Table 6.5 is a consolidated version of these decisions and grouped according the following decision areas:

- Macro logistics network
- Upstream feed supply clusters
- Downstream product supply clusters

Table 6.4 : Long term supply chain decisions within an enterprise
(Inter-supply chain decision areas across BUs for multiple supply chains)

Macro logistics network
Investment decisions, budgets and yearly volumes.
Macro logistics network (economies of scale on facilities and corridors - leads to lower unit costs, greater efficiencies and commercial benefits).
Infrastructure (sharing of the same facilities, corridors).
Integration of new added ventures into enterprise's aggregate logistics network.
Future market aspirations for different business units; aggregate consensus view of on future volumes and geographical spread of product family streams.
Supply chain due diligence evaluation of possible joint ventures, mergers or acquisitions (sound understanding of both businesses' supply chains).
Analyse new and existing business units' supply chain strategic plans for interdependencies & synergies (to co-operate with other divisions and business units) for group benefit and risk implications.
Cross enterprise transportation synergies (corridors of movement).
Shared infrastructure; capacity interdependencies or synergistic opportunities to consolidate.
Commercial synergies - shared service providers.
Upstream feed supply clusters
Inventory interdependent (feedstock).
Determine interdependent feed clusters.
Aggregate feed supply priorities if in short supply (profitability staircase of units and volumes).
Governance on contract feed supply for group interest.
Long term feed supply sources and agreements (internal and external).
Wedge optimization; optimize enterprise economics of upstream feed and stream allocation, and downstream derivatives across chemical businesses.
Directives on competition for the scarce molecules.
Group optimization management (profit management and providing group directives and required policies).

Downstream product supply clusters

Inventory interdependent (products).

Determine interdependent product supply clusters (e.g. regions, shared customers).

Aggregate product supply priorities if in short supply (margin and volumes staircase of regions).

Governance on contract product sales for group interest.

Business cluster optimization management (profit management and providing group directives and required policies).

Group margin optimization and allocation of downstream products and across businesses domains.

Directives on competition for the scarce products.

Table 6.5 : Long term supply chain decisions between enterprises in industry
(Inter-supply chain decision areas for multiple supply chains)

Macro logistics network

Structural Synergistic opportunities to share logistics network and infrastructure; corridors of movement and facilities.

Joint capital investment in infrastructure.

Co-shipment agreements on shared corridors.

Upstream economies of scale in shipping opportunities (e.g. joint chattering of VLCCs).

Unite in shared cross enterprise/industry efforts (e.g. cargo owners forums).

Long term cooperation with government.

Upstream feed supply clusters

Long term feed supply sources and agreements.

Possible exchange agreements of like and unlike products with trading partners.

Cooperation between liquid fuels and gas companies in terms of supply agreements.

Possible sharing of inventory in the "supply pipeline".

Possible sharing of depot facilities.

Downstream product supply clusters

Possible exchange agreements of like and unlike products with trading partners.

Possible sharing of inventory in the "supply pipeline".

Possible sharing of depot facilities (hospitality arrangements).

Medium- and short-term inter-supply chain decision will fall within the expanded scope of individual supply chain decision where the different segments will co-operate with each other.

6.7 Supply chain planning processes

Supply chain planning processes exist to support supply chain decision making. As indicated in Paragraph 6.6, different supply chain decisions are taken in the long- (strategic), medium- (tactical) and short- (operational) term time frames. Much has been written on supply chain planning processes for individual supply chains–viewed as intra-supply chain planning processes in this dissertation. However, the area not properly covered in literature, is the inter-supply chain planning processes. The latter aim to support decision making related to interdependent supply chains or related segments across multiple supply chains where potential synergies exist.

Figure 6.7 indicate the extended scope of intra- and inter-supply chain planning processes across the strategic, tactical and operational decision levels found in the petrochemical industry. An indication is also given of what functional areas are covered (bottom of Figure 6.7) by each of the planning processes. In the paragraphs following, each of these processes is described and their interrelationship with one another is indicated (starting with the long term planning processes for individual supply chains). Since most of the supply chain planning processes for the intra-supply chain domain have to a large extent been properly covered in the literature study, only a brief description of each will be made. The supply chain planning processes for the inter-supply chain domain will thus receive more attention and be described in more detail.

6.7.1 Strategic operations planning (intra-supply chain)

Strategic supply chain operations planning focuses on long-term decisions for a specific business unit's supply chain (refer to Paragraphs 1.1.3 & 2.2.2.1). An number of strategic supply chain operations planning processes are typically applied and require contributions from all the supply chain partners involved (internal & external to company). Paragraphs (a) to (e) under 6.7.1.1 describe these strategic planning processes and include:

- Supply chain scenario evaluation
- Concept supply chain network design and configuration
- Detail supply chain operational and functional design
- Alliance and trading partner strategic planning
- Supply chain implementation and commissioning

Although these strategic planning processes apply to the design of new supply chains, they can also be used for the re-design of existing supply chains. The major differences between the design of new and re-design of existing supply chains, relate to the reduced number of choices and options available. Figure 6.8 indicates how the design and re-design cycles interrelate, as well as the major process stages of assessment, design, implementation and operation in this cycle.

A number of supply chain **enabling planning processes** also exist. The focus of these processes is to assure that the operations planning and transactional processes can be carried out effectively in future. These include (described in paragraph 6.7.1.2):

- Strategy formulation
- Business process design & configuration (for planning and transactional processes)
- Organizational design with anchor positions
- Monitoring & control methods design (based on performance metric targets)
- Information technology enablement design

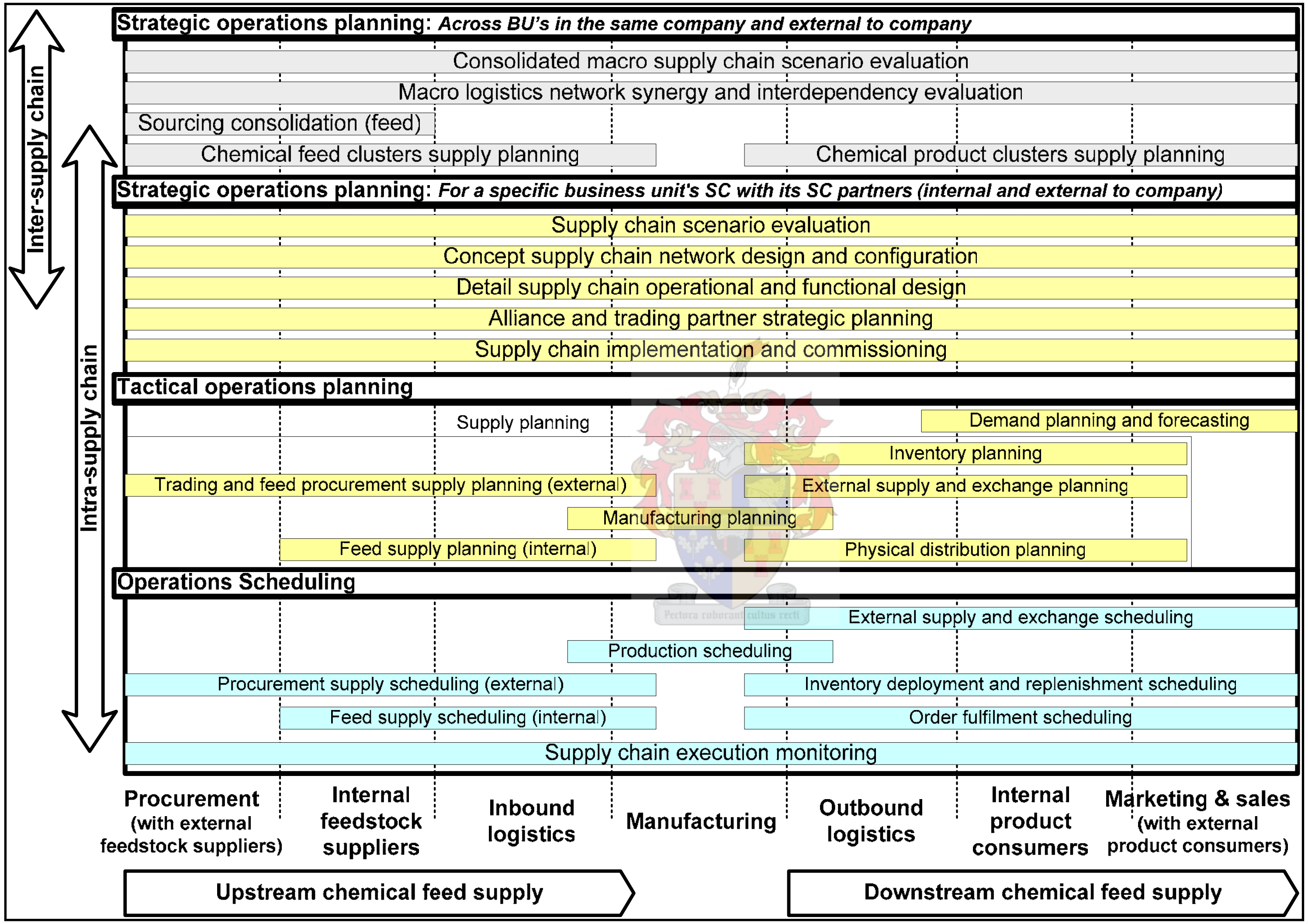


Figure 6.7 : Intra- and inter-supply chain planning processes

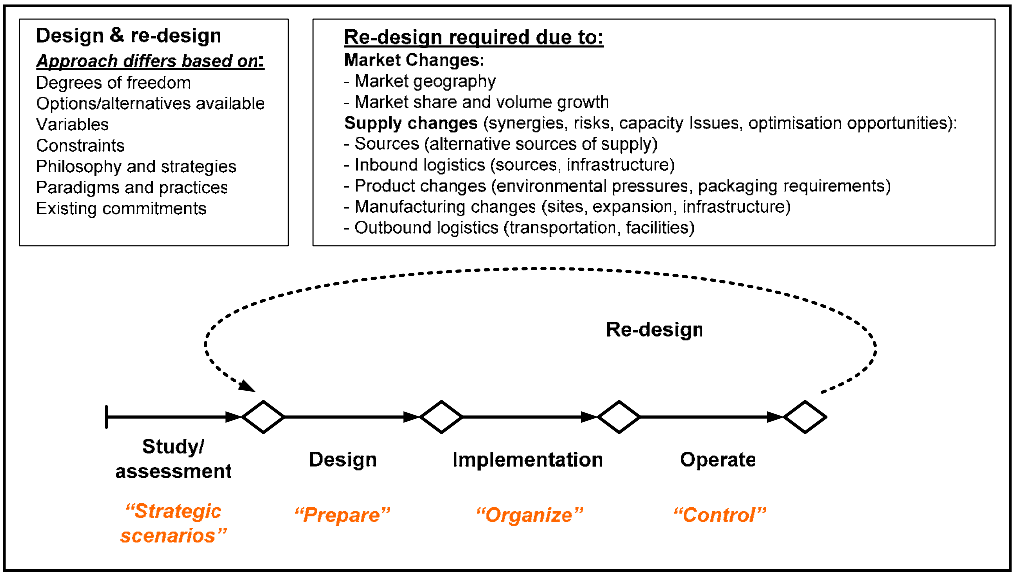


Figure 6.8 : Stage gate process of supply chain design (associated with a project's life cycles) – *also indicating the design and re-design cycle*

6.7.1.1 Strategic supply chain operations planning

a) Supply chain scenario evaluation

For the various business scenarios being considered, viable high level supply chain alternatives are developed and proposed. Scenario evaluation intend to assist senior managers in evaluating defined scenarios of their firm's long-term future. The goal of scenario planning is to organize and demystify the broad, collective and qualitative views of the future.

A basic business orientation and supply chain alternative form the basis for identifying viable strategic options. The focus is on macro supply chain network alternatives (inbound and outbound) and basic supply chain element configuration for the different market scenarios, manufacturing site options and sourcing alternatives being considered. The major issues are infrastructure availability, overall capacity levels and very rough order of magnitude cost estimates. These factors are used for trade-off analysis between supply chain alternatives (competitive, service, profit margins and feasibility factors). The early identification of potential supply chain operational risks/impacts is also carried out. These risks relate to: infrastructure availability, capacity, reliability, flexibility, variability, and material/product hazardousness.

b) Concept supply chain network design and supply chain element configuration

From a reduced number of supply chain alternatives that can support the intended business (resulting from supply chain scenario evaluation), the most viable and feasible supply chain structure(s) and configuration(s) are selected and designed to incorporate appropriate operational practices. A supply chain conceptual design (conceptual proposal) is developed. The major constituent parts derived from the design include:

- Supply chain structure and supply chain element configuration concept proposal
- Strategic relationships required, sourcing strategy and short-listed suppliers
- High level supply chain business processes categories required
- High level information technology architecture proposed
- Supply chain management components required

c) Detail supply chain operational and functional design

Based upon the supply chain conceptual design, the supply chain's functional/operational design must be established. By collaborating with key supply chain stakeholders, the functional/operational design requirements can be finalized. This design base sets the operational philosophy and constraints for supply chain planning and operations decisions in future. The following key actions should also be performed:

- The Final SC design and operational plan should be tested for operability with a dynamic simulation model (How will the design operate in the real world with all its variability? This will test the dynamic effect on reliability, flexibility, and related performance measures).
- The drafting of the expected supply chain performance measures and targets.
- Draft and refine scope for commercial and operational agreements with suppliers.

d) Alliance and trading partner strategic planning

Since many operational activities in a supply chain are outsourced, careful consideration must be given to alliance and trading partner selection. This strategic planning process runs parallel to the supply chain network design, configuration and implementation processes, and provide the required input for the scope required for commercial and operational agreements with suppliers.

The supply chain structure alternatives provide an early indication of what supply chain partner groups would be applicable and play a specific role in future. These partners groups relate to:

- Upstream [feedstock, process materials, 3rd party utilities (water, power) logistics services]
- Downstream [other toll manufacturers, logistics services, product consumers]
- Alternative sources of product [toll manufactures, product exchange partners]
- Internal [receiving, storage, packaging, material handling, dispatch, waste and recovery streams]

From the strategic relationships required, a sourcing strategy is developed. The sourcing strategy relates to cross-functional, cross-divisional, cross regional or global collaborative sourcing options as well as the strategic importance and number of suppliers available. Supplier selection criteria also play a vital role in choosing future business partners. A first-order supplier base (local and abroad) is developed through screening for availability of feedstock, process materials, and logistics services. The integration, cooperation requirements and strategic fit of suppliers also need to be assured.

From the finalized sourcing strategy and the first order supplier base, a short list of suppliers is established. With the potential strategic relationships defined, the sourcing and negotiation processes are initiated (draft agreements, request for proposals/quotations, and clarification of provisional terms and conditions)

Agreements and contracts with selected suppliers and 3rd party logistics service providers are finalized and implemented. These include commercial, operations and service level agreements.

e) Supply chain implementation and commissioning

The operational implementation of a supply chain design forms a major part of a new business's establishment. The infrastructure for the agreed upon supply chain design needs to be established. This will focus on detail equipment design, establishment of operating procedures and preparation of the related inbound and outbound operations for commissioning. Expectations, from both the company and the 3rd party suppliers' side, need to be clarified to finalize the required agreements (for both the inbound and outbound segments of the supply chain).

The supply chain operations will deal with the required upstream and downstream supply activities (sourcing, transportation, storage, handling, packaging) of feed material, intermediate and final refined products for customers. The focus is on commissioning and start-up of infrastructure and equipment for the operations in a supply chain.

6.7.1.2 Strategic supply chain enablement planning

a) Supply chain strategy formulation

One of the key long-term supply chain decisions revolve around formulating a supply chain strategy. The corporate and individual business's strategy need to be translated into an appropriate supply chain strategy. The strategy formulation process establishes a holistic long-term plan that a business unit's supply chain manager will typically follow to reach the strategic objectives derived. Some of the strategic components are directly related to the operations while others relate to enabling components. A framework for the Development and Implementation of a supply chain strategy include the following:

Development

- Understanding of business context (environment, forces, strategy, business drivers and imperatives).
- Derive major supply chain drivers.
- Establish a clear supply chain vision, purpose and intent.
- Conducting a swot analysis (strengths, weaknesses, opportunities and threats).
- Identify major supply chain focus areas and perspectives.
- Develop strategic objectives and targets and hierarchy of key measures.

Implementation

- Develop a portfolio of programs per focus areas and perspectives.
- Define initiatives per program and macro timeframe.
- Define action plans per initiative.
- Define strategic actions, key activities, priorities, deliverables and milestones.
- Assign roles, responsibilities and budgets.
- Compile a strategy map (initiatives spread across perspective and time horizon).
- Do proper change management:

  (Stakeholder management and communication maintain clear vision, communication, pressure for change, skills, incentives, resources and execution of action plans)
- Project management of action plans, measure and report on progress.
- Celebrate success.

Using the above framework for the development of a SC strategy for each business unit's supply chains, the **SC strategy** should be documented to incorporate the following components:

- Supply chain operation strategy (design and operations model).
- Supply chain inventory strategy.
- Supply chain contingency strategy.
- Supply chain commercial and partner strategy.
- Supply chain organizational strategy.
- Supply chain people strategy.
- Supply chain planning, collaboration & communication strategy.
- Supply chain monitoring and control strategy (based on performance targets).
- Supply chain information technology strategy.

b) Supply chain business process design and configuration (for planning and transactional processes)

The supply chain complexity, span and scope provide an indication on a high level of supply chain business process type and categories required (related to the SCOR process model). Based on these business process categories, a concept proposal for the supply chain planning (demand and supply planning) and operational execution processes can be developed. These processes will focus on the tactical and operational levels of the supply chain.

This concept proposal forms the basis for the work related to supply chain business process design, functional design, and configuration of enabling systems. For the supply chain planning processes, the application of specific OR/MS techniques are also indicated. The first releases of these business process and sub-processes are then implemented, fine-tuned and monitored to assure that they are running according to the design intent.

Subsequent releases and implementation of planning business process and sub-processes will assure the required refinement and improvement in process effectiveness and efficiency.

c) Supply chain organizational design with anchor positions

From the initial supply chain conceptual design, a first order indication can be provided of the organizational requirements. This relates to some of the key functions required and provides a first indications of anchor positions to fill in future. Apart from a draft organizational structure and anchor positions the required management methods must also be developed. The key competencies for anchor positions must also be derived. As part of an implementation plan, a resource rollout plan for the proposed staff establishment must be developed. After implementation, the effectiveness of the organizational practices are evaluated and related to the original design intent. Benchmarking and a continuous improvement cycle will assure an appropriate and fine-tuned organization.

d) Supply chain monitoring and control methods design (based on performance metric targets)

The first order supply chain process definition provides the basis for which first order performance measures are applicable and which realistic targets can be used. With the formalization of the required supply chain planning processes the required performance measures can be standardized and implemented. Regular review of results will indicate how well the supply chain processes are performing. Utilizing the correct performance measures can also provide the capability for benchmarking with relevant supply chains internal and external to an enterprise. This can indicate areas for improvement and potential root causes for problems that exist.

e) Supply chain IT enablement design

The high level indication of supply chain business process categories provide the basis for which high level enabling systems would be required in future. As the supply chain business processes become clearer, high level supply chain information technology architecture can be proposed. Supply chain planning and execution systems typically require analytical and transactional IT systems respectively. The design, configuration and implementation of the supply chain process enabling systems follow during supply chain implementation and commissioning.

After implementation, the first releases of these enabling systems are fine-tuned and monitored to assure that they are running according to the design intent.

Subsequent releases and implementation of enabling systems will assure the required refinement and improvement in system effectiveness and efficiency.

6.7.2 Tactical operations planning (intra-supply chain)

Tactical operations planning focuses on the medium term decisions for a specific business unit's supply chain (refer to Paragraph 2.2.2.2). The two major overarching operations planning processes are demand planning and supply planning. Demand planning normally initiates the tactical operations planning processes and provides an unconstrained, consensus demand plan. Given the constraints of the available supply resources, the supply planning process then facilitate the evaluation of how best the demand plan can be executed. Through proper collaboration, by following an iterative approach and evaluating a number of “what-if” considerations, these two overarching processes interact with one another and eventually establish an agreed demand plan with feasible and profitable operational supply plans (upstream, production and downstream). This iterative process also relates to the popular Sales and Operations Planning (S&OP) approach followed in many businesses. The following paragraphs describe the demand planning and supply planning processes. The supply planning process is broken down further into a number of sub-planning processes namely:

- Inventory planning
- External supply and exchange planning
- Physical distribution planning
- Manufacturing planning
- Feed supply planning (internal)
- Trading and feed procurement supply planning (external)

6.7.2.1 Demand planning

The demand planning process consolidates the anticipated/committed demand for a given supply chain's product(s). The demand information can then be viewed from specific aggregate demand views, time horizons and time intervals. A number of hierarchies/dimensions typically exist and are used to aggregate and disaggregate demand information, and are also used as the basis for forecasting. These dimensions include (also relate to Figure 2.28):

Demand side views

- Market geographics (e.g. countries, states)
- Customers (e.g. customer categories, target customers, customer locations)
- Sales organization (e.g. regions, districts, territories)
- Sales channels (e.g. mass merchandisers, wholesalers)

Supply side views

- Product/Manufacturing (e.g. product family, major product line, division product line)
- Logistics (locations/originating facilities, corridors of movement)
- Company organization (e.g. company, business unit, sub-unit)
- Planning horizon/time period (e.g. years, quarters, months)

A typical demand planning process includes some of the following ingredients:

- One of the keys to excellence in demand forecasting is collaboration
- Use of a cross-functional, consensus-based process
- Generation of baseline forecast
- Translation to common terms
- Reviewing forecasts from various perspectives
- Events and overrides (management intervention)
- Consensus meetings

6.7.2.2 Supply planning

Supply planning determines the optimal supply plan to meet the anticipated demand. One of its outputs include a constrained master schedule for the manufacturing plants. It also produces a distribution requirements plan and first-order material requirement plan. Supply planning aim to synchronize the flow of materials along the entire supply chain. It also aims for the effective utilization of production, transportation, supply capacities, and inventory buffers in the evaluation process of balancing supply and demand. Supply plans are time-dependent and use a "time buckets" concept (supply planning is typically done monthly or weekly). Supply plans may consider aggregate views of multistage production processes by incorporating partial levels of a manufacturing plant's routings and a product's bill-of-materials (BOM). This planning is typically done by using aggregated product groups over longer periods of time (quarters or months). The setup and changeover times may also be considered, but not the sequencing of orders through a manufacturing facility (done on short-term planning level). The supply planning process intend to develop sourcing, production, deployment, and distribution plans (flow of goods), taking into account the supply chain network configuration already in place with supply entities such as suppliers, plants, distribution centres, and transportation lanes. The ***sub-planning processes of supply planning*** are (with some major activities/issues listed):

a) Inventory planning

Inventory planning is closely linked with upstream sourcing and supply planning, distribution planning and downstream supply planning. It is normally the first planning activity after demand and production planning to screen all current stock levels and indicate where material and product inventory would be needed. Key issues to consider include:

- Consider all stock levels in network
- Safety stock considerations
- Deployment and fill rate planning
- Service level considerations

b) External supply and exchange planning (for products)

Where product exchange or toll manufacturing agreements exist, the external supply and exchange planning process (for products) will establish the amount of product that could be supplied from agreed external sourcing locations.

An agreed external supply and exchange plan is drafted after all the necessary iterations and balancing has been completed.

c) Physical distribution planning

Distribution planning sets minimum safety stock levels for each stock keeping unit (SKU) at each warehouse location and determines the replenishment frequency. Based on available inventory, distribution planning develops a schedule of planned shipments with priorities for different demand types/service segments.

Based on the anticipated demand, geographical location of supply nodes and available inventory, a rough-cut inventory deployment plan and stock transfer plan is created (taking lead time into account) to determine if any constraints pose capacity problems. First-order resource levelling is done to stay within capacity constraints along a supply chain's physical distribution resources. Transportation resources required are determined and the focus is on the selection of transportation modes, carriers, freight consolidation, routing and scheduling, and the management of private fleets and/or rate negotiation with public carriers. Key issues to consider include:

- Stock deployment planning
- Stock transfer planning (relate to Distribution Requirements Planning [DRP])
- Demand fulfilment planning (firm customer orders)
- Transportation planning
- Variability in supply and demand

d) Manufacturing Planning

From the master schedule (output from supply planning) and inventory plan, a detailed production plan is created by simultaneously planning materials and plant resources. Capacity limitations and potential overcapacity situations that might occur are assessed. Resource levelling is performed where possible. Feedback is given on which demand requirements cannot be met. Key issues to consider include:

- Establish/optimize production programmes (e.g. product wheel, yield considerations)
- Maintenance considerations
- Available & committed capacity
- Review inventory build-up status
- Review manpower loading

e) Feed supply planning (internal)

From the master schedule (output from supply planning) and provisional production plan, an upstream supply plan (from internal sources to the enterprise) is developed and evaluated for feasibility. Key issues to consider include:

- Feedstock supply requirements
- BOM and MRP
- Secure availability of critical material
- Review supply plan changes

f) Trading and feed procurement supply planning (external)

From the master schedule (output from supply planning) and provisional production plan, create a sourcing plan (from external suppliers), and evaluate for feasibility. Key issues to consider include:

- Feedstock purchase requirements
- BOM and MRP
- Secure availability of critical material
- Review supply plan changes

6.7.3 Operations scheduling (intra-supply chain)

Supply chain operations scheduling processes focus on short-term operational coordination, synchronization and control (refer to Paragraph 2.2.2.3). The daily and weekly operations activities must carry out the resource allocation and utilization decisions made at the tactical level. Each of the supply chain operations scheduling processes are described in the following paragraphs and include:

- External supply and exchange scheduling (product)
- Production scheduling
- Inventory deployment & replenishment scheduling
- Order fulfilment scheduling
- Feed supply scheduling (internal)
- Procurement supply scheduling (external)
- Supply chain execution monitoring

These processes typically look 1-4 week ahead in hourly, daily and weekly time buckets.

6.7.3.1 External supply and exchange scheduling (product)

Based on the agreed external supply and exchange plan, product supply from the alternative sources is scheduled for delivery to specific customers. This delivery schedule relates to an allocated transporters' selected routes and delivery windows for specific orders.

6.7.3.2 Inventory deployment and replenishment scheduling

Based on the inventory and deployment plan (medium term planning), finished goods inventory replenishment schedules are derived and used for transport scheduling. Replenishment is typically related to stock transfers to warehouses and depots closer to the end consumers, or where Vendor Managed Inventory (VMI) and consignment stock are used. Key issues include:

- Inventory deployment and replenishment scheduling
- Scheduling of transport for stock transfer requirements

Replenishment scheduling also includes short-term planning of transport activities. Optimized outbound and inbound material flow schedules aim to minimize transportation costs and/or maximize the utilization of private truck fleets. Consolidated shipments are evaluated for options of full truckloads, trainload, shiploads, routing and sequencing delivery/pick-up locations. Current carrier freight rates is often used in order to support lowest cost shipping calculations or using causal calculated rates combined with indices. Other key issues include:

- Transport capacities
- Mode and carrier selection
- Ship nomination
- Routing and transport schedule
- Load planning and management

- Shipment rating
- Fleet maintenance considerations

6.7.3.3 Production scheduling

The optimal sequencing (schedule) and routing of production orders are determined based on detailed product attributes, changeover requirements, customer order due dates, work centre capability, labour required, and other constraints. Key issues include:

- Process sequencing
- Production run lengths
- Shift Scheduling (people)
- Establishing work assignments

6.7.3.4 Order fulfilment scheduling

This scheduling process determines when actual customer demand/orders will be fulfilled (promised order fulfilment date). Fulfilment of customer orders typically come from committed stock or ATP stock (customer queries are also evaluated based on future availability of stock/production schedules). Key issues include:

- Organizing shipments of finished goods
- Scheduling of actual customer orders with delivery plans

Based on production schedule and inventory, allocation of products are made to regions, customers segments or prioritised orders. Key issues include:

- Screen orders received from sales
- Prioritise according to market segment
- Allocate inventory to prioritise order
- Backlog shortfalls

6.7.3.5 Feed supply scheduling (internal)

Related to the feed supply plan, actual rail/road delivery and pipeline schedules are created. The feed supply scheduling is typically based on the production plan and bill of material (BOM). MRP techniques are used to allow for lead time. Key issues include:

- Consider BOM for each product and inventory on hand
- Offset order planned replenishment with lead time
- Organizing and scheduling/sequencing of raw materials supply (e.g. road deliveries, pipeline schedule)

6.7.3.6 Procurement supply scheduling (external)

Related to the sourcing plan, actual rail/road delivery and pipeline schedules are firmed up with suppliers. Procurement and supply scheduling is typically based on the production plan and bill of material (BOM). MRP techniques are used to allow for lead time. Key issues include:

- Consider BOM for each product and inventory on hand
- Offset order planned replenishment with lead time
- Organising and scheduling of raw materials supply (e.g. road deliveries, pipeline schedule)

6.7.3.7 Supply chain execution monitoring

As the operation schedules are being executed, monitoring is done to assure schedule achievement and provide demand fulfilment visibility. It supports the control processes for managing activities and events within and between companies along the supply chain. The event management sub-processes include: monitor, notify (advance notice of early/late deliveries), control and measuring supply chain activities. Key issues include:

- Manage integrated supply chain inventory (relate to supply chain inventory plan)
- Monitor inventory replenishment according to plan
- Regularly review stock policy

6.7.4 Strategic operations planning (inter-supply chain)

The concept of extended supply chain integration (Paragraph 6.4) and the related long-term, inter-supply chain decisions (Table 6.4) require the use of appropriate advanced supply chain planning processes. These planning processes would assure a systematic evaluation of all the consideration to be assessed. The scope of these processes reach across the supply chains of individual business units (or relates to elements thereof) in the same company and/or related external companies. The three dimensions to be covered by these planning processes are:

- Upstream chemical interdependencies/synergies (upstream in chemical value chain)
- Downstream product interdependencies/synergies (downstream in chemical value chain)
- Macro logistics network interdependencies/synergies (within and across enterprises related logistics networks for liquid bulk, dry bulk, packaged goods and gasses)

The inter-supply chain planning processes that transpired though the literature study and empirical research include the following and will be discussed in the following paragraphs :

- Consolidated macro supply chain scenario evaluation
- Macro logistics network synergy and interdependency evaluation
- Sourcing consolidation (feedstock)

- Chemical feed clusters supply planning
- Chemical product clusters supply planning

6.7.4.1 Consolidated macro supply chain scenario evaluation

The effect of large, company-wide business scenarios also require proper evaluation from a supply chain perspective. These evaluations typically need to highlight potential synergies, opportunities, effect of interdependencies and potential risks that may arise. Some of the large, company-wide business scenarios include the following:

- Company growth—investment planning:
  - o *New business.*
  - o *New manufacturing technology.*
  - o *New product introduction.*
- Mergers.
- Acquisitions.
- JV evaluations (due diligence assessments)

These evaluations serve the purpose of either formulating corporate strategies, or supporting high impact decisions. The appropriate information and supply chain alternatives that can support a given scenario must be supplied. Any potential supply risks that could adversely impact such a scenario must also be highlighted.

6.7.4.2 Macro logistics network synergy and interdependency evaluation

Integrated logistics network planning between the major industry players within the same company and/or related external companies could lead to the cost effective establishment and sharing of common logistics infrastructure (e.g. transportation corridors, terminals). The logistics synergies and interdependencies that exist could thus be used for mutual benefit. Closer collaboration and gradual sharing of increasing relevant supply information would reveal the potential synergies and interdependencies for specific logistics networks types. The related logistics networks types (basis for logistics value clusters) depend on the handling and packaging characteristics of the product (related to liquid bulk, dry bulk, packaged goods and gases).

A proper assessment of the geographical spread of the related logistics networks per type covered by each industry player forms the basis for this evaluation. The facilities and transportation corridors used for product movement should be made visible. Volumes transported, facility activities (e.g. storage, packaging) and supply chain partners involved provide some of the basic information required. An aggregate view and analysis would indicate potential synergies and interdependencies for specific logistics networks types between the different focal companies involved.

Synergistic opportunities between the related players across the types of logistics networks can be leveraged for mutual benefit. Interdependencies can be indicated for facility and transportation infrastructure along specific corridors. With a long-term perspective, the parties involved could then evaluate the effect of future growth prospects and potential bottlenecks that currently exist or will develop in future. They can then jointly influence the optimal investment in infrastructure upgrading or expansion (related to facilities or transport routes).

Commercial synergies can also be derived through consolidation processes (strategic sourcing practices). Logistics service providers that serve a number of business units within a corporation, can be leveraged for economies of scale and commercial synergy. A similar strategic sourcing process can be followed for the logistics service providers as described in paragraph 6.7.4.3 for feedstock.

Risk assessment also forms part of macro logistics network evaluation. The aggregate risk impact on the environment and societies along associated corridors and within facilities should be assessed given applicable tolerances. Typical assessment and mitigation process steps include: identification; analysis and evaluating; reconfiguration and preventative measures; establishing a contingency plan; and communicating to all parties involved.

6.7.4.3 Sourcing consolidation (feedstock)

Feedstock, chemical commodities and process material shared by multiple business units within the same company and/or related external companies could provide synergic opportunities. This can be achieved through a consolidation process (strategic sourcing practices). The aim is to reduce Total Cost of Ownership (TCO) of materials. The strategic sourcing process typically comprises:

- Spending analysis
- Supply strategy (determine supplier base)
- Request for information/quotation and negotiation
- Contract awarding
- Supplier monitoring and improvement

A sound understanding of the industry’s structure for a specific feedstock form the vital first step in deriving a consolidated sourcing strategy. The total demand for a specific feedstock and the alternative sources of supply in a specific domain should be assessed. Different sourcing strategies are followed for monopolistic vs. perfect competition industrial structures. The conduct and performance of the different feedstock suppliers also form a critical part of the assessment.

Understanding the components that make up a supplier's cost structure form an important basis for informed contract negotiations and future price adjustments. The cost drivers of these components can then be linked to the correct indices. This provides the capability to be pro-active in anticipating and preparing for future price changes.

A sound understanding of the typical feedstock price cycles is also critical in the petrochemical industry. Since feedstock comprises such a big component of the final manufactured product's price, sourcing strategies should be derived to mitigate any adverse effects as far as possible.

6.7.4.4 Chemical feed clusters supply planning

Chemical feed clusters supply planning takes an enterprise-wide perspective of the upstream segments of interrelated supply chains (supply chains that share common chemical feed steams). The upstream portion of the macro chemical value chain typically consists of chemical feed steams that need to be allocated to downstream associated business units' supply chains for further transformation into higher valued chemical products. These chemical streams within or between manufacturing facilities could have multiple possible internal and external destinations.

If there are adequate upstream feed available to satisfy all the downstream requirements, the chemical feed streams are not in a constraining condition. However, when the downstream demand for chemical feed exceeds the available supply, sound trade-off analysis is required to assure enterprise-wide optimal decisions across the related supply chains. This analysis also aims to balance push and pull situations that exist (co-products and dominant value chain driven products). Although there is a strong drive to maintain business unit autonomy (i.e. business units responsible for their own profit and loss) within large petrochemical company businesses, this is subject to company-wide optimization and should not be compromised. A number of factors should be considered to assure informed decision making and typically include:

Downstream business units' requirements

- Marketing and sales aspirations (e.g. volumes, market penetration plans)
- Alternative value of downstream chemical products
- Cascading margin staircase of different market segments per chemical product
- Contractual obligations to specific consumers

Supply constraints

Production unit capacity limits

Maintenance requirements

Supply logistics constraints

Feed availability

Other considerations

Corporate imperatives

Economic assumption

Production costs (fixed and variable)

Products demand variability (seasonality, cycles, randomness)

Supply variability (feedstock, plant availability, transportation)

The feed clusters supply planning process aims to support the allocation decisions in the long- and medium-term. The long-term (1 to 10 year horizon) corporate imperatives provide valuable guidelines for establishing strategic supply priorities for constraining chemical feed streams across the upstream segments of the related, interdependent supply chains. The required directives are also developed as guidelines for allocation decisions. Proper conflict resolution mechanisms should exist regarding stream allocation. Conflict can arise should a specific supply chain receive less feedstock than what is required to achieve its objectives (e.g. profit target).

An optimized macro supply plan is typically represented as a molecule mass balance across all the transformation processes for all the chemical feed streams, intermediate commodity chemicals and downstream chemical products. This molecule mass balance forms the basis for the associated business units to draft their annual sales budgets and resulting supply plans.

As a typical year progresses (medium term horizon), quarterly reviews are required to track any changes in the assumptions made during long term feed clusters supply planning process. This tracking also identifies and highlights critical dependencies and risks. Typical changes include: pricing trends; unexpected operating conditions; unforeseen feed restrictions; and new spot sales opportunities. New feed supply directives should then be issued based on these changing conditions.

6.7.4.5 Chemical product clusters supply planning

Specific situations may exist where related downstream chemical products are exchanged between supply chains. Product exchanges or swap processes (like and unlike swaps) can exist within a large enterprise between business units or external to the enterprise. Mutual benefit is derived by both participating entities in that their markets are served from alternate supply points at reduced logistics costs (normally covering a shorter distance from alternative sourcing point to delivery point).

In cases where more that one business unit produces the same product within a large enterprise, the optimization of global inventories can be achieved through cooperation with regional supply chain functions in order to balance working capital vs. product availability. Allocation planning of the product to the various sales regions should thus be done on a collaborative basis to assure individual as well as collective optimal and feasible supply plans. Inter-business unit forecasting processes are typically used within these product supply clusters.

A specific customer might also be served by a number of business units from the same enterprise with various products. These then typically become mutually shared strategic customers. Synergistic opportunities could exist between these different supply chains (e.g. corridors of movement, adjacent geographical facilities, same destination points). Since the customer views the business as "with the holding company" rather than with each separate business unit, caution should be taken not to follow practices within one business unit's supply chain that could adversely effect the other. The focal company's image and interest should remain the shared objective. Close cross-functional (marketing, logistics, production) and cross-business unit cooperation is thus vital to maintain sound long lasting business relationships with these shared strategic customers.

6.8 Supply chain planning process enablers

A number of key enablers are required to assure that supply chain planning processes operate properly. These enablers are categorized as follows, and are explained in the next paragraphs:

- People, roles and organization
- Applicable practices
- OR/MS techniques
- Decision Support Systems (DSS)
- Information management and enterprise information architecture

6.8.1 People, roles and organization

Supply chain planning processes can only function as well as the involved people's efforts will allow. Competent and capable personnel are required in the correct positions within a streamlined organization that is structured around the applicable supply chain planning processes. Roles and responsibilities should be clarified between the different supply chain planning functionaries within business units, along a supply chain (intra-supply chain) and macro, enterprise-wide (inter-supply chain). Intra-supply chain planning processes would normally be housed within a business unit structure, while intra-supply chain planning processes would typically be covered by shared service of corporate structures within an enterprise. With planning processes properly documented, they indicate the interrelationships internal and external to focal companies. These planning processes also play a vital role in clarifying roles and responsibilities and indicate the cooperation required. The competencies for people working in supply chain planning were properly articulated as part of the empirical research and indicate the critical skills, attributes and knowledge required (refer to Table 5.9). When sophisticated and advanced planning technologies are employed, it further elevates the required capability of supply chain planners and schedulers.

Leaders responsible for planning groups also need specific competencies. Planning leaders should have a vision that extends beyond the functional silos in an enterprise. They must also be able to deal with the complexity associated with a supply chain-wide viewpoint. The mastering of recruitment, management and development of supply chain planners will become crucial to future success. The establishment and management of correct performance standards, coupled with applicable reward structures, is an important ingredient in assuring a motivated and focused group. These leaders typically need to be of that rare breed; a non-hierarchical, facilitation-oriented manager. They also need sufficient authority to overcome functional boundaries, balanced with functional expertise in required places. Additional important skills and competencies for successful planning leaders include being a great communicator, driving and inspiring teams, being committed to delivering results, and most importantly, to stay customer-focused. The ability to forge strong relationships both internally and externally will support the drive to achieve more transparency.

6.8.2 Applicable Practices

The application of ***Sales and Operations Planning*** (S&OP) is an appropriate best practice for tactical supply chain planning (refer to Paragraph 2.2.2.2 b). It provides a vital link between business/supply chain strategy and the associated constraining operational realities. The more advanced chemical businesses are using S&OP to anticipate and profitably respond to demand. Business units take a variety of factors into account to develop plans that guide sales in lean times (excess capacity) and profitably allocate feedstock, capacity and products in boom times. Some important factors include: price/volume trade-offs based on market segments, customer and raw material supplier contract compliance, constraining operational realities and contingency plans.

Sound demand planning is increasingly becoming part of integrated supply chain planning solutions. This supports the supply chain drive of becoming ***demand/customer focused***. The typical best practices applied in demand planning are:

- Integrated demand forecasting, planning and execution
- Following a cross-functional forecasting process
- Using top-down, bottom-up and adjustment capability in consensus reaching
- Following signals from a pull-based demand planning approach
- Using fitting statistical techniques
- Appropriate performance monitoring and tracking

Advanced supply chain planning also requires multiple contact/interaction points between partners across the supply chain. Sound ***collaboration*** along these interaction points should happen internally between a business unit's relevant functions, and externally with the relevant functions of partners across the supply chain (refer to Paragraph 2.2.3.2). Collaboration should take place between the relevant people on strategic, planning and execution levels (relate to Figure 6.9). Joint strategy determination with partners can replace old attitudes and habits with trust, commitment and cooperation from the top. It is no longer sufficient to have only one point of contact between partners (e.g. only sales and procurement).

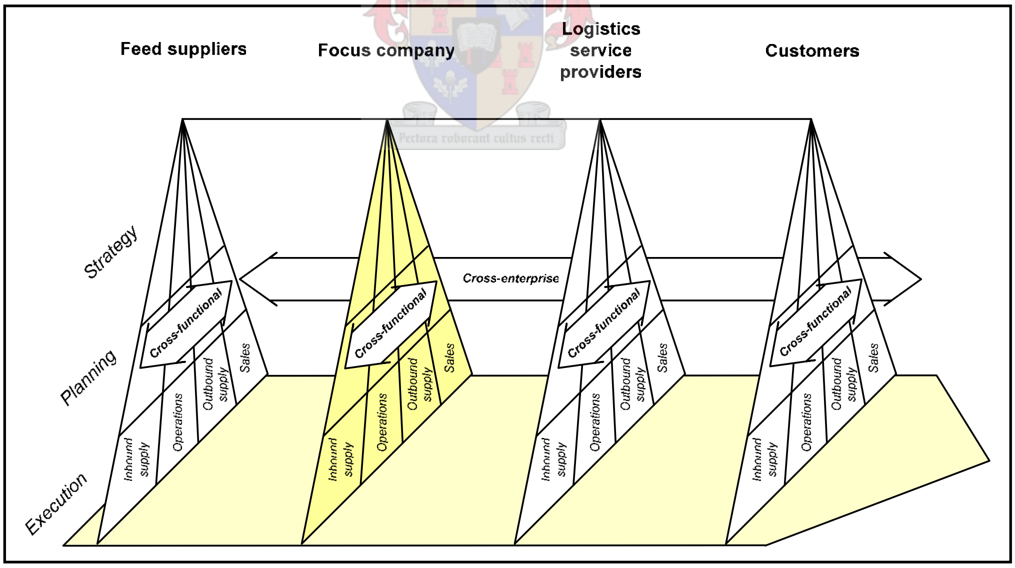


Figure 6.9 : Coordination and cooperation across functions and between supply chain partners

Utilizing optimization techniques for planning in the supply chain can either be done on a ***concurrent or a sequential planning*** basis. Figure 6.10 indicates the difference between these two practices. In cases where multiple supply chain decision domains exist, a sequential planning practice is typically followed. Information and decisions are moved in sequence from one planning domain to the next. This requires a number of iterations until a feasible, and as near as possible optimal, answer is reached. If the information required for decisions in each domain is not shared without delay and without distortion, reaching feasible solutions and aiming for global optimal answers become almost impossible. This highlights two problems from an optimization perspective:

- Each planning component's resource constraints are typically not considered, nor is there any attempt to optimize an objective.
- Separate optimization of each planning process rarely produces an optimized plan in the context of the whole supply chain.

Concurrent optimization is the ideal practice and requires that a single model–that includes all requirements, relevant constraints, parameters and optimizing objectives –is used to provide global and feasible answers to supply chain decisions at hand (refer to Paragraph 2.2.3.3 d). The demand, distribution, manufacturing, and procurement plans are thus jointly developed.

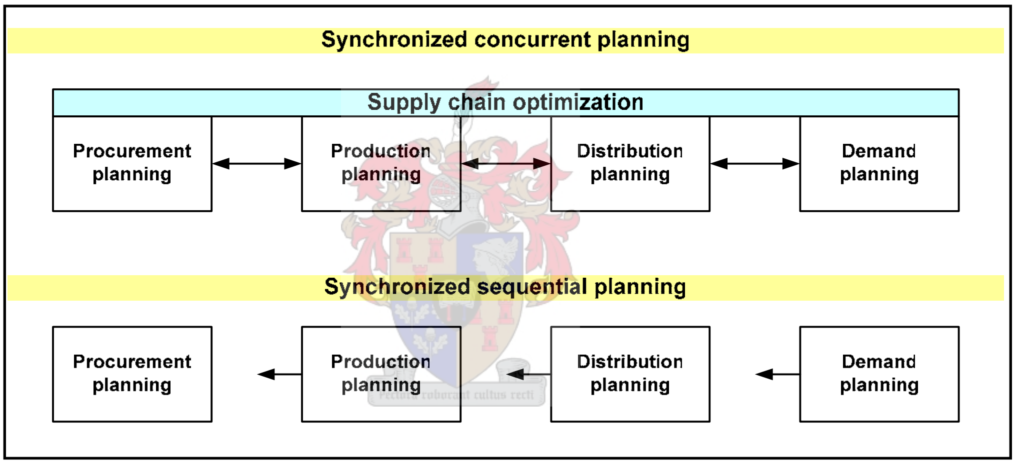


Figure 6.10 : Concurrent vs. sequential planning and optimization

Synchronizing the supply chain planning levels also relate to the ***hierarchical planning practice***. Strategic, tactical and operational planning provides input into one another through synchronization and integration mechanisms to assure that the supply chain is continually operating in a feasible and optimized fashion. In practice, where the supply chain planning levels are not synchronized, the optimal solutions generated at higher levels in a planning hierarchy provide the input and umbrella constraints for the optimization taking place at lower levels. Disjointed plans and data aggregation levels do not ensure that optimization is achieved. A number of approaches can be used to assure synchronization and consistent optimization across hierarchical planning levels. These include:

- The use of telescoping planning horizons
- The use of a common data structure for all planning levels
- The monitoring and control of the degree of synchronization

Telescoping planning horizons use "time buckets" that vary over time (relate to Figure 6.4):

- The first few weeks may be planned in continuous time, like minutes or hours.
- The next few months might be planned in weeks.
- The last periods of the planning horizon might be represented in months or quarters.

Data aggregation provide the means of making masses of data easier to handle. For the different time horizons, and review periods considered, the data's required level of detail differ (more aggregate date for strategic decisions: decision information; less aggregate for operations: more detailed information).

Performance measures regularly measured lead to supply chain improvements. A set of balanced (BSC) and carefully selected performance measures regularly measured will indicate/highlight supply chain areas for improvement. "What gets measured gets improved, or tied to action for improvement". Related to planning, a number of appropriate performance measures were positioned for supply chain planning during the empirical research of this dissertation. Distinction can be made between direct and indirect indicators that show how well planning is performing. These include (relate to Table 5.8):

Direct performance measures *(Measuring how good the planning is)*

- Planning accuracy
- Adherence to plan and Schedule achievement (adherence)
- Planning and re-planning cycle time
- Model accuracy
- Decision data accuracy

Indirect performance measures *(Measuring the effect of planning)*

- Inventory Levels and Value
- Total supply chain cost
- Throughput for whole supply chain
- Cash-to-cash cycle
- Capacity utilization
- Profitability
- Perfect orders
- Unallocated orders (from the planning systems)
- Actual takeoff vs. committed takeoff

6.8.3 OR/MS techniques and DSS for supply chain planning processes

Descriptive and Normative models are used to provide the appropriate analytical techniques (OR/MS) in support of supply chain planning processes. They are distinguished by (refer to Paragraph 2.3.2):

- **Descriptive models**: typically enable the required business intelligence (e.g. Forecasting models, Simulation models)
- **Normative models**: provide the Optimization capabilities (e.g. linear programming models)

Database systems, modelling tools and solvers (optimizers) form the basic building blocks for a Decision Support System (DSS). Together with the appropriate graphical user interface (GUI) and presentation mechanisms, end users can properly interact with a DSS. The database systems do not only provide the required decision information, but also the means to drive master data standardization, a viral requirement for data aggregation and descriptive analysis. Modelling tools and solvers utilize OR/MS techniques to provide optimization capabilities. Table 6.6 provides a summary of the typical OR/MS techniques and DSS that support the enablement of supply chain planning processes.

6.8.4 Information management and enterprise information architecture

Once a business's appropriate supply chain processes are defined, the related information technology can be selected and implemented. Systems hardly ever operate in isolation. An appropriate enterprise architecture for information technology, with the required interfaces for integration, provides the means to send meaningful information back and forth, and to do business. This also applies to the supply chain. Important integration issues for data are the data transfer formats/the presentation problem (ASCII, EDI, HTML, XML, etc.), the version and standard used (refer to Paragraph 3.1.5.1). A common understanding of the business processes between two functions or two companies is also a prerequisite in order to send meaningful information back and forth, and to do business.

The right enabling systems and technology can improve the efficiency of business processes. Information should be captured once, and as close to the source as possible. It should then be accessible to all relevant parties across applications. Enterprise architecture should reduce integration complexity and reduce cost to the greatest possible extent by standardizing on strategic technology solutions. Enterprise should also optimally leverage the information products at its disposal.

Table 6.6 : Supply chain planning processes with OR/MS techniques and DSS

Supply chain planning processes	OR/MS techniques	DSS tools
Strategic operations planning (inter-supply chain)		
Consolidated macro supply chain scenario evaluation	GIS, NPV comparative analysis	Strategic optimization modelling systems (with mathematical programming capabilities), supply chain configuration tools for network design
Macro logistics network synergy and interdependency evaluation	GIS, NPV comparative analysis	
Sourcing consolidation (feedstock)	Simple mathematical calculation	
Chemical feed clusters supply planning	Mathematical programming (LP, IP or MIP)	
Chemical product clusters supply planning	Mathematical programming (LP, IP or MIP)	
Strategic supply chain operations planning (intra-supply chain)		
Supply chain scenario evaluation	Mathematical programming (LP, IP or MIP) NPV comparative analysis	Strategic optimization modelling systems (with mathematical programming and descriptive modelling capabilities), supply chain configuration tools for network design
Concept supply chain network design and configuration	Mathematical programming (LP, IP or MIP)	
Detail supply chain operational and functional design	Simulation (test dynamic behaviour, policy, capacity) Stochastic modelling	
Alliance and trading partner strategic planning	Simple mathematical calculation	
Supply chain implementation and commissioning	-	-
Tactical operations planning (intra-supply chain)		
Demand planning	Statistical forecasting techniques, neural networks	Demand forecasting and planning systems (to predict and reach consensus on future demand)
Supply planning:	Mathematical programming (LP, IP or MIP) Simple algorithmic methods (Based on TOC) Simple mathematical calculation	Inventory optimization and distribution planning systems Transportation planning systems Production planning optimization modelling systems Logistics optimization modelling systems
Inventory planning		
External supply and exchange planning		
Physical distribution planning		
Manufacturing planning		
Feed supply planning (internal)		
Trading and feed procurement supply planning (external)		
Operations scheduling (intra-supply chain)		
External supply and exchange scheduling (product)	Simple mathematical calculation Scheduling heuristics Algorithmic methods Genetic algorithm Simulated annealing	Distribution requirements planning systems Distribution scheduling optimization modelling systems Production scheduling optimization modelling systems Materials requirement planning systems
Production scheduling		
Inventory deployment & replenishment scheduling		
Order fulfilment scheduling		
Feed supply scheduling (internal)		
Procurement supply scheduling (external)		

Chapter 7: Roadmap for the application and implementation of the recommended framework.

7.1 Introduction

The advanced supply chain planning concept and processes defined in Chapter 6 outline the extended planning framework. A roadmap for the application and implementation thereof is however needed. Chapter 7 provides such a proposed roadmap to guide a petrochemical company along the journey. This roadmap starts by articulating the advancement stages, dimensions, characteristics and motive for progression. Typical characteristics associated with the advancement stages and dimensions provide the means for a company to assess their level of progression. The essential mechanisms that can enable interventions are also articulated. Finally a roadmap for intervention to advance supply chain planning processes is proposed.

7.2 Stages and dimensions of advancement

The literature study of this dissertation indicated that many frameworks exist whereby a company can assess the maturity level of individual supply chains and their associated planning processes (intra-supply chain integration) (refer to Paragraphs 3.1.1 & 4.2.1). Frameworks that can assist petrochemical companies in assessing how advanced they are relative to inter-supply chain integration, are however lacking. Related to intra-supply chain integration, the typical objective is to extend the scope of supply chain planning to cover:

- Activities within a function/department (internally focused)
- Functions within a business unit (internally focused)
- Supply chain partner within supply chain – backwards integration with suppliers, and forward integration with customers and with other supply chain partners (externally focused)

Intra-supply chain integration forms the basic building block for extending the scope of advanced planning across multiple supply chains (inter-supply chain integration). The extended scope of inter-supply chain planning covers (multiple supply chains or segments thereof – internally and externally focused):

- Business units within a division
- Divisions within an enterprise
- Enterprises in the same industry
- Enterprises in different industries

7.2.1 Dimensions and overview of the advancement stages

Table 7.1 provides an overview of the advancement stages and dimensions of advanced supply chain planning. This is articulated by characteristics such as:

planning scope, planning processes (reach), people skills level, organizational structures, and maturity realization and motivation to advance to the next stage/dimension. The two primary advancement stages and the associated dimensions are used to articulate the domains that advanced supply chain planning processes should cover (refer to Paragraph 6.4 for the concept). These are:

- o Intra-supply chain integration:
  - Within business unit (internal)
  - Along supply chain including all supply chain members (internal and external)
- o Inter-supply chain integration:
  - Upstream chemical feed clusters
  - Logistics networks and strategic partners
  - Downstream chemical product clusters

Clusters are used to indicate groups of businesses that need to cooperate closely due to interdependencies and synergies that exist between their supply chains or segments thereof.

Related to intra-supply chain integration, a focal company's maturity typically moves through stages. Initially the supply chain is treated as non-integrated discrete functional areas within a business. The next level of maturity is when these separate functional areas are integrated. Functional integration must occur within the organization before integration can occur throughout the entire supply chain. The key functions that need to be integrated within an enterprise are supply management (sourcing, vendor selection, and purchasing), manufacturing (production planning, scheduling, and packaging), logistics, and marketing. Integration evolution also goes through changes in focus from function to process.

A specific supply chain finally reaches maturity when integration extends across the whole supply chain (across internal functions and external supply chain partners– suppliers, customers, and logistic service providers). This also implies that the related functions of all the supply chain partners cooperate in reaching the intended supply chain objectives. Planning processes across these partners are then also properly aligned in support of an explicit supply chain strategy and strategic objectives. Supply chain planning and scheduling processes enable the drive of becoming more proactive (advancing from short term scheduling to medium- and long term planning).

Planning processes aim to extend from within organizations, along total supply chains, and finally across industry networks/value clusters. As planning processes extend, there is also a focus shift from a transactional relationship to a deeper trust, information sharing and collaborative approach. A good sign of advancement is when these supply chain planning processes are formalized, properly documented, regularly reviewed for relevance, and updated/refined with new knowledge.

The supply chain approach should also advance from a cost to a customer focus, and ultimately to a strategic focus where the supply chain is used for competitive advantage. In this regard the profile of supply chain structures within an organization also elevates from being viewed as a support function to being a core process.

Organizations, structures and employees are also affected by transition as supply chain planning advances. Cross-functional cooperation is the first sign of advancement. The establishment of supply chain planning positions is another indication of adoption and appreciation of the value that can be unlocked. Employees in planning positions constantly need to enhance their competencies and capabilities to deal with the expanded scope of supply chain planning decisions they have to support. Paragraph 7.3.5 further expands on the role played by organizational and people factors related to this roadmap.

Any company that wants to implement the planning framework provided in this dissertation should typically evolve through these advancement stages. Each stage and dimension covered provides the building blocks required for the next level of advancement. Advancement can however be fast-tracked, based on a company's readiness and capacity for change.

The ***three advancement dimensions*** used for ***supply chain planning process*** in the empirical research (refer to Chapter 5; Section II), provide a more detailed basis for assessing advancement in intra-supply chain and inter-supply chain integration for petrochemical companies. Cross-mapping these dimensions with the decision levels involved indicate the applicable impact and time scale of decisions (Hierarchical decision integration). The landscape of these three advancement dimensions is described in the following paragraphs. These include:

- Horizontal supply chain integration *(integration along the stages of a specific supply chain)*
- Petrochemical value chain cluster integration *(up- and downstream of manufacturing)*
- Logistics network integration *(cross-business unit, cross-company, cross-industry)*

Table 7.1 : Advanced supply chain planning stages and characteristics

Stage	**Intra-supply chain focus (1st stage)**		**Inter-supply chain focus (2nd Stage)**		
Dimension	**Internal to business**	**External to business**	**Upstream feed clusters**	**Logistics networks**	**Downstream product clusters**
Characteristics					
Planning scope	Within function(s) Across functions in a specific business unit	Across functions within a supply chain (internal & external)	Across upstream divisions (internal) Across enterprises (external)	Across divisions (internal) Across enterprises (external)	Across downstream divisions (internal) Across enterprises (external)
Macro planning processes (reach)	Strategic supply chain operations planning Strategic supply chain enablement planning Tactical operations planning *(demand and supply planning)* Operations scheduling		Consolidated macro supply chain scenario evaluation Macro logistics network synergy and interdependency evaluation Sourcing consolidation (feedstock) Chemical feed clusters supply planning Chemical product clusters supply planning		
People skills level required	Semi-structured problem solving Dealing with an environment of diverse situations Situations requiring analytical, interpretative thinking and judgement		Complex conceptual thinking, judgement and establishing new innovative approaches Exceptional levels of holistic integrative thinking Broad range of experience in different functions and petrochemical businesses		
Organizational structures	Mostly functional and some integrating process structures (still very silo orientated)	Mostly integrating process with functional excellence structures (internal and external)	Internal feed collaboration forums and group planning structures External virtual feed cluster hub structures	Internal logistics collaboration forums and group planning structures External virtual logistics hub structures	Internal product collaboration forums and group planning structures External virtual product cluster hub structures
Realization and motive to progress	Internal functions aligned and cooperating with a single set of objectives in mind External partners in the supply chain still focus on their own objectives	Internal and external partners in the supply chain focus on a single set of objectives Interdepen-dencies and synergies between supply chains not taken into account	Interdepen-dencies and synergies– supply chains in upstream feedstock optimized holistically Logistics networks and downstream product cluster interdepen-dencies and synergies not taken into account	Macro logistics network interdepen-dencies and synergies– across supply chains optimized holistically Downstream product cluster interdepen-dencies and synergies not taken into account	Downstream product cluster interdepen-dencies and synergies– across supply chains optimized holistically
Potential benefits scope	Within function(s).	Within a supply chain	Within a cluster of a supply chains *(related to available synergies)*		

7.2.2 Horizontal supply chain integration

Table 7.2 indicates the internal and external advancement scope for individual supply chain integration (Supply chain partners involved along a supply chain's stages upstream and downstream). This is cross-mapped with the possible level of supply chain decision integration (refer to Table 6.1 to 6.3 for the associated supply chain decision).

The arrow in Table 7.2 indicates the typical advancement direction that a business's supply chain planning processes will follow as its impact expands. Initially the focus is primarily internal (within functions or advancing to cross-functional). The decision levels involved should extend to long term strategic planning to assure internal alignments.

As strategic relationships develop with key external supply chain partners (upstream and downstream), the integration focus extends externally. The decision levels involved also extend from short-term operational level interaction to more medium- and long- term strategic planning and collaboration. Since the petrochemical industry's businesses are so dependant on access to upstream petroleum and chemical feedstock, backwards integration with a business unit's (BU) own upstream supply chain partners initially gets preference before they advance to forward integration with their own downstream supply chain partners and customers.

Table 5.11 provide an example of the current level of advancement in internal and external integration found in petrochemical business units.

7.2.3 Petrochemical value chain cluster and supply chain integration

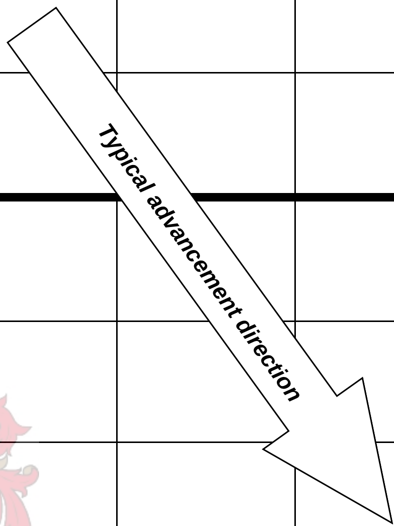
Chemical transformation processes can be spread across multiple geographically dispersed facilities. Interdependencies amongst the individual value chains exist and can take any of the following forms (refer to Paragraph 6.4):

- Sequential *(linear dependency where one chemical is produced from one feed stream)*
- Pooled *(many chemicals can be produced from one feed stream)*
- Reciprocating *(backward and forward use of chemicals)*

Individual petrochemical value chains exist around a specific product or product family and forms the basis for business unit structures in this industry. Tightly interdependent value chains form value chain clusters. These value chain clusters then closely cooperate in balancing their interrelationships, collaboratively allocating scarce molecules and the reaching of shared objectives. Value chain business decisions relate to long-, medium- and short-term decisions and typically include: market selection; processing technology and licensing; site selection; processing facility investment; further refining a chemical derivative or selling it; intermediate blending; and inventory allocation for region/customer.

Table 7.2 : Horizontal supply chain integration advancement

Horizontal SC integration advancement: Reach of a specific supply chain *(Supply chain partners involved)*	**Decision making level involved *(decision impact and time frame)***		
	Short Term	Medium Term	Long Term
	Operational scheduling. (e.g replenishment scheduling)	*Tactical planning. (e.g material requirement and distribution planning)*	*Strategic planning. (e.g. supply chain network design)*
Internal BU integration: ***Within each department/function/facility*** of the business unit (e.g. logistics – vehicle loading & dispatch)			
Internal BU Integration: ***Across departmental facilities of a business unit*** (e.g. procurement, production, logistics, marketing, R&D)			
External/***backwards integration: BU with its own Upstream SC partners -*** *BU* with its own 1st tier suppliers and logistics service providers			
External/***forwards integration: BU with its own downstream SC partners –*** with its own logistics service providers & 1st tier customers			
External integration ***(upstream & downstream)***: ***BU with its own SC partners.*** (e.g. suppliers, plant, customers, logistics service providers)			



A supply chain forms a critical part of a petrochemical business's value chain (covering three of the primary activities in the value chain). Supply chain realities, constraints and costs should thus be considered because they influence value chain decisions and assure feasibility and optimality. Value chain decisions, however, form the business context for supply chain decisions. These two decision domains should therefore closely integrate with one another.

Table 7.3 indicates the typical advancement direction in considering supply chain decisions in petrochemical value chain cluster decisions. The typical decisions applicable to this table are articulated in Table 6.4 and 6.5. Initially the value chain decisions of a business unit (typically taken by its BU manager) are only concerned with it own upstream chemical feed source(s) and downstream consumer(s), and only consider the impact of short term supply chain decisions (e.g. production scheduling). Supply chains are thus fairly reactive and only become proactive when medium term and long term supply chain decisions are also considered.

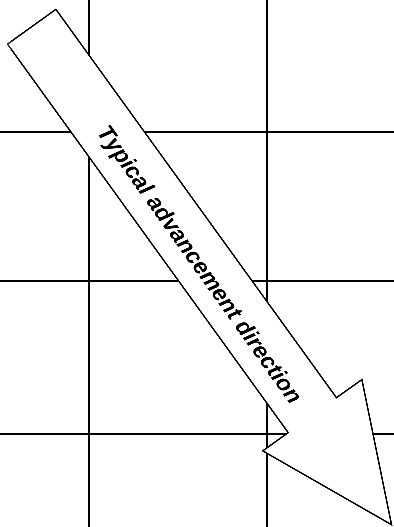
As petrochemical companies expand, multiple business units or joint venture partners form into an upstream value chain cluster around a specific chemical feedstock (e.g.

propylene). Value chain decisions are typically made concerning the best alternative use among the downstream consumers. These decisions are often taken with assumptions about the alternative downstream consumer's profitability potential. When the correct supply chain economics information is not part of the value chain assumptions, the allocation decisions could be wrong from a global optimization perspective. Without considering each downstream value chain's supply chain constraints, it might also lead to infeasible decisions. As the supply chain decisions considered extend from short-term to medium- and long-term (in relation to upstream and downstream value chain cluster decisions), global optimization and feasibility becomes more probable.

Table 5.12 provides an example of the current level of advancement in petrochemical companies with integrating value chain and supply chain decisions (long-, medium- and short-term). This is an indication of which level of supply chain decision consideration is being incorporated when taking chemical value chain and value chain cluster decisions.

Table 7.3 : Petrochemical value chain cluster and supply chain decision integration advancement

Extent of petrochemical value chain clusters decision integration *(Could be: - Vertical integration, - JV contract, or - Term contract)*	**Level of supply chain decisions considered**		
	Short-term *(e.g. Production scheduling)*	Medium-term *(e.g. Inventory distribution & allocation)*	Long-term *(e.g. Site selection & SC network design)*
Single BU value chain integration with 1st **upstream** chemical feed sources			
Single value chain integration with **upstream** feed source(s) **and downstream** derivative consumer(s) *(Including external exchange/supply agreements)*			
Multiple BUs & JVs **collaborating in a specific feedstock or product value chain** and taking a "profitable volume" allocation approach. *"Value chain cluster approach"*			
Multiple BUs & JVs **collaborating across feedstock or product value chains** and taking a "profitable volume" allocation approach. *"Value chain cluster approach"*			



7.2.4 Logistics network integration

This type of integration only really comes into play where cross-business unit or cross-enterprise logistics network interdependencies or synergies exist. These interdependencies and synergies could exist in freight corridors, trade-lanes, shared infrastructure, or compatible products/packaging formats. Table 7.4 indicates the typical advancement direction in logistics network decision integration for large scale petrochemical companies (Cross-business unit, Cross-company, Cross-Industry). The typical decisions applicable to this table are articulated in Table 6.4 and 6.5.

Different logistics network categories exist in the petrochemical industry. The cooperation potential within and across these logistics network categories is the result of interdependencies or synergies that could exist. The different logistics network categories are:

- *Liquid bulk (e.g. Hexene, Acetone, MEK, Fuel, Phenol)*
- *Dry bulk (e.g. Coal, Salt, Sulphur)*
- *Packaged goods (e.g. Boxed Waxes, Containerized Polypropylene, Bagged Fertilizer)*
- *Bulk gases (e.g. Propylene, Ethylene, LPG, Town Gas)*
- *Containerized gases (e.g. Cylinders, Tank containers)*

As indicated in Table 7.4, the entry point to this advancement dimension is where corporate unity develops within an enterprise across related business units' logistics networks. These logistics networks cover the upstream and downstream integration of manufacturing facilities with first tier suppliers, logistics service providers and first tier customers. Initially, only short-term inter-supply chain decisions are considered (e.g. shipment consolidation). As trust and collaboration maturity improves, inter-logistics network decisions expand to medium-term (e.g. freight consolidation on corridors) and long-term (e.g. shared infrastructure investment) decisions. When an enterprise reaches that point where they have dealt with all the corporation's inter-logistics network interdependencies or synergies, they would start looking for cooperation opportunities within the petrochemical Industry. As soon as all the inter-logistics network interdependencies or synergies within the petrochemical Industry have been exhausted, companies would start looking for cooperation opportunities between related industries.

7.3 Mechanisms to utilize for planning interventions

Key mechanisms can also be applied in aiding the advancement of supply chain planning intervention. These include:

- Planning process improvements and reengineering
- Advancement in analytical techniques
- Decision support systems' advancement

- Change management
- Organization, roles and people
- Continuous improvement practices

Table 7.4 : Advancement in logistics network decision integration

Extent of logistics network integration	**Level of supply chain decisions considered**		
	Short-term *(e.g. Shipment consolidation)*	**Medium-term** *(e.g. Freight consolidation on corridors)*	**Long-term** *(e.g. Shared infrastructure investment)*
Same Enterprise: Corporate Unity in Upstream/Backwards integration with first tier suppliers & logistics service providers			
Same Enterprise: Corporate unity in Downstream / Forward integration with logistics service providers and first tier customers			
Same Enterprise: Corporate unity in Downstream and Upstream integration Cooperation of the corporate entity (e.g. shared infrastructure and economies of scale)			
Petrochemical Industry: Upstream of multi-enterprises – backwards integration with first tier suppliers and logistics service providers			
Petrochemical Industry: Downstream of multi-enterprises – forwards integration with logistics service providers and possible market swap agreements			
Petrochemical industry: Downstream and upstream integration/cooperation for the corporate entities (e.g. shared infrastructure & economies of scale)			
Multiple Industry: Downstream and upstream cooperation for the synergistic cluster (e.g. shared infrastructure & economies of scale)			

Typical advancement direction

7.3.1 Planning process improvements and redesign

Following a process approach to manage a business related to "the how of managing the white space on an organization chart". Most supply chain processes (such as supply and demand planning) are cross-functional, spanning the 'white space' between the boxes on a company's organization chart as well as the external partners involved.

Planning process improvement and reengineering projects normally first evaluate the current processes, compare it with applicable best practices/frameworks and then determine an appropriate future process model that can best meet business requirements (refer to Paragraph 2.1.1.4). The gap is then closed through minor process improvements or redesign and the ultimate implementation thereof. Planning improvement and reengineering projects also aim to eliminate non-value add activities. Eliminating non-value add work and simplifying process activities can significantly improve performance. Process improvements also set the stage for the effective utilization of people and systems.

The approach to process improvement varies in terms of the extent of change required. Three distinct levels of change might be required to address the gaps that exist. These levels relate to:

Minor process enhancements. This type of change normally calls for small, local teams to come together and explore how a process can be enhanced, typically addressing issues of cost, quality, or cycle time.

Redesign typically involves large, cross-functional processes. A formal project is normally required and managed through a steering committee. A more formal approach is thus followed for improvement.

Fundamental and wide-ranging changes of processes might require a total rethink in some segment of the business. Strategic choices are then also made regarding the insourcing/outsourcing of these processes.

7.3.2 Advancement in analytical techniques

Analytical techniques (represented by various model types) provide the means of supporting supply chain planning processes through answers/decisions to real world supply chain questions at hand. These models range from being either descriptive (to provide business intelligence) to optimization focused. Both these categories of models utilize OR/MS techniques. As businesses advance their supply chain scope, the models used to support associated planning processes also expand from descriptive to optimization models. In early stages of trying to advance supply chain planning processes, descriptive models (e.g. forecasting, cost relationship, resource utilization relationship) provide a relatively easy starting point for supply chain analysis. By using some descriptive models (providing business intelligence–with a very basic data model and related master data), decision information can be abstracted from large volumes of data. This appropriate information is then available to the decision-maker. This is normally the ***first step*** in basing decisions on fact rather than on perception and gut feel alone. The skill level required is normally higher for optimization than for descriptive models. Qualitative skill levels also need to be complemented with sound quantitative analytical skills.

The ***next step*** of becoming more advanced in the application of OR/MS techniques is to use descriptive models (e.g. simulation models) for evaluating "what-if" questions.

The decision-maker thus evaluates the effect of certain supply chain parameters or logic changes with the aid of an analytical model. The model is thus used to assess viable alternative courses of action and implications of decisions, rather than testing the effect in the real world. Through the use of “what-if” evaluation, the decision-maker develops the required appreciation for analytical techniques and is ready to move to the next step. The ***final step*** involves the use of optimization models. Given a set of parameters, objectives and constraints, these models not only derive feasible solutions to a supply chain problem at hand, but also determine the optimal solution.

7.3.3 Decision support systems’ advancement

With the advancement of information technology, ample information is now readily available through connected networks. Information is now easily shared through the appropriate integration technology. Computing power and software applications have improved significantly and became more affordable. Decision support systems (DSS) can leverage these opportunities to enhance decision making. Although sound transaction processing is vital to form a repository of historic information (e.g. through ERP systems), advancing to analytically based systems can truly enable forward-looking supply chain planning (e.g. through APS systems). The enabling applications can also advance to enterprise-wide planning process integration rather than optimizing within each silo of information along the supply chain (thereby not limited to focus only within the four walls of a company). Data and decision information form a vital part of DSS. By advancing data from raw data to information and ultimately to intelligence, DSS can thus provide decision makers with the accurate and critical facts needed. The information repositories used for a DSS also advance from distributed disparate databases to central shared data warehouses structured according to a master data model. These data warehouses provide sound business intelligence capabilities.

Applications also advance from time-phased reorder point systems in the form of MRP and DRP (batch-oriented focused with manual exception handling) to integrated planning systems that has holistic optimization capabilities and utilizes hierarchical planning capabilities. In a similar fashion, non-integrated point solutions (e.g. spreadsheets) also move to these more integrated planning systems. The optimization approach also move from a sequential batch orientation to more dynamic and concurrent optimization.

7.3.4 Change management

The change management approach proposed for planning intervention relate to the '3-P' approach as indicated in Figure 3.30. This change management approach is based on the relationship between **p**hilosophy, **p**rinciples and **p**rocesses. This approach also forms the basis for the framework and concept defined in Chapter 6. Change management starts with clear and common understanding regarding the topic/issue under consideration. A company should be cautious in using supply chain management as a buzzword without adopting the mindset and aligning future strategies and structures accordingly.

Planning interventions should normally start by asking the basic questions for change: "where are we now, where do we want to be and how are we going to get there?" Sound understanding of current planning processes and the rational behind current practices also form an excellent starting point. Ignoring these current processes implies that the people involved are unimportant and could suggest that what employees currently do and what they know, is not important. It also implies that their input to any change is unwanted and unnecessary. Allowing staff to contribute helps to "buy into" the change. Evolution, rather than revolution, results in incremental changes with step-change results. Defining the perfect end-state for world class supply chain planning might be easy, but getting there while having a business to run is not so easy. Therefore, a change management process and programme approach for improvement will be more suitable than a one-time project for improvement.

Capable and competent leadership is required to oversee planning interventions since leadership, not management, makes change happen. Leaders drive change and managers keep the process under control. Support for initiating change has to come from the top. Senior management support helps to eliminate organizational barriers that undermine change. Leaders should also focus on a number of critical success factors to manage change. These include stimulus/pressure for change, a clear shared vision, capacity for change (skills, incentives and resources), actionable fist steps and sound tracking of progress. All of these factors must be present else sustainable change will not be achievable.

Table 7.5 provides an overview of the typical change stages and change mechanisms applicable in change management processes. In ***preparing*** for change, the change landscape is properly understood and all major change dynamics are identified. ***Alignment*** assures that all key stakeholders are in support of the case for change and focusing on the same expected outcome. The impact and synergies with other initiatives are also assessed. A ***Situational and Change Impact Assessment*** is a high-level approach to determine an organization's change situation, readiness and potential impact on the organization and individuals.

Organizational transitions consist of the organizational changes in structures, processes, systems and technologies required to implement the organization's vision and strategy successfully. Organizational transitions are critical to the organization's change efforts, but without ***individual transitions***, the potential for the success of the organization's change effort is severely diminished. Individual transitions consist of changes in behaviours, skills and attitudes that are just as important as the changes in organizational strategy and structure. The behavioural side of change will eventually determine the success of the change effort. Individual transitions are the psychological processes that people go through in order to come to terms with the new situation.

Adoption, embedding and stabilization happen when the new order of business is finally accepted by the applicable structure and individuals. Leaders also understand their new roles, and are equipped to perform in these assigned positions. An effective performance management system is in place to reward appropriate behaviours and address non-compliance or poor discipline in terms of the requirements of the new environment. ***Communication*** plays a vital role throughout a change intervention. Key stakeholders should have a clear understanding of the case for change, objectives and updates on intervention milestones reached.

Table 7.5 : Change stages and mechanisms

Change stages	**Change mechanisms**	
As is	Preparation	**Communication**
	Alignment	
	Situational and change impact assessment	
Transition	Organizational transitions	
	Individual transitions	
To be	Adoption	
	Embedding and stabilization	

The leaders overseeing change interventions should also find ways and means to resolve factors that can hamper advancement in supply chain planning (as part of a change impact assessment). These factors include:

- The petrochemical industry has a very conservative culture (corporate mentality discourages risk taking and speedy decision making).
- Inadequate understanding of the perceived importance of the supply chain.
- Fragmented planning processes and applications that hamper business planning.
- Internal organizational boundaries prevent the flow of consistent and timely information.
- Conflicting objectives and poor interactive communication between departments and divisions also hamper planning.
- Lack of information visibility and transparency across the business renders timely decision making impossible.

- The oil industry is largely refinery-centric and production-driven. It must become more customer-centric and, therefore, partly demand-driven (where appropriate) in order to maximise margins.
- Refinery planning is currently separate from distribution planning and order fulfilment (a major opportunity to be integrated).

7.3.5 Organization, Roles and People

The approach followed in grouping planning processes into specific roles/positions and then structuring/locating them within and external to an organization, is one of the critical success factors to assure effective supply chain planning. People ultimately fulfil these positions and require specific competencies (another critical success factor).

The Petroleum industry is still a victim of “silo mentality”. Breaking down existing silos may be tough because the oil industry is organized around highly specialized business processes/units that encourage fragmentation. This industry has formed into silos which are very confidential with their information. One of the first major challenges to overcome in the petrochemical industry is the silo mentality. Paragraph 5.7.3 provides a number of sound practices to eliminate functional silo strongholds and reduce the secrecy mentality.

Supply chain organization structures and the design thereof, is more than just reporting and decision-making structures. An effective organizational design should take into account the complex and interdependent nature of strategy, structure, process and people. By paying adequate attention to each of these (and their related interdependencies) an organization can guide the change in behaviour, culture and resultant supply chain performance.

Organizational structures have become a way for the senior management to focus the organization on key supply chain issues. However, clear roles and responsibilities are now more important than formal structure. For enterprises that embrace and adopt process management, crystal clear lines of authority and responsibility (typical of functional command and control) become difficult and undesirable to maintain. The seamless flow of information to decision makers becomes critical for supply chain success and organizational barriers should not stand in the way. Supply chain planning needs to play that important role of deriving appropriate strategies and tactics on how to address these issues. Successful supply chain organizations today are typically based on one of three basic models:

- Cross-business-unit supply chain organization coordinated across the enterprise (internal and external with other industry players).
- At business unit level, the end-to-end supply chain function reporting directly to the head of the business unit.

- Within the traditional functional model (e.g., logistics, sales, marketing, etc.), key supply chain activities reporting directly to relevant functional heads.

Supply chain organizational structures would typically evolve over time as the supply chain strategy evolves (refer to Paragraph 3.3.2). Structures should however be utilized to support the advancement in cross-functional cooperation. Supply chain planning processes is a fitting mechanism to cross the organizational barriers and assist in balancing functional excellence with a customer-focused orientation (typically supporting an organization-wide objective). As indicated in Figure 7.1 the initial organizational evolution occurs when a value chain orientation is adopted (Moving away from structures that are separated into manufacturing, logistics and marketing and working toward their own functional objectives). In the petrochemical industry, value chain structures are predominantly organized in business units along chemical product families focused on their target customers. A supply chain approach compliments a value chain orientation and supply chain planning processes are then typically applied within each business unit to align the supply segments with consumer demand requirements (intra-supply chain planning). As the supply chain structures mature, the participants in supply chain teams become more cross-functional. Typical "process teams" develop and consists of experts from procurement, manufacturing, marketing, finance and distribution. Ultimately cross divisional enterprise functions are established to utilize inter-supply chain planning processes and derive the associated benefits.

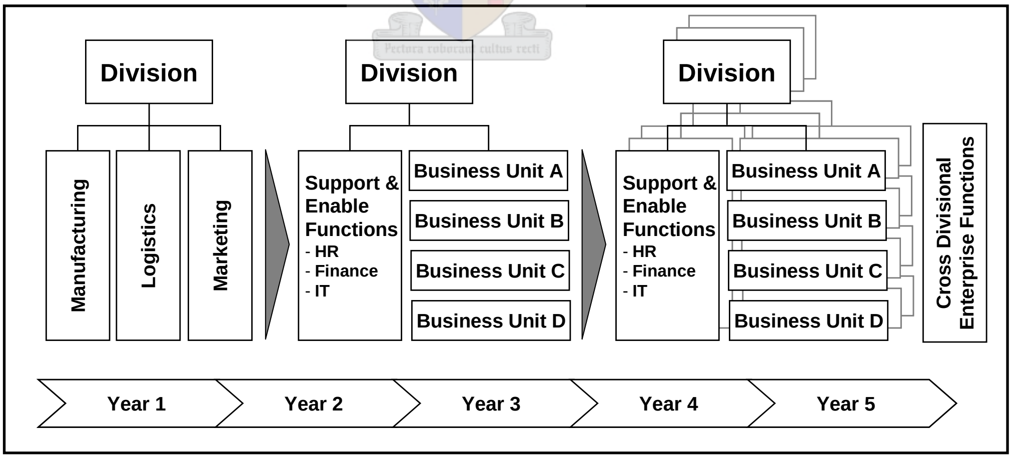


Figure 7.1 : Typical organisational transition

Individuals constitute and run a business's supply chain. Their values, beliefs, attitudes and skills make up a company's inherent capability. The driving force, ambition, passion, efficiency, innovation, and ethics of individuals determine the effectiveness of an organization and not only the business models, strategies, and visions that guide them. Appropriate recruitment, selection, development, retention and motivation/reward practices directly influence whether the correct people with the right competencies perform and excel in their positions (Relate to key people competencies derived in Paragraph 5.6.5).

Although top management support is important, supply chain planning must be institutionalized within the business model (Via formal business processes and/or technology). When executives or key personnel move on, the advancement in supply chain planning is thus sustained. Proper succession planning of supply chain planning personnel is also needed to sustain credibility and capability.

7.3.6 Continuous improvement practices

Companies striving for supply chain excellence should have a model in place for continuous improvement. Harnessing the innovative spirit of employees provide the thrust to improve performance continuously (refer to Paragraph 3.1.4.2). Once supply chain planning processes have been established in a business, they don't remain the same. Organizations typically evolve and mature over time resulting in changes in the scope and reach of supply chain planning processes. Since supply chain planning processes are in their very nature cross-functional, they are prime candidates for continuous improvement (due to changes within functional areas as well as transitioning from functional to process structures). These processes need to be updated, refined and re-deployed using continuous improvement practices. As supply chain planning processes mature, they can also incorporate more advanced practices resulting in unlocking more value.

Planning processes also rely on analytical models. Descriptive and optimization models are abstractions of the real world. A supply chain changes over time as the business change, grows, expands and extends its geographical footprint. Supply chain models should thus continually be refined to assure their relevance and accurate representation of the real supply chain. A number of appropriate continuous improvement practices include:

- Continuously challenging current performance levels.
- Benchmarking supply chain planning practices and supplying chain performance against key competitors and setting new improvement targets.
- Establishing systems that value and encourage innovation and creativity.
- Improving productivity and quality by constantly moving down the learning curve.
- Automation of processes with enabling technology where possible.
- Advancing from "what-if" descriptive analytical- to full optimization techniques.

7.4 Roadmap for planning interventions

To guide a petrochemical company along the planning intervention journey, a roadmap can be followed that articulates the stages for advancing supply chain planning. Such a roadmap is provided in Figure 7.2. It articulates the different plateaus reached which, in their own right, provide the basis for the next level of advancement. These stages include supply chain grounding basics followed by first - and second stage advanced supply chain planning. Any such intervention should follow a programme approach and needs a champion to lead It. These initiatives normally require a “cross section” of participants from all relevant functions and disciplines.

7.4.1 Supply chain grounding basics

Establish supply chain awareness and interest. Adopting a supply chain approach must ultimately originate from the senior management of a business. Viewing their organizations as a collection of functions, and not as an interrelated system of highly integrated processes that primarily focused on the customer’s requirements, will reduce their chance of future survival. For companies to compete in future, they need to reassess the strategic importance of their supply chain processes. These cross-functional and cross-company processes are the next frontier for enhancing revenue, reducing costs, enhancing quality, and reducing working capital. Customers and products should not be viewed by volume or revenue alone, but rather by profitability.

Proving to senior management the value unlocking potential and worth to the company of following a supply chain management orientation, is a first important hurdle to cross. To justify a supply chain intervention and get the attention and interests of senior managers, supply chain levers should be linked (as far as possible) to financial benefits and other key non-financial performance measures in a company. The analysis of these opportunities should be conducted by applying a system analysis approach (looking for how to improve the total system). Benchmarking against the competition is an effective way to determine areas for improvement. Presenting a sound business case in this regard, can assist in convincing senior management to change to a supply chain management orientation.

Supply chain approach/orientation adoption and implementation. A clear and common understanding regarding a supply chain management orientation is required. Clarifying the philosophy followed, principles, approach and concepts used, play an important role to secure and embed a supply chain foundation. An acceptable guideline for a supply chain interventions relate to: 50% of effort spent on organizational change, 40% on process definition, and 10% on technology enablement. A balanced set of key roles and responsibilities should be established (Project Manager, with a project leader, technical leader and business/organizational change leader). Organizational change includes such items as: culture, motivation, maturity, skills development, performance measures, and process design. A time-phased programme roadmap with milestones and measurable deliverables will keep the momentum and interest during implementation (Balance quick-win opportunities with a systematic long-term investment). Ongoing organizational alignment can be assured by creating a senior leadership forum/steering team supported by a program management office.

Introduce supply chain processes (including planning processes). Moving from functional to a supply chain process orientation require the introduction of relevant internal and external processes. Internal processes are typically cross-functional in nature. External processes extend a company's boundaries and reach across the organizations of the supply chain partners involved. These processes relate to supply chain planning and execution processes. Evaluating the current processes and comparing them with appropriate world class process practices would indicate the extent of process change required. Changes required could vary from minor process improvements to total re-design. Supply chain processes can typically be grouped to form key roles that employers should take ownership of. Initially processes can be executed on an almost manual basis. Relationship building among the supply chain parties involved also forms an important foundation to support process effectiveness. Enabling systems can be introduced to enable and automate some of the more transactional and repetitive processes. Related to supply chain planning processes, OR/MS techniques need be incorporated to support decision making. The first analytical techniques applied relate more to simple mathematical calculations and descriptive analytical tools (e.g. forecasting techniques).

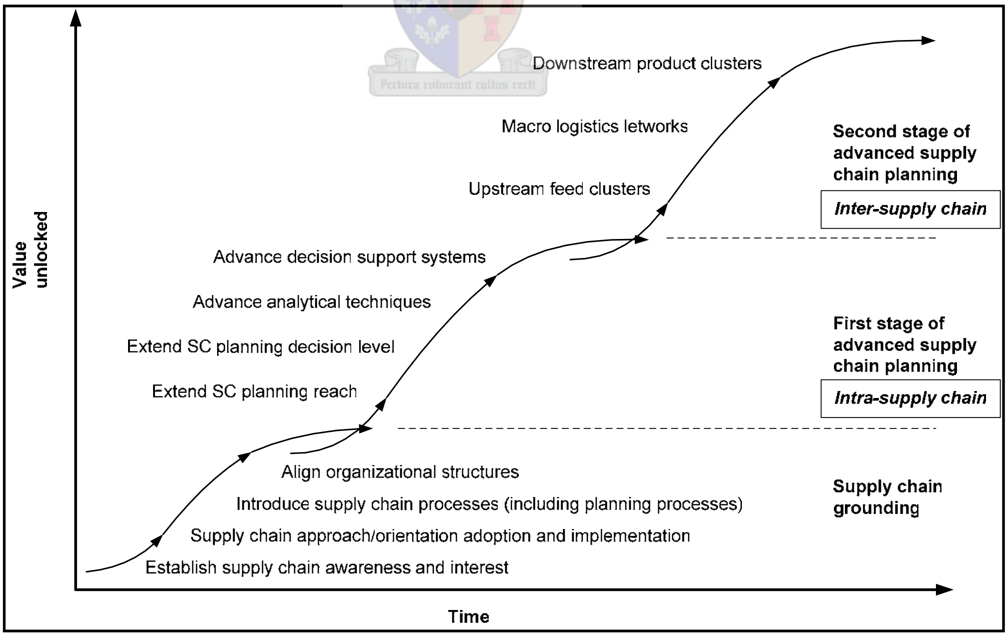


Figure 7.2 : Roadmap stages for advanced supply chain planning

Align organizational structures. As supply chain processes are grouped into key roles, these roles can be institutionalized into organization structure. Clear roles and responsibilities are established. A formal supply chain structure form the basis for establishing the required profile within the business alongside other core business process groups. It is vitally important to assure that the right people with the right competencies occupy the key positions within the formal supply chain structures. Their capability, ambitions, attitude, and efficiency ultimately determine the effectiveness of the supply chain organization.

7.4.2 First stage of advanced supply chain planning (for individual supply chains)

With the basics of a supply chain approach properly established, a business can start to advance its supply chain planning processes in a number of ways.

Extend supply chain planning processes reach. The reach of supply chain planning processes extends as it covers more of the related internal functions in a business. It also extends externally as it covers the external supply chain partners (upstream and downstream of manufacturing).

Extend supply chain planning processes decision level. The level of planning extends from operational decision level to cover also tactical and strategic decision levels. Through this, the supply chain becomes more pro-active and more capable of responding to future customer demand requirements.

Advance analytical (OR/MS) techniques. As businesses advance their supply chain scope (reach and decision level), the models used to support the associated planning processes also expand from descriptive to optimization models. Models also advance from being sequentially linked between the different decision domains to becoming more concurrent.

Advance Decision Support Systems. Advanced Planning and Scheduling (APS) systems are normally deployed in a phased approach. Manufacturers require planning and scheduling applications to be up and running as quickly as possible to start realizing the benefits. They must evaluate the time, fit, and resources required for a successful overall implementation. APS vendors tend to pre-configure software components and industry templates and thereby support relatively fast implementations. The benefits derived from each phase/release of new sophistication added, provide a funding mechanism for subsequent releases. Companies that use advance decision support systems, still have to address the major challenges associated with implementation:

- developing the infrastructure to provide integrated data of adequate quality,
- developing the internal skills to use these technologies effectively, and
- instilling the discipline to use these tools actively.

7.4.3 Second Stage of advanced supply chain planning (across supply chains)

With each business unit's supply chain optimized and both related internal functions and external supply chain partners extended, a business can start to advance its supply chain planning processes to incorporate a number of additional dimensions. These relate to the advanced supply chain planning dimensions described in paragraph 6.7.4.

Upstream feed clusters. Chemical feed stream interdependencies/synergies result in upstream chemical value chain clusters. These clusters incorporate multiple value chains and their associated supply chains. Decisions related to the profitable allocation of feed streams are made while considering all relevant supply chain parameters and constraints.

Macro logistics networks. Macro logistics networks exist when related supply chains have interdependencies/synergies within and across enterprises related to liquid bulk, dry bulk, packaged goods and gasses. By taking a holistic integrative approach, optimal and feasible decisions can thus be derived within and across these logistics network categories.

Downstream product clusters. Final product interdependencies/synergies result in downstream chemical product value chain clusters. These clusters incorporate multiple value chains and their associated supply chains. Products exchanged between supply chains are one of the typical practices that exist in downstream chemical product value chain clusters.

7.4.4 Requirements for sustainable change

Once a supply chain planning capability has been established, it is important to make sure that it can be sustained. The following are typical practices that can be utilized to sustain a supply chain planning capability:

- Recognize the need to change culture/orientation (cross functional/process thinking).
- Apply holistic integrative thinking.
- Measure and report benefits.
- Show small benefits as soon as possible.
- Break the big project up into small business releases.
- Ensure that all processes have owners.
- The new processes must become the normal practice on a day to day basis.
- Recognize that planning processes are "living" and will continuously evolve and improve over time.
- Provide for on-going support and enhancements.
- Reward champions.
- Publicize successes and share learning.

7.5 Knowledge added through this research

This dissertation aimed to add knowledge to the supply chain planning field of study by developing a theoretical framework for advanced supply chain planning processes in the petrochemical industry. It also established a roadmap for the application and implementation thereof. Approaches from current literature and research only partially cover what advancement in supply chain planning processes constitute of, and primarily focus on intra-supply chain integration. These approaches relate to how a focal business integrates a specific supply chain across its relevant internal functions and external supply chain partners.

Due to the highly integrated nature of petrochemical value chains, related supply chains should also be integrated by taking account of enterprise/industry-wide synergies and interdependencies (viewed as inter-supply chain integration). The framework developed in this dissertation indicates the advanced supply chain planning processes required for the broader scope and dimensions of inter-supply chain integration in large-scale petrochemical companies.

A creative approach was followed in defining and structuring this framework in that it consists of an appropriate philosophy, concept, guiding principles, typical petrochemical supply chain decisions, and the supply chain planning processes themselves. It also indicates how these planning processes should be enabled.

The roadmap developed for the application and implementation of this framework is believed to be useful and appropriate in that it could guide a petrochemical company along the journey of advancing its supply chain planning processes and ultimately contribute to its competitiveness.

Since not much research has been done indicating the level of supply chain planning advancement in large-scale, South African based petrochemical companies, the empirical research in this dissertation provides the first of its kind. It covers both the intra- and inter-supply chain planning advancement domains. This empirical research provides useful information regarding an understanding of the petrochemical industry, appropriate supply chain planning practices, and the level of advancement in a number of related planning areas.

7.6 Areas for further research

This dissertation did the groundwork to frame and articulate the scope and reach of advanced supply chain planning processes applicable within and across large scale petrochemical companies. More detailed research can still be performed related to the following focus areas:

- Research and development work to establish OR/MS models and DSS templates that can support advanced supply chain planning process. These example models and templates can aid in dramatically reducing implementation efforts and assure that models and systems can be up and running as quickly as possible, thereby realizing their quick benefits.

- Defining appropriate organizational and governance structure frameworks that can enable inter-supply chain integration.

- Based on the broad supply chain planning process framework proposed in this dissertation, a complete formalized framework (similar to the Supply Chain Council's SCOR model) can be developed. Such a framework can articulate the detailed process elements required to fully describe the advanced supply chain planning processes in the inter-supply chain domain. This framework can then be used by participating petrochemical companies.

- Case studies, examples, and action research into the different clusters of advanced supply chain planning processes found in large-scale petrochemical companies and within the industry. These studies and examples can serve the purpose of prototypes that indicate the benefits achievable. Process maps of these advanced supply chain planning process can indicate and articulate the process elements required.

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APPENDIX A : Introductory letter used for empirical research and interview questionnaire

<u>Subject:</u> Research regarding advanced supply chain planning in the petrochemical industry

Invitation to participate in empirical research regarding "advanced supply chain planning processes and decision support systems for large scale petrochemical companies"

Dear Stakeholder

As businesses grow and expand, their supply chains broaden and become more complex. The number of facilities and linkages to manage escalate and it becomes increasingly difficult among supply members to agree on a common goal. Supply chain members also become more dependent on each other. Following a supply chain approach means much more than "fixing logistics"; it means focusing the organizations concerned on its clients and aligning people on critical processes that cut through functional silos.

The chemicals industry is at an "inflection point" in supply chain and manufacturing capability. The traditional focus on optimizing within functional areas or only integrating functions within individual business units would not be enough to maintain and sustain profitability. An increasing number of managers in a wide range of companies are seeking to manage their supply chains based on facts, that is, data and proper analytical methods assisting them to become more proactive. Identified and applicable best practices, if properly implemented, could dramatically improve the overall performance of supply chains. Strategic planning and operational management of supply chains are two leading decision problems in managing supply chains.

The above are some of the compelling reasons that motivated me in doing a PhD dissertation with the title "Advanced Supply Chain Planning Processes and Decision Support Systems for large scale Petrochemical Companies". I am conducting this research under the guidance of my promoter, Prof WJ Pienaar from the Department of Logistics at the University of Stellenbosch. The research methodology includes an extensive literature study (already completed) combined with empirical research in South Africa to assess appropriate best practices and level of advancement in the relevant supply chain planning processes. Because there are not too many large scale integrated and complex petrochemical companies in South Africa, the appropriate way of conducting the empirical research is by using semi-structured interviews (to assess appropriate best practices) combined with a brief advancement questionnaire (to assess level of advancement) with identified key stakeholders. By working with these key stakeholders in industry, consultancy, enabling technology suppliers and academia, this empirical research would provide the required balanced contribution to this dissertation.

You have been identified as one of the key stakeholders in this empirical research. Your experience and understanding of the process and petrochemical industry as well as your involvement in the supply chain planning and decision support disciplines could make a substantial contribution to this research.

The Interview Questionnaire will consist of the following two sections and focus areas:

Section I : Interview questions *(to assess appropriate best practices)*

- Basic company information (only for petrochemical companies interviews)
  - Value chain orientation and understanding the nature of business
  - Business structure
  - Some business indicators
- Company and industry's supply chain (SC) approach/orientation
- Company and industry's supply chain process approach
- Company and industry's supply chain planning and decision making processes
- Supply chain planning challenges for the petrochemical industry/companies

- Supply chain planning opportunities for the petrochemical industry/companies
- Best practices used in supply chain planning
- Supply chain planning Intervention approaches followed
- Supply chain planning and enabling technology solutions
- Organizational issues

Section II : Questionnaire *(to assess level of advancement)*

- Level of supply chain adoption and approach in your company and the Industry
- Dimensions of advancement in supply chain integration
    - Horizontal (SC stages) and hierarchical (SC decision impact) integration
    - Petrochemical value chain clusters and supply chain decision integration
    - Cross business unit, company or industry logistics network integration
- SC Planning processes and techniques used
- Decision Support Systems (DSS) used/applied in supply chain planning

I believe that my background and broad experience in the petrochemical industry, my promoter's support and understanding of qualitative and quantitative approaches needed in the logistics and supply chain disciplines, together with your participation, will make a positive contribution to new knowledge in this domain.

Why will you benefit by participating in this research?
The participants will be able to share in the following:

- Influence the proposed advanced supply chain planning practises in the petrochemical industry
- Obtain access to the outcome of this empirical research as well as the literature study completed
- Also receive a CD with the final outcome of the dissertation as a basis, orientation and guide for initiatives in advanced supply chain planning processes and decision support systems for large scale petrochemical companies

I realise that during the interview, all the information required might not be available at that time. For this reason I will first send the outcome of the session back to you (Interview Questionnaire as recorded). You can then conclude on any outstanding items indicated in the interview and validate the contents thereof.

The information received from the various stakeholders will stay anonymous and would be aggregated into appropriate categories to assure that no confidential information would be exposed.

My expectation is to complete the Interview Questionnaires with the identified stakeholders by the end of December 2005. As soon as the empirical research has been completed, I would be in a position to complete the rest of my dissertation and start sharing the outcome of the research thereafter.

I will schedule a suitable session with you to conduct the interview and complete the questionnaire.

Thank you in advance for you participation and trust that you are as anxious as I am to see the outcome of this research.

Kind Regards,

Johan Louw

Manager: Outbound Strategy & Projects
Supply Chain Optimisation
Sasol Ltd.

E-Mail : johan.louw@sasol.com

Interview Questionnaire - Background and Purpose

This interview questionnaire is part of empirical research regarding "Advanced Supply Chain Planning Processes and Decision Support Systems for large scale Petrochemical Companies" in South Africa. The interview questionnaire comprises the following:

- A semi-structured interview section to be conducted with identified stakeholders to clarify best practice, concepts and approaches followed by key industry leaders, consulting practices, enabling technology suppliers and academia, and
- A questionnaire section to assess the level of advancement in supply chain adoption and relevant planning processes (to be completed during the interviews).

Supply chain terms of reference

A ***supply chain*** is the physical representation of a business' value chain. The anticipated demand for final products, the production facility(ies) and sources of feedstock are the primary determinants of how a supply chain should be configured. The physical configuration of a supply chain is the operational activities required to enable the flow of inventory. These activities include facilities (manufacturing, storage, handling and packaging), transportation and support services. With a supply chain operationalized for a business, ***supply chain processes*** provide the means for supply chain partners to align, synchronize and efficiently execute their activities related to an agreed demand and supply plan for specific materials and products.

Many of the recent developments in supply chain management (***SCM***) represent a move towards allowing downstream demand (in the form of forecasted future needs, actual orders or consumption of final products) to drive upstream supply activities.

As with most asset intensive manufacturing organizations, some sections of the supply chain can be linked to either the direct or indirect value chains (refer to figure below). In petrochemical companies the ***direct supply chains*** primarily deal with the supply of feedstock, intermediate and final refined products for the end customer. Indirect supply chains on the other hand, deal with the supply of hard goods, spares and maintenance equipment for the asset management functions of an enterprise. This interview questionnaire is primarily focused on the direct supply chains. The direct supply chains in a petrochemical business also relate to the supply chain stages ***upstream*** and ***downstream*** of the refineries.

The figure below details the typical goods and services required in the direct and indirect supply chains. The demand for logistical services required in the inbound and outbound legs of the supply chain is also dependant on the demand and requirements for material and final products.

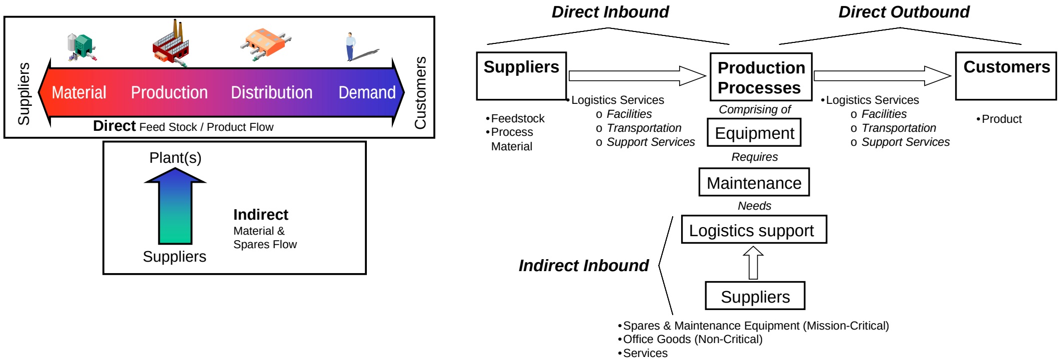

Figure: Focus of **Indirect & Direct Supply Chains** and associated **Material & Services Required**

1. Section I : Interview questions

1.1 Basic company information (only for petrochemical companies interviews)

1.1.1 Value chain orientation and understanding the nature of business

a) What are the major products produced and marketed (80/20 pareto principle)?

(Major product families and subsidiary business units associated with them)

____.

____.

____.

____.

b) Markets served (% - revenue split) and market share (%)

Market	**% of Revenue**	**Market share**	**Major competitors**
Domestic (home base) ?			
Abroad ?			

c) Manufacturing Sites (Number)

Domestics (Home base)? ________.
Abroad ? ________.

d) Does the company utilize Toll Manufacturing & Market Swap agreements?

Domestics (Home base)? Yes / No
Abroad ? Yes / No

e) Major sources of inbound feed material supply (indicate with a **X**)?

Sources	**In-house**	**External**
Domestics (home base) ?		
Abroad ?		

f) In what life cycle stage is the overall business and its products?
(Mark the appropriate box with an **X**)

Life cycle stage	***Products***	***Business***
Start-up/market development		
Growth		
Maturity		
Decline		

1.1.2 Business Structure

a) Does the company comprise of corporate and subsidiary businesses? Yes / No

b) Does the company have JV businesses? Yes / No

c) On what basis is the business structured?

(e.g. product families, regional structures, etc.)?

____.

____.

____.

____.

1.1.3 Some Business indicators

a) Company turnover and profit (R million)? ________________________.

b) Company's value chain cost distribution (cost as % of turnover)?

Function	%
Marketing and sales	
Outbound logistics	
Manufacturing	
Inbound logistics	
Sourcing: feedstock and process materials	
Business support activities (e.g. HR, Fin, Proc)	

c) Total inventory value as % of turnover? _________________.
(material, intermediate & final product inventory)

d) Direct supply chain cost as % of sales (relate to above?) ______________.

e) Company's asset replacement value (R billion)? ____________________.

1.2 Company and Industry's supply chain approach/orientation (only for petrochemical companies interviews)

a) Does the company follow a supply chain approach in managing its business?

If yes, how are the company and business units' functions structured to support a supply chain approach (i.e. cross functional processes)?

From a supply chain orientation point of view, does the firm recognize that internal integration by itself is not sufficient?

b) How does the organization incorporate supply chain considerations into the business strategies?

c) How are supply chain strategic drivers and objectives derived from the BUs and corporate strategy?

Is there a supply chain strategy in place with associated supply chain goals and performance measures?

What are the major components of your supply chain strategy (e.g. operations strategy, logistics / channel strategy, commercial / supplier strategy)?

d) What are the profile, adoption, focus and representation of supply chain thinking in managing your organization? (related to functions, disciplines, key positions, executive representation)

e) How complex are your company's supply chains? briefly assess the following:

Stages of the supply chain *(sources, inbound, plant, outbound, markets)*	
Customer base *(no. of customers local & abroad)*	
Range of products *(with associated inventory distribution requirements)*	
Nature of manufacturing processes *(continuous, campaign or batch)*	
Supplier base *(no. of feedstock & process material suppliers)*	
Logistics Service providers *(no. Transport, facilities, support services contracts)*	
SC Length - Geographical Spread & Reach *(SC operation model - upstream & downstream)*	
▪ *1st Tier (Local - Overland)*	
▪ *2nd Tier (Local and Abroad - Overland, Marine)*	
▪ *3rd Tier (Local and Abroad - Overland, Marine, Overland)*	

1.3 Company and industry's supply chain process approach

a) For the variety of supply chain processes utilized in you organization, what major supply chain process categories could be used for grouping?
(The following serve as an example)

- Physical and inventory flow processes [*across the physical supply chain network*]
- Transactional processes [*Workflow clearly defined ; tasks in succession*]
- Information processes [*for sharing, exchanging information and collaboration*]
- Planning and decision making processes [*to support and enable supply chain decisions*]

____.

____.

____.

____.

b) Do the following categories of supply chain processes and sub processes (from AMR) also provide a useful framework?

- Supply chain planning (*sc network design, demand planning, supply planning, etc.*)
- Supply chain execution (*transport management, warehouse management, etc.*)
- Supply chain event management
- Supply chain performance management
- Reverse logistics/returns management

____.

____.

____.

____.

c) Are you currently using, or planning to use the SCOR model (Supply Chain Operations Reference Model - *from the Supply Chain Council*) as a basis to align the supply chain approach/orientation in your organization?

____.

____.

____.

____.

1.4 Company and Industry's supply chain planning and decision making processes

a) Related to your supply chain, what are the major short, medium and long term supply chain decisions formally taken in your company (key questions to be answered, also distinguish between what is currently considered and what is planned to follow in future)?

What are the typical considerations taken into account for these decisions?

What are the interdependencies between these major short, medium and long term supply chain decision?

Term	Decision/questions	Typical issues & considerations
Long-term (Company wide / across multiple Business Units)	SC logistics network synergies Freight densification Aggregate corridor risks Consolidation of contracts	
Long-term (per BU)	Strategic planning: (e.g.) Site selection - Manufacturing - Distribution centres Corridors of movement Trading and alliance partners	
Medium-term (per BU)	Tactical planning: (e.g.) - Inventory deployment	
Short-term (per BU)	Operational scheduling: (e.g.) - Production (product)	

____.

____.

____.

____.

b) For these decisions, what are the typical processes followed to explore, evaluate and make these decisions (*also relate to next question 1.4 (c) - see examples*)?

____.

____.

____.

____.

c) For these planning processes, what is the typical reach across the organization and within the relevant value chains?
(This relates to stakeholders involved in the process. Indicate the involvement by marking the associated stakeholder's block - within or external to the organization)

Examples of typical direct supply chain planning processes (for decision-making)	Across company boundaries	Across BU's in the same company	Within a specific business unit or subsidiary business				
			Marketing and Sales	Outbound logistics	Manufacturing	Inbound logistics	Procurement *(For feedstock)*
Cross-functional (within BUs)							
Supply chain network design							
Demand planning and forecasting							
Supply chain/inventory planning							
Distribution planning							
Manufacturing planning							
Feed procurement / supply planning							
Distribution scheduling							
Feed procurement scheduling							
Production scheduling							
Across multiple enterprises, company-wide (across BUs)							
Upstream chemical feed clusters *(Inventory flow dependencies)*							
Macro SC network alignment *(Logistics Synergies)*							
Strategic sourcing *(Commercial Synergies)*							
Risk reduction *(Aggregate Effect)*							
Technology governance *(Standardizing systems & data models)*							
Manpower planning *(Critical jobs & cross-BU succession)*							

d) What analytical techniques (OR/MS) are used to support these decision-making processes?

____.

____.

____.

____.

e) What information sources are used to provide the relevant data required by these decision-making processes? What challenges exist regarding the availability of this key information (e.g. transparency, range, quality, timeously)?

____.

____.

____.

____.

f) What major performance measures (metrics) are used to assess the effectiveness of these decision making processes and how are they related to supply chain leavers?

Performance measures	Supply chain leavers

____.

g) What Decision Support Systems (DSS) are used to enable these processes and utilizing the analytical techniques mentioned under question 1.4 (d)?

____.

____.

____.

____.

h) How does the contribution of the DSS get recognized in unlocking and enabling value for the supply chain decision-making processes?

____.

____.

____.

____.

i) What critical people competencies are required for supply chain planners to get maximum contribution from advanced planning and scheduling processes (*including the use of OR/MS techniques and DSS systems*)?

____.

____.

____.

____.

j) What management components are required to support these decision making processes? *(the following are some examples)*

- ***Physical and technical*** *(planning and control methods, work flow /activity structure, organization structure, communication and information flow facility structure, product flow facility structure, key positions/jobs)*
- ***Managerial and behavioural*** *(power and leadership structure, risk and reward structure, culture and attitude, management methods, key competencies)*

k) From a supply chain approach and using supply chain planning processes, what big opportunities and potential value add benefits do you believe exist?

1.5 Supply chain planning challenges for the petrochemical Industry/companies

a) What are some of the major fundamental differences between the process industry and other discrete manufacturing industries?

b) How does SA petrochemical industry differ from the global petrochemical industry and what unique supply chain challenges does it bring?

(RSA challenges v/s international? Degree of regulation and effect? How is the environment changing and what issues and dilemmas are being faced?)

c) What limits the SA petrochemical companies' success in following a SC approach?

d) What strategies could be used to break down silo/secrecy mentality and autocratic command-control practices in large scale petrochemical companies to get cross-functional cooperation and collaboration supply chain going?

e) What major competitive challenges are SA petrochemical companies facing to compete globally?

Examples: *The volatility of the rand*
Inadequate infrastructure (op parts, rails)
Our costs to manufacture are too high
Our physical location in the world
The foreign market's perception of SA
Inadequate incentive/support from the government
Our quality/price ratio is too high
Import duties are too high

1.6 Supply chain planning opportunities for the petrochemical Industry/companies

a) Which are the "dominant petrochemical value chains”?
(Taking a perspective from feedstocks and to their derivatives)
(The seven feedstocks: Ethylene, Propylene, C4’s, Benzene, Toluene, Xylenes, Methane)

What determines dominance (Revenue, Volume, End use)?

____ .

____ .

____ .

____ .

____ .

b) Related to the above, what major strategic value chain decisions need to be made in petrochemical organization?
(e.g. Clusters for feed allocation, investment / expansion, netback, etc.)

____ .

____ .

____ .

____ .

____ .

c) Which “clusters of value chains” form a good basis for value and supply chain collaboration?
(Where more than one value chain share a common interest (e.g. Feedstock, Inventory, Customer, Infrastructure, etc.)

____ .

____ .

____ .

____ .

____ .

1.7 Best practices used in supply chain planning

a) Which of the following best practices are applicable in the process industry and are used in your company's supply chain planning domain (mark with a **D** if directly applicable, **I** if indirectly applicable or **N** if not applicable at all)?

	Whole supply chain	**Inbound**	**Manufacturing**	**Outbound**
Hierarchical Planning *(To integrate: Strategic-, Tactical Planning and Operational Scheduling)*				
MRPII *(Material Requirements Planning)*				
DRP *(Distribution Requirements Planning)*				
JIT *(Just in Time)*				
TQM *(Total Quality Management)*				
TOC *(Theory of Constraints)*				
Other (e.g. CPFR, S&OP, etc.)?				

b) What typical methods are used for supply chain planning process improvement?
e.g. BPR (More suited for well defined and discrete processes; e.g. Admin)
SCOR (Used for project in supply chain improvement)
TQM (Needed for flexible judgement and collaboration type processes)
Best Practice Benchmarking

____.

____.

____.

____.

c) What Process Mapping techniques are used for visual presentation?
e.g. Organizational descriptive language
Event process chain modelling
Integration Definition for Function (IDEF)
SCOR (Swim Diagrams)/cross-functional flow diagrams

____.

____.

____.

____.

1.8 Supply chain planning intervention approaches followed

a) Were/is there a need to change/enhance the supply chain planning processes in your organisation? Compelling factors driving the need for change? What are the key issues for "business case development"?

b) What approach and process (with major milestones indicated) were used/will be followed to tackle a supply chain planning intervention?

c) How were/will the supply chain planning interventions driven/be driven?

e.g. *Internally driven*
Internal with some external assistance
Externally driven (consultant/SC partner)

d) What key enablers helped with managing the change?

e.g. *Communication, sponsorship, vision clarity*, *readiness assessment*, *transition planning* ,*transition implementation*

e) What were the key supply chain planning issues/lessons learned with the interventions?

e.g. *Planning process approach*
OR techniques used
Enabling technology application

f) What are the key requirements for sustainable change relating to supply chain planning implementations?

Advanced supply chain planning need to be properly introduced into a corporate culture. You don't get sustainable change if you can't implement software. You don't get sustainable change if the people don't use the software. If it takes too long to implement and to get the return on investment, you don't get the benefit.

1.9 Supply chain planning - enabling technology solutions

a) What are the key considerations to take into account when selecting the appropriate supply chain planning enabling technology in the process industry?

b) What are the key considerations to take into account when selecting the appropriate supply chain planning enabling technology vendor(s)?

____.

____.

____.

____.

c) What major data repositories are / will be established and used for the supply chain planning applications?

e.g. *Within ERP solution*
Outside ERP solution
Within or outside organisation?
Data warehouse?

____.

____.

____.

____.

1.10 Organizational issues

a) What are the major challenges and organizational issues encountered while changing from vertical to horizontal process focused structures?

____.

____.

____.

____.

____.

b) What type of organizational structure/approach best enables true supply integration and allows and promotes cross-unit cooperation?

____.

____.

____.

____.

____.

c) What leadership styles and leadership competencies did you find are working well for supply chain planning groups?

____.

____.

____.

____.

____.

2. Section II : Questionnaire - level of advancement

2.1 Level of supply chain adoption and approach

a) Depending on you company's competitive environment, indicate which one of the following statements gives a true indication of the supply chain approach within you organization.

Indicate with an ***X*** *or* ***N/A*** *if Not Applicable to you company.*

Focus	Indicators	Mark
Cost focus	Supply chain is only viewed as area for cost control	
Customer focus	The company recognizes that by adopting a supply chain approach, it could have a revenue enhancing impact on sales	
Market differentiating focus	A supply chain approach is one of the key ways in which a firm can differentiate itself from its competitors	
Strategic focus	One of the firms strategic / competitive advantages is associated around its integrated supply chain activities	

2.2 Dimensions of advancement in supply chain integration

Related to the supply chain decisions indicated in section 1.4 (a) and (c), give an indication of the level of advancement in the dimensions following.

2.2.1 Horizontal *(SC Stages)* and Hierarchical *(SC Decision impact)* integration

Indicate on the following matrix what level of supply chain decision integration has been achieved in the business units of your organization:

Use a scale of; **S** - Still Developing, **M** - Mastered or **N/A** if Not Applicable

(A) Horizontal SC integration advancement: **Supply chain reach** ***(Supply chain partners involved)***	**(B) Hierarchical decision integration** **Decision making level involved** ***(Decision impact & time scale)***		
	For a Business Unit		
	Short Term	Medium Term	Long Term
	Execution and local operational processes (e.g short term scheduling)	*Tactical planning (e.g material requirement & distribution planning)*	*Strategic planning (e.g. supply chain network design)*
Internal BU Integration: ***Within each department / function / Facility*** of the Business Unit (e.g. within logistics - vehicle loading & dispatch)			
Internal BU Integration: ***Across departments / facilities of a Business Unit*** (e.g. procurement, production, logistics, marketing, R&D)			
External / ***Backwards integration: BU with its own upstream SC partners -*** *BU* with its own 1st tier suppliers & logistics service providers			
External / ***Forward integration: BU with its own downstream SC partners -*** with its own logistics service providers & 1st tier customers			
External integration ***(upstream & downstream)***: ***BU with its own SC partners -*** (Customers, 3PLs, logistics management, plant, suppliers)			

2.2.2 Petrochemical value chain clusters and supply chain decision integration

Starting with large volumes of coal, oil, gas or naphtha feed, these materials typically get transformed into the two major value streams of petroleum products and the higher value add chemical products (starting with the seven basic chemical feedstocks). The chemical feedstock are refined further into higher valued commodities, derivatives and finally into fine and specialty chemicals ready for end use applications. The divergent nature of the petrochemical industry's value chain brings with it a number of critical value chain business decisions (These long-, medium- to short-term decisions ranging from further refining, investment, site selection, tactical derivative/intermediate blending to inventory allocation for regions/customer).

Supply chain realities, constraints and costs should however be considered and influence value chain decisions to ensure feasibility and optimality. Value Chains however form the background for supply chain decisions (These decisions are typically iterative by nature).

Value chain decision characteristics:
- value add and profitable feed allocation/unconstraint/financial perspective

Supply chain decision characteristics:
- networks/constraints/physical /feasibility/operability perspective/lead time

a) Related to the above and section 1.6 question (c), what progress has been made in your company in integrating the value chain and supply chain decisions (Long, Medium and short term)?

____.

____.

____.

____.

b) Related to petrochemical value chain clusters, indicate what level of supply chain decision consideration has been incorporated in your organization on the following matrix:

Use a scale of; **S** - Still Developing, **M** - Mastered or **N/A** if Not Applicable

(C) Extent of petrochemical value chain clusters decision integration *(Could be: - Vertical integration, - JV contract, or - Term Contract)*	**Level of supply chain decisions considered**		
	Short-term *(e.g. Production scheduling & order promising)*	**Medium-term** *(e.g. Inventory distribution & allocation)*	**Long-term** *(e.g. Site selection & SC network design)*
Single BU with 1st **upstream** chemical feed sources			
Single BU with **upstream** feed source(s) **and downstream** derivative consumer(s)			
Multiple BUs & JVs that **collaborate in a specific feedstock value chain** and take a “profitable volume” allocation approach.			
Multiple BUs & JVs that **collaborate across feedstock value chains** and take a “profitable volume” allocation approach.			

2.2.3 Cross-business unit, company or industry logistics network integration

This type of integration only really comes into play where cross-business unit or cross enterprise logistics network synergies exist.

These synergies could exist in freight corridors, trade-lanes, shared infrastructure, compatible products / packaging formats.

The types of logistics networks that could co-operate are the following:
- *Liquid bulk (e.g. Hexene, Acetone, MEK, Fuel, Phenol)*
- *Dry bulk (e.g. Coal, Salt, Sulphur)*
- *Packaged goods (e.g. boxed waxes, containerised polypropylene, bagged fertilizer)*
- *Bulk gases (e.g. Propylene, Ethylene, LPG, Town Gas)*
- *Containerized gases (e.g. cylinders, tank containers)*

a) Indicate what level of integrations has been achieved by your organization on the flowing matrix:

Use a scale of; **S** - Still Developing, **M** - Mastered or **N/A** if Not Applicable

(D) Extent of logistics network integration	**Level of supply chain decisions considered**		
	Short-term *(e.g. Shipment consolidation)*	**Medium-term** *(e.g. Freight consolidation on Corridors)*	**Long-term** *(e.g. Shared infrastructure investment)*
Same enterprise: corporate unity in upstream / backwards integration with first tier suppliers and logistics service providers			
Same enterprise: corporate unity in downstream / forward integration with logistics service providers and first tier customers			
Same enterprise: corporate unity in downstream and upstream integration cooperation of the corporate entity (e.g. shared infrastructure and economies of scale)			
Petrochemical industry: upstream of multi enterprises - backwards integration with first tier suppliers and logistics service providers			
Petrochemical industry: downstream of multi enterprises - forwards integration with logistics service providers and possible market swap out agreements			
Petrochemical industry: downstream and upstream integration / cooperation for the corporate entities (e.g. shared infrastructure and economies of scale)			
Multiple industry: downstream and upstream cooperation for the synergistic cluster (e.g. shared infrastructure and economies of scale)			

2.3 SC Planning processes and techniques used - test advancement

a) By considering the following analytical methods, please indicate what level is used in different supply chain planning processes:
(Refer to answers in section 1.4 (a) and (b))

Level 1: *Rule of Thumb and gut feel*
Level 2: *Rule-based methods (e.g. heuristics and artificial intelligence)*
Level 3: *Descriptive, advanced heuristics and local optimality models (e.g. forecasting models, simulation models, simulated annealing or genetic algorithms)*
Level 4: *Global optimization algorithms and mathematical programming models (e.g. Linear Programming (LP), Mixed Integer Programming (MIP))*

Indicate with an ***X*** *or* ***N/A*** *if Not Applicable to you company*

SC Planning Processes	**Advancement in Level of analytical techniques used**			
	Level 1	Level 2	Level 3	Level 4
Long-term (Macro/company wide)				
Long term (per BU) Strategic planning processes:				
Medium-term (per BU) Tactical planning processes:				
Short-term (per BU) Operational scheduling processes:				

2.4 Decision Support Systems (DSS) used/applied in supply chain planning

a) By using the following matrix, please indicate (by marking the appropriate block with an **X**) the implementation status of the major categories of supply chain management tools:

Major categories of supply chain management tools	**Implementation status**			
	No plans to install	Planning to install	Busy installing	Has installed; system in use
Supply chain configuration tools *(strategic, network design)*				
Demand planning tools *(to predict future demand)*				
Supply planning tools *(to match supply and demand)*				
Inventory distribution planning tools *(to plan the deployment of inventory)*				
Transportation planning and management tools *(Transportation selection, sequencing and tracking)*				
Warehouse management tools *(Transactional, managing activities between the four walls)*				
ERP tools *(The single data model; transactional backbone)*				

b) By using the following matrix, please indicate the level of advancement in supply chain information management systems for decision support:

Use a scale of; **S** - Still Developing, **M** - Mastered or **N/A** if Not Applicable

Advancement in information management systems	**Mark**
Data in distributed disparate repositories; no shared master data model *(Difficult to share and aggregate data to information)*	
Data kept in decentralized repositories but structured according to a master data model *(databases organized according to supply chain structural elements; e.g. transport, facilities, customers)*	
Data abstracted from transactional repositories to form supply chain information according to a master data model	
A central shared data warehouse exits and integrated with the supply chain decision support tools	