

FRAMEWORK FOR ADVANCED SUPPLY CHAIN PLANNING: LARGE-SCALE PETROCHEMICAL COMPANIES

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Abstract

Most petrochemical companies are undergoing radical changes. The markets being served have expanded globally, customer service expectations have increased, and demand has become much more volatile and hence less predictable. The resulting product supply chains evolve/develop over time, with integrating decision-making processes and advanced planning practices becoming more prominent. A proactive approach with longer time horizons becomes the norm for excellence. Refinery expansion and highly integrated/sophisticated manufacturing technology have also contributed to increased interdependency within and between supply chains (upstream to feed sources, downstream to end consumer, and between logistics networks). These developments resulted in what is termed advance supply chain planning. Notwithstanding its unique differences, the petrochemical industry still has a lot of ground to cover before it can reach some of the advance supply chain planning benefits reported in other industries. This article presents what is believed to be an appropriate supply chain planning approach/framework for decision making in large-scale, integrated petrochemical companies.

Keywords: petrochemical industry, strategic planning, supply chain planning, value chain

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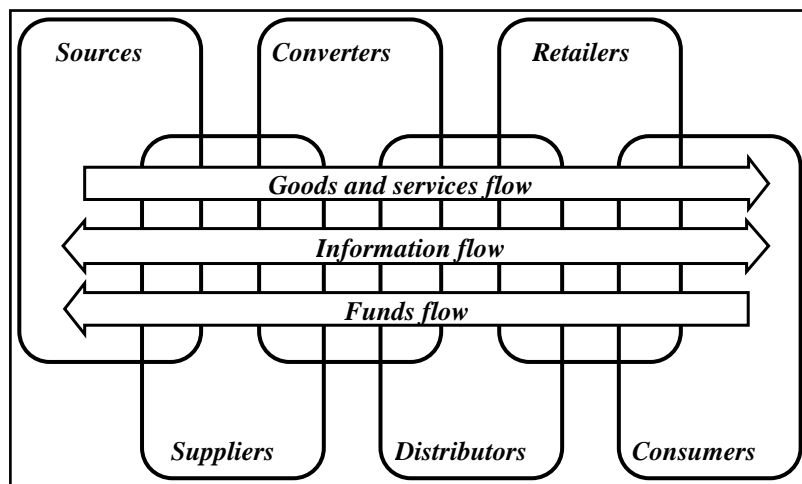
Introduction

Supply chain approach

The original value chain concept (introduced by Porter) is based on a process view of an organization. This view approaches a manufacturing (or service) organization as a system made up of subsystems, each with inputs, transformation processes and outputs (Porter, 1985:37). The value chain concept identified nine strategically relevant activities that create value and costs in a specific business. Of these nine, five activities are viewed as primary successive activities: inbound logistics, operations, outbound logistics, marketing and sales, and service. (The other four activities relate to support activities.) The scope of primary activities extends from the suppliers of raw materials to the point of finished goods consumption by the customers of an organization.

A supply chain is the physical representation of a business's value chain. A supply chain exists for each product/product family (viewed as a "product supply chain" in this article). The supply chain 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, operations and outbound logistics) (Pienaar, 2010: 448).

With a broadened supply chain perspective (inter-company cooperation) the supply chain is considered as an extended enterprise and similarly suggests that all firms involved should focus their sequential but cumulative efforts on quality, dependability, flexibility, agility and, finally, cost efficiency (Chapman et al., 2002:60). The extended enterprise (as illustrated in Figure 1) forms the basis of how supply chains may pursue objectives for each of these priorities (the basis for competitiveness in the future).

Figure 1. The extended enterprise and the virtual supply chain

[Source: Christopher, 1998:266]

A North American supply chain benchmarking study conducted by the Performance Measurement Group in 2002/3 (with 60 companies participating) indicated that well-developed supply chain planning processes are critical to achieve a competitive advantage (Wawszczak, 2003). Companies with mature and advanced planning practices were found to be 38% more profitable than average companies (relating to four stages of advancement).

Combining mature planning processes with advanced planning systems contributes to additional supply chain performance improvements. Wawszczak (2003) concludes that:

“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”.

Petrochemical companies in context and 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, or purifying, or by chemical reaction. Discrete manufacturing uses a bill of materials (with the product supply chain convergent in nature) to make each finished product. Process industries often end up with a greater variety of products than raw materials, resulting in a bill of products (with the product supply chain divergent in nature) as opposed to a bill of materials (Rossouw, 1994:26). Other differences relate to the type of technology employed, flexibility, product volume, capital required and unit cost. Process industries typically account for half of all

manufacturing and this share/sector/component is growing (Centre for Logistics, 2005:20).

The macro petrochemical value chain is characterised 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. Some products are made intentionally, while others are the result of the processing technology being used (co-products). The various stages of the macro petrochemical value chain typically deal with: raw material (e.g. coal, oil, natural 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 and resins) and speciality chemicals (e.g. adhesives, films and fibres, paints and additives).

Upstream of the processing facilities relatively 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.

Problem statement and objective

The primary objective of this research was to extract, compare and relate the relevant available knowledge to the petrochemical industry's supply chain structures and conduct. Large-scale petrochemical companies in South Africa were the prime focus of this study. Although the number of these companies is relatively small, their unique challenges are significant.

As petrochemical companies expand their sources and develop their markets globally, their supply chains become longer, more divergent, increasingly complex and more costly. Supply chain

planning becomes more advanced as the supply chain scope it covers expands (number of partners, decision domains), the planning time horizon extends, the level of detail increases, more sophisticated techniques are used and decisions become more complex.

Limited supply chain and supply chain planning literature is available that specifically focuses on applicable solutions for the petrochemical industry. Most supply chain literature focuses 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 those of other industries, a tailored approach needed to be developed to cope with new knowledge in this field of study.

Research methodology

An extensive literature survey was conducted, including more than 280 sources, to capture knowledge gained through relevant studies and appropriate publications. The literature study aims to lay the theoretical foundation for an appropriate supply chain planning management approach.

The literature survey was supplemented by empirical research to obtain more information. Because of the small population size in South Africa related to this research, key stakeholders in the industry were identified and used as a mechanism to support the findings and recommendations. The empirical research consisted of the following:

- *Semi-structured one-to-one interviews* were conducted with 21 stakeholders to clarify the best practice, concepts and approaches adopted by key academics, consulting practices, industry leaders and technology providers;
- A *questionnaire* was used (and completed during the interviews) to assess the level of advancement in the identified planning business processes within the relevant different supply chain dimensions.

The literature study and first portion of the empirical research (interviews) formed the basis for developing a generic framework for relevant planning processes within the identified supply chain dimensions. Subsequently, a generic framework for advanced supply chain planning was 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 advancement in supply chain planning process integration.

Synthesis from the literature study and empirical research

From the literature reviewed and empirical research conducted, it became evident that abundant research studies are available and many approaches have been developed/followed on how to plan and manage supply chains for individual products or product families. Although these approaches provide a sound basis for managing individual supply chains, they cannot provide appropriate solutions for the supply chain challenges faced by large-scale integrated petrochemical companies for two reasons. Firstly, supply chain processes utilized for liquid and discrete products differ with respect to the supply chain practices applicable (e.g. continuous vs. discrete flow dynamics) (Klatch & Walker, 2005:90). Secondly, interdependencies exist within and across supply chains for petrochemical manufacturing companies which are not always found in discrete manufacturing processes. 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).

There is 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 supply chain decisions will guide medium- and short-term decisions and ultimately actual operations (Fleischmann, Meyr & Wagner, 2000:58, 63). There are, however, few petrochemical companies that have expanded their supply chain thinking to include additional value-adding dimensions of supply chain planning in their interdependent chemical supply chains and logistics networks.

The supply chain focus and planning can 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: backward integration with suppliers, 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).

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 that are 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. 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 global competitive pressures, supply chain complexity has increased dramatically (Cecere, 2006). Companies are now starting to realize the major role that supply chain planning can play in dealing with these increased complexities.

The use of Operations Research (OR) techniques within appropriate supply chain planning processes to support sound decision making still leaves major room for improvement. OR techniques can provide the proper analytical basis to ensure sound decision making for complex supply chain problems based on facts, rather than perception and judgement alone. Many supply chain managers still lack a basic understanding of the OR techniques applicable to the supply chain discipline (Frazelle, 2002:15). Decision support systems that incorporate OR techniques have developed significantly and their application is growing.

Proposed supply chain planning framework

The proposed supply chain planning framework is logically structured and consists of the following progressive elements: (a) an appropriate philosophy, (b) concept, (c) guiding principles, (d) typical petrochemical supply chain decisions, (e) the supply chain planning processes themselves, and (f) the means through which planning processes should be enabled. Each of the elements is briefly discussed in the following paragraphs.

Petrochemical supply chain philosophy

In future, supply chain leaders in the petrochemical industry will leverage their supply chain approach and capability to distinguish themselves from their competitors. They will look outside their own manufacturing operation for bottom-line improvements (and not primarily focus on reduction of manufacturing costs) (Whitfield, 2004). 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' demands.

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. Fostering a supply chain culture will drive the correct values and required behaviours for a true supply chain approach (Brosset, 1999:21; Keen, 1997:107).

Appropriate 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.

By evaluating future demand requirements and constraints, supply chain planning processes ensure a proactive approach and enough time to prepare supply chain operations properly for synchronized execution. Supply chain planning will play the key role in aligning all the supply chain partners to reach a common goal on strategic, tactical and operational levels.

By following a holistic integrative approach and removing organizational barriers (silos) between interdependent chemical value chains, process-wide optimality can be achieved. As a rule this is far better than the local optimization of the individual value chains. 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. This moves beyond this first plateau and can be viewed as *inter-supply chain integration*. Inter-supply chain integration can typically develop within three dimensions:

- Upstream chemical feed interdependencies/synergies;
- Downstream product interdependencies/synergies;
- Macro logistics network interdependencies/synergies.

Concept of advanced supply chain planning

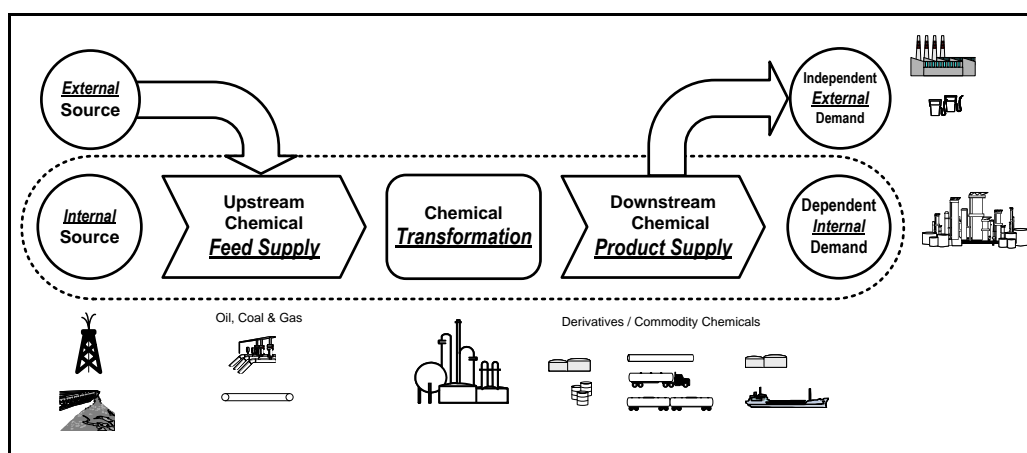
Supply chain planning supports the Supply Chain Management (SCM) objectives to minimize the total supply chain cost, to maximize net revenues and to

achieve non-monetary objectives, such as customer service, availability, reliability, product variety and quality. A supply chain must be viewed as one system (Lummus, Krumwiede & Vokurka, 2001:428), since changes at one segment of a supply chain affects the overall performance of the whole supply chain.

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 2). Sources for chemical feedstock supply could either be

internal or external to the business. The demand for final product supply could also be internal or external to the business. The external demand is typically viewed as an independent demand (external consumers' demand driven by their own business dynamics). On the other hand, internal demand is viewed as a dependent demand, since the downstream consumptions can be derived from known drivers (e.g. downstream production plan/schedule).

Figure 2. A petrochemical value chain with its associated supply chain elements



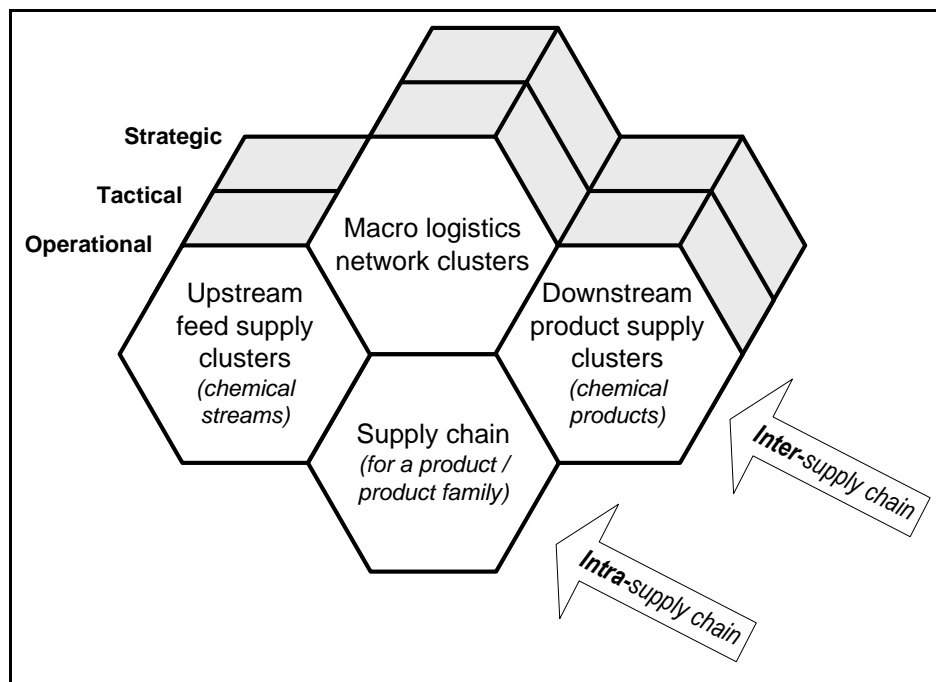
Tightly interdependent value chains form value chain clusters (upstream and downstream in the macro petrochemical value chain). These chemical value chain clusters then closely cooperate in balancing their interrelationships and aligning to reach shared objectives. Upstream, the focus is on collaboratively allocating scarce molecules profitably to downstream consumers. Downstream, the focus is more on collaborative inventory allocation to regions/customers and swaps/exchanges with other industry competitors (downstream product supply clusters). From a logistics perspective, large-scale petrochemical companies can work more closely within themselves, within the chemical industry, and also with related industries (e.g. chemical, paper and pulp, and chemicals and paints). Interdependencies can exist related to storage at facilities, and transportation along specific corridors (represented by the key logistics service providers).

Figure 3 indicates the expanded chemical supply chain operations and decision domains (two distinct advancement stages) that supply chain planning processes should cover. These two stages relates to *intra-supply chain* (for a product/product family) and *inter-supply chain* (interdependencies/synergies across supply chains or segments thereof).

Guiding principles related to the petrochemical industry

A number of principles related to a supply chain planning approach are briefly noted and described.

- A supply chain exists for each product/product family. A supply chain is the physical representation of a business's value chain (Stephens, 2005).
- 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 (Dawe, 1996:112).
- Progressing from intra- to inter-supply chain thinking will become a competitive requirement in the petrochemical industry. In the petrochemical industry the level of interdependencies is such that individual supply chains must work together in value clusters to ensure optimal and feasible plans for each related supply chain.

Figure 3. Expanded chemical supply chain operations and decision domains

- Supply chain planning processes enable supply chain decision making and ultimately guide supply chain execution activities. Supply chain planning processes exist within and relate across three decision layers, namely: strategic (long-term), tactical (medium-term) and operational (short-term) (La Londe, 2005).
- 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 for fact-based analysis and decision making (Vakurka & Lummus, 2003:55).
- Decision domains exist along and between individual supply chains. Many decision domains could exist along a supply chain (because of functional domains and different parties involved in the supply chain) or between segments/elements of supply chains. These domains require cross-coordination to ensure effective supply chains.
- Effective supply chain planning orchestrates the synchronised flow of goods. This is achieved through adherence to a single transparent demand-and-supply plan and execution in a well coordinated fashion.
- 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.
- Appropriate planning performance measures should be used for each supply chain planning timeframe. These performance measures (reaching across the whole supply chain) can then be used as the means of measuring how some of the agreed-upon supply chain objectives are achieved (Higgins & Hack, 2004:43).
- Independent demand to drive dependent demand (through causal relationships). The projected off-take is dependent on the expected sales of finished goods (independent demand) (Miller, 2001:90-91).
- Supply chain planning involves collaboration and coordination. Collaboration requires a climate of trust and cooperation (for information sharing on foreseen demand/developments and visibility of the current activities). Collaboration is a key approach to breaking down secrecy and a silo mentality along the supply chain.

Petrochemical supply chain decisions

Supply chain decisions should be guided by the overarching corporate and business decisions. The competitive environment faced by an enterprise and its subsidiary businesses 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.

Intra-supply chain decisions typically cover a number of decision areas across the long-, medium- and short-term timeframes for a specific supply chain. Brief descriptions of the different supply chain decisions timeframes are given below.

Long-term supply chain decisions, looking 1 to 5 years ahead in monthly, quarterly, yearly time buckets. (Mindset: Strategise and prepare.)

Taking account of corporate and business strategic decisions (having a long-lasting effect), the business's 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, manufacturing and distribution of products to the marketplace served. Strategic supply chain objectives and targets are also determined.

Medium-term supply chain decisions, looking 3 to 6 months ahead in weekly and monthly time buckets. (Mindset: Structure and organize.):

Working under the umbrella of the long-term decisions (e.g. supply chain network, prescribed material flow-management policies), the prime focus is on converting the supply chain strategy into supply chain operational plans. Medium-term decisions also focus on optimizing supply to the market within the supply chain resource capability available.

Short-term supply chain decisions, looking 1 to 4 weeks ahead in hourly, daily & weekly time buckets. (Mindset: Commit and control.):

Conscious of the medium-term economics (e.g. profitable product allocations, crude slate decisions already taken), the prime focus is on converting the supply chain operation plans into supply chain operation schedules.

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. Three typical dimensions for grouping inter-supply chain decisions are: (a) macro logistics network, (b) upstream feed supply clusters, and (c) downstream product supply clusters.

Supply chain planning processes

Supply chain planning processes exist to support supply chain decision making. Different supply chain decisions are taken in the long-term (strategic), medium-term (tactical) and short-term (operational) timeframes.

Figure 4 indicates 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 by each of the planning processes (bottom of Figure 4). In the paragraphs following, these processes are briefly described and their interrelationship indicated.

Strategic operations planning (intra-supply chain)

The strategic intra-supply chain planning processes related to long-term decisions for a specific business unit's supply chain focus on the design, structuring and configuration of individual supply chains and require contributions from all the supply chain partners involved (internal and external to company). These strategic planning processes include:

- Supply chain scenario evaluation: For the various business scenarios being considered, viable high-level supply chain alternatives are evaluated;
- Draft supply chain network design and configuration: A supply chain conceptual design proposal is developed for the selected supply chain alternatives describing viable and feasible supply chain structures, configurations and appropriate operational practices;

- Detailed supply chain operational and functional design: A supply chain functional/operational design is established/finalized by collaborating with key supply chain stakeholders;
- 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;
- Supply chain implementation and commissioning: The operational implementation of a supply chain design forms a major part of a new business's establishment. Some of these major activities revolve around infrastructure, equipment design, operating procedures, contingencies and commissioning.
- Inventory deployment and replenishment scheduling;
- Order fulfilment scheduling;
- Feed supply scheduling (internal);
- Procurement supply scheduling (external);
- Supply chain execution monitoring.

Strategic operations planning (inter-supply chain)

Extended supply chain integration requires the use of appropriate advanced supply chain planning processes (for the systematic evaluation of all the long-term considerations). The scope of these processes reaches across the supply chains of individual business units (or relates to elements thereof). The extended dimensions of inter-supply chain interdependencies/synergies relate to upstream chemical supply clusters, downstream product supply clusters and macro logistics network clusters.

The inter-supply chain planning processes that emerged from the literature study and empirical research include the following:

Tactical operations planning (intra-supply chain)

Tactical operations planning focuses on the medium-term decisions for a specific business unit's supply chain. The two major overarching operations planning processes are *demand planning* and *supply planning*. Demand planning normally initiates the tactical operations planning processes and consolidates the anticipated/committed demand for a given supply chain's product(s). Supply planning determines the optimal supply plan to meet the anticipated demand. These two overarching processes interact with one another and eventually lead to the establishment of an agreed demand plan and a feasible, profitable operational supply plans (upstream, production and downstream). This process also relates to the popular Sales and Operations Planning (S&OP) approach followed in many businesses.

The supply planning process is broken down further into a number of sub-planning processes that are closely related to one another. These include:

- 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)

The scheduling of supply chain operations processes focuses on short-term operational coordination, synchronization and control. The daily and weekly operations activities must carry out the resource allocation and utilization decisions made at the tactical level. These supply chain operations scheduling processes include:

- External supply and exchange scheduling (product);
- Production scheduling;

- Consolidated macro supply chain scenario evaluation: The effect of large, company-wide business scenarios also requires proper evaluation from a supply chain perspective. These evaluations typically need to highlight potential synergies, opportunities, effect of interdependencies and potential risks;
- Macro logistics network synergy and interdependency evaluation: Major industry players within the same company and/or across related external companies collaborate on logistics synergies and interdependencies related to common logistics infrastructure that could be leveraged for mutual benefit (e.g. economies of scale, commercial synergies, mitigating aggregate risk);
- 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 synergistic opportunities. This can be achieved through a consolidation process (strategic sourcing practices). The aim is to reduce total cost of ownership (TCO) of materials;
- Chemical feed clusters supply planning: Chemical feed clusters supply planning takes an enterprise-wide perspective on the upstream segments of interrelated supply chains (supply chains that share common chemical feed streams). If there is 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 ensure enterprise-wide optimal decisions across

the related supply chains. Operational constraints should also be considered;

- Chemical product clusters supply planning: Specific situations may exist where related downstream chemical products are exchanged between supply chains. Product exchanges can occur within a large enterprise between business units or external to the enterprise. Other interdependencies relate to where more than one business unit produces the same product within a large enterprise. 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).

Enabling supply chain planning

A number of supply chain enabling planning processes exist that can enhance the execution of future operations planning and transactional activities. These include:

- Supply chain strategy formulation;
- Business process design and configuration (for planning and execution);
- Organizational design with anchor positions;
- Monitoring and control methods design (based on performance targets);
- Information technology enablement design.

Operations Research (OR) techniques and Decision Support Systems (DSS) also play an important role in enabling supply chain planning processes. Database systems, modelling tools and solvers (optimizers) form the basic building blocks for Decision Support Systems. 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 vital requirement for data aggregation and descriptive analysis. Modelling tools and solvers utilize OR

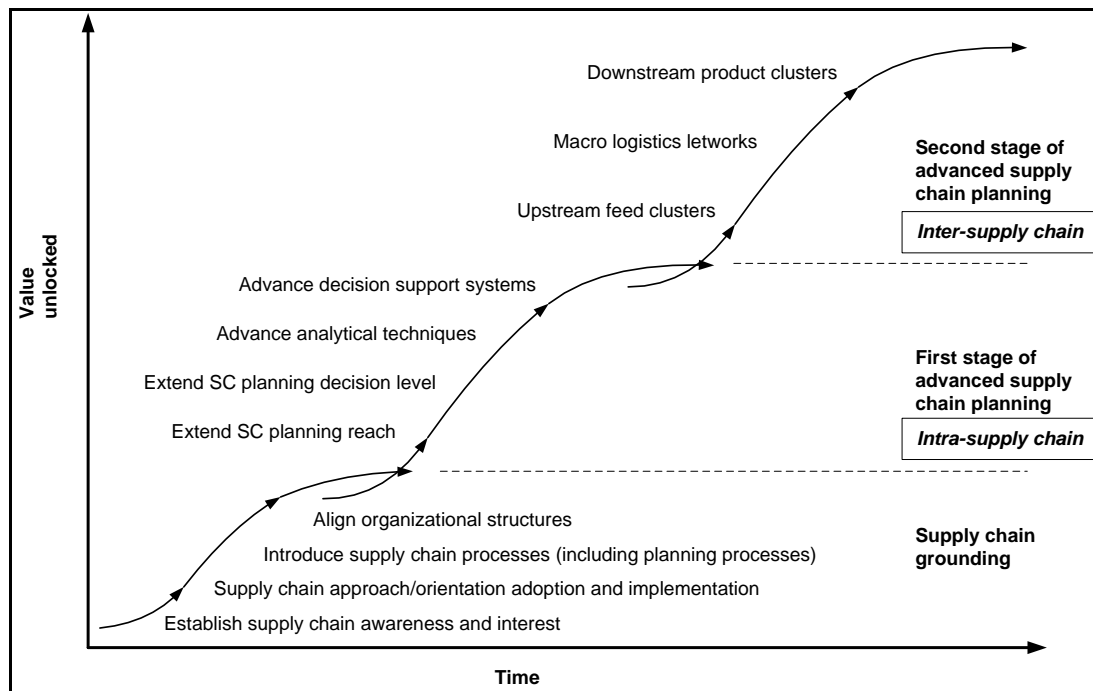
techniques to provide optimization capabilities. Descriptive and normative models are used to provide the appropriate analytical techniques in support of supply chain planning processes (Shapiro, 2001:10-12). Descriptive models typically enable the required business intelligence (e.g. forecasting models, simulation models) while normative models provide optimization capabilities (e.g. linear programming models).

Proposed roadmap for supply chain advancement

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 5. It articulates the different plateaus reached, which each 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 intervention related to planning should follow a programme approach (i.e. a set of initiatives supporting an agreed objective) and requires a focused champion to lead it. These initiatives normally require a “cross-section” of participants from all relevant functions and disciplines.

Any company that plans to implement advanced planning should typically evolve through advancement stages. Each stage covered provides the building blocks required for the next level of advancement. Advancement can be fast-tracked, however, based on a company’s readiness and capacity for change.

Key mechanisms that can be applied to aid the advancement of supply chain planning intervention include: planning process improvements and reengineering, advancement in analytical techniques, decision support systems’ advancement, change of management practices, organization design, role-definition and people-competency development, and continuous improvement practices.

Figure 5. Roadmap stages for advanced supply chain planning

Supply chain grounding basics

A number of basic building blocks are required to commence with the planning process. These building blocks initiate the first important stage to secure the proper grounding of supply chain basics in an organization. They include:

- Establish supply chain awareness and interest;
- Introduce supply chain processes (including planning processes);
- Align organizational structures.

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. By extending the reach of supply chain planning processes, more of the related internal functions in a business and external supply chain partners are integrated. Extending the supply chain planning processes decision level from the operational decision level to also cover tactical and strategic decision levels makes the supply chain more proactive and capable of responding to future customer demand requirements and foreseen operational realities. As businesses advance their supply chain scope (reach and decision level), the decision support models used to support the associated planning processes also expand from descriptive to optimization models (more advanced analytical OR techniques being used). The introduction of Advance Decision Support

Systems helps to embed and enable the supply chain supply chain planning processes.

Second Stage of advanced supply chain planning (across supply chains)

With each business unit's supply chain optimized and related internal functions and external supply chain partners extended, a business can start to advance its supply chain planning processes to incorporate the value-addition dimensions described earlier (i.e. upstream feed clusters, macro logistics networks and downstream product clusters.)

Requirements for sustainable change

Once a supply chain planning capability has been established, it is important to ensure that it can be sustained. The following are typical practices that can be utilized to sustain a supply chain planning capability:

- Apply holistic integrative thinking;
- Measure and report benefits;
- Show small benefits as soon as possible and reward champions;
- Publicize successes and share learning;
- Break the big interventions up into smaller projects (each with key deliverables);
- Ensure that all processes have owners;
- The new planning 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.

The roadmap outlined above is considered useful and appropriate in that it could guide a petrochemical company along the journey of advancing its supply chain planning processes and ultimately enhance its competitiveness.

The resulting framework for this research could also be applied to small to medium-sized chemical organizations, although they might not be faced with the same complexities as those of large-scale petrochemical companies.

The philosophy, concept and guiding principles derived in this article could also be applied in other industries where interdependencies between related supply chains (or segments thereof) become apparent.

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