

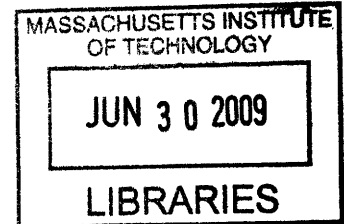
Supply Chain Management in the Cement Industry

by

Isabel Agudelo

Industrial Engineering
Pontificia Universidad Javeriana
Cali, Colombia. 1995

MBA
Los Andes University
Bogota, Colombia. 2001



Submitted to the Engineering Systems Division in Partial Fulfillment of the
Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

June 2009

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Signature of Author.....
Master of Engineering in Logistics Program, Engineering Systems Division
May 8, 2009

Certified by.....
Executive Director, Center for Latin-American Logistics Innovation (CLI) Partnership
Thesis Supervisor

Accepted by.....
Prof. Yossi Sheffi
Professor, Engineering Systems Division
Professor, Civil and Environmental Engineering Department
Director, Center for Transportation and Logistics
Director, Engineering Systems Division

Acknowledgements

I wish to thank the cement company which sponsored this project for sharing with me relevant information and for dedicating time from its employees to answer my questions.

I wish to thank the company I work for, Fundación LOGyCA, and especially to its director, Rafael Florez, for all the support and the confidence I received during the ten months of the program.

I wish to thank Edgar Blanco as a representative of MIT CTL he extended himself to work with Fundación LOGyCA and establish the Center for Latin-American Logistics Innovation (CLI), a center created to promote world class supply chain research and training in Latin America. I wish to thank Edgar for his personal and professional support during this year. I also wish to extend my gratitude to Yossi Sheffi, Chris Caplice and Jarrod Goentzel for this opportunity.

Finally, I wish to thank my husband, my family and my MLOG classmates to share with me the MLOG journey.

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ABSTRACT

Traditionally supply chain management has played an operational role within cement and mineral extraction commodity companies. Recently, cost reduction projects have brought supply chain management into the limelight. In order to clarify the reasons of the evolution of supply chain management and to demonstrate the value of efficient supply chain management within the cement industry, an analysis of the cement supply chain has been carried out using Michael Porter's five forces. In addition, a comparative analysis of the supply chain strategy of the four largest cement companies has been presented, according to Larry Lapede's excellent supply chain framework. Also, a characterization of the current cement supply chain has been done, using the Supply Chain Council's SCOR model processes; plan, source, make, deliver and return. Five authors' various frameworks of supply chain design have been used to gain insight into the general characteristics of the cement supply chain and propose a definitive supply chain strategy. Finally, three case studies from mineral extraction commodity companies have been presented to demonstrate the potential of supply chain management. The study concludes that supply chain management has tremendous potential to add value as a strategic function for companies in these industries.

Thesis Supervisor: Dr. Edgar Blanco

Title: Executive Director, Center for Latin-American Logistics Innovation (CLI)
Partnership

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1 Introduction

Commodity products are the starting point of manufacturing processes. They are normally tied to the extraction or exploitation of natural resources. The economies of developed and underdeveloped countries are based on commodity exploitation.

Cement is produced in more than 150 countries all over the world. Cement, as the most important ingredient of concrete, is essential in the development of infrastructure and construction in general. The level of advancement in cement and concrete Supply Chain Management (SCM) can facilitate or constrain world economic development.

The four research questions of this thesis are:

- What are the unique characteristics of SCM in the cement industry?
- Why SCM traditionally played an operational role in the cement industry?
- What is the right supply chain for cement?
- Can SCM generate value in the cement industry?

To gather information about the unique characteristics of SCM in the cement industry, SCM employees from three of the eight largest cement companies and one medium size cement company were interviewed. A list of the respondent companies and the interviewee position in the organizational chart are presented in Appendix A.

To enrich the analysis, three companies in the mineral extraction business; one in the oil industry, one in the coal industry and one in the steel industry were interviewed. The reason why these companies were interviewed is because they are facing similar SCM challenges as cement companies.

A questionnaire that covers the five logistics processes defined by the SCOR Model: Plan, Source, Make, Deliver and Return, was used to conduct the interviews. The questionnaire is presented in Appendix B.

This thesis is organized as follows. In section 3.1, a competitive analysis of the cement industry using Michael Porter's framework of five forces driving industrial competition was made, using the information gathered in the interviews and the information in the literature review.

In section 3.2 a comparative analysis of the supply chain strategy of the four largest cement producers was made using the Supply Chain Excellence Framework (Lapide, 2006).

In section 3.3 an analysis of the cement supply chain operating model using two perspectives: processes and product. The process perspective analysis was made using the SCOR model, the Four Types of Supply Chain Design Framework (Reeve and Srinivasan, 2005) and the Matching Supply Chain (SC) strategies with Products Framework (Simchi-Levi et al., 2008). These frameworks will be described in the literature review.

The product perspective analysis was made using the Demand Uncertainty Framework (Fisher, 1997), the Uncertainty framework (Lee, 2002) and the Triple A framework (Lee, 2004). These frameworks will be described in the literature review.

In section 4, three cases studies were documented to confirm that SCM can add value to the strategy of the cement and the mineral extraction commodity industry. The first case is the implementation of a single 3PL (Third Party Logistics Provider) by three of the largest oil companies in Colombia. The second case is a collaboration project between concrete and cement supply chain in Cemex Colombia. The third case is collaborative port operation contract in the steel industry.

Finally, a summary is presented with the conclusions about the evolution of supply chain management in the cement industry. The majority of these conclusions can be extended to the mineral extraction commodity industry.

2 Literature Review

The literature review covers six topics:

- Review of literature of SCM in the cement industry
- Cement industry background
- Definition of commodity products and the key factors in the evolution in their supply chain
- Michael Porter’s five forces model for the cement industry analysis
- Three frameworks used to analyze the supply chain strategy of the largest companies in the cement industry
- Six frameworks, the first three to analyze cement supply chain processes and the remaining three to analyze cement supply chain structure from a product perspective.

2.1 SCM research in the cement industry

Supply Chain Management (SCM) is a topic with limited research in the cement industry. A search made in April 6 of 2009 in Business Source Complete database from 1970 to present using the words “supply chain,” yields 47,101 records. A search within these 47,101 records with the word “commodity,” yields 659 records. A search within the 47,101 records with the word “cement” yields only 34 records. The same search in Compendex database within the same time period yields 4224 records for “supply chain,” 175 records for “supply chain” and “commodity” and only 37 records for “supply chain” and “cement.” Combining the records obtained and excluding common records and documents non-related to cement as a construction product, a total of 48 documents was classified into nine topics as shown in Table 1.

Cement supply chain management research topics reflect the major concerns of the cement industry like manufacturing, cement material management and sustainability.

Table 1. Supply Chain Research Topics in the Cement Industry

Topic	Quantity	Participation
Manufacturing	12	25.0%
Material management	10	21.0%
Sustainability	7	14.5%
Industry overview	7	14.5%
Distribution	6	12.5%
Demand management & Forecasting	4	8.3%
Transportation	2	4.2%
Total	48	100.0%

From an economic perspective, there is significant research about the cement industry by Pankaj Ghemawat from Harvard University. He is particularly interested in the history of Cemex, the third largest cement producer. 32 Harvard Business School cases are related to cement companies and ten of them are about Cemex. Research about Cemex from a Supply Chain perspective was made by Hau Lee and his research group in Stanford University.

In the sources reviewed, there was no conceptualization about the role of SCM or the right structure of the cement supply chain in the cement industry from a broad perspective, without focusing on a particular company. The focus of this project is to present an insight into the role and structure of SCM in the cement industry, and provide certain generalizations applicable to the overall extraction commodity industry.

2.2 Cement Industry Background

In general, cement is a mixture of limestone, sand, clay and iron. The most common type of hydraulic cement is the Portland cement. The term hydraulic cement is used

because cement hardens when mix with water. According to the Portland Cement Association (2008), “Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process.” Portland cement may be gray or white but blends can be generated based on the two products.

Cement is the major component of concrete. According to Van Oos (2005), concrete is “an artificial rock-like material made from a proportioned mix of hydraulic cement, water, fine and coarse aggregates, air, and sometimes additives.” Concrete can also be made from a ready-mix formula in a concrete plant. Concrete is one of the most important and widely spread building materials in the world.

According to Cembeureau (2008), the cement industry is capital and energy intensive, but not labor intensive. According to Lafarge (2007), the cost of a new cement plant is between 50 and 160 Euros per ton of annual capacity, depending on the country. According to Ghemawat (2002), the minimum scale that is efficient for a cement plant is approximately one million tons of annual capacity. Combining this information, the average investment for an efficient plant is approximately 105 million Euros. Labor usage in the cement industry is relatively low because it is a continuous process with a high level of automation.

A description of the upstream component of the cement supply chain, including sourcing of raw materials, manufacturing and delivery from the plant is shown in Figure 1.

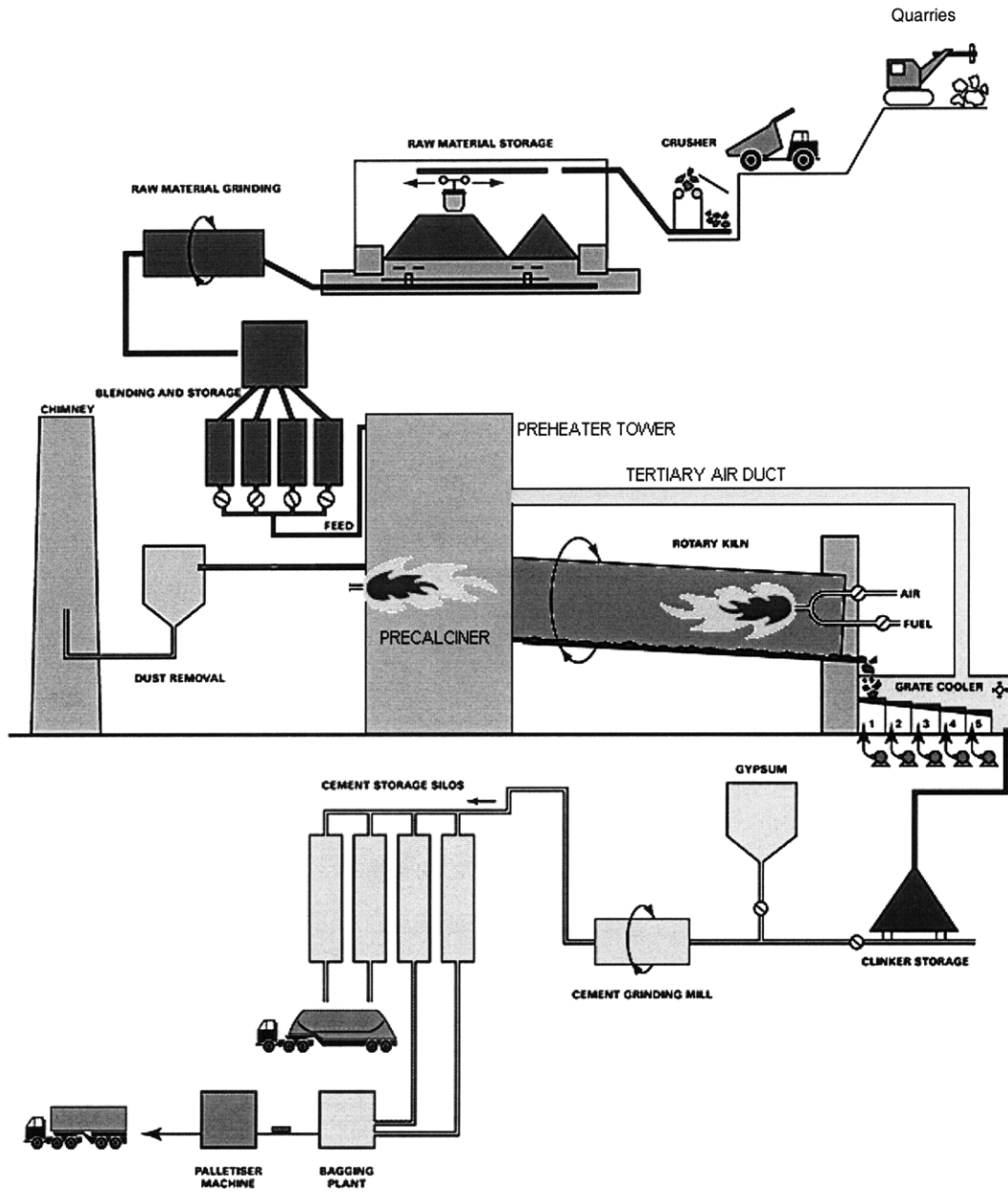


Figure 1. Upstream Cement Supply Chain. Source: Cemex (2008) [WWW Document] URL <http://rugby.cemex.co.uk/images/Howcementismade.gif> (visited 2008, November 2).

Cement plants are normally located near the quarries which are the source of their main raw materials. The main reason for their location is that 1.6 tons of main raw materials are required to produce 1 ton of cement. According to the information gathered, there are no constraints on the availability of main raw materials needed for cement.

There are two main steps in cement production. The first step is the production of clinker from raw materials. The second step is the production of cement from clinker. The first step requires raw materials to be transported to the plant and then to be crushed and homogenized to enter a big rotating pipe called a kiln. The kiln is heated to very high temperatures, and then it is inclined, allowing the raw materials to roll to the other end, where they are quickly cooled. The result is a solid grain called “clinker.” The second step is the transformation of clinker into cement in a grinding mill process. Additional elements like gypsum and perhaps other minerals might be aggregated to obtain a fine powder called cement. Finally, cement is moved to storage until a customer place an order.

According to the U.S. Geological Survey (2008) in 2006, cement world production was around 2.6 billion of metric tons. The production is highly concentrated in Asia – Pacific countries as shown in Figure 2.

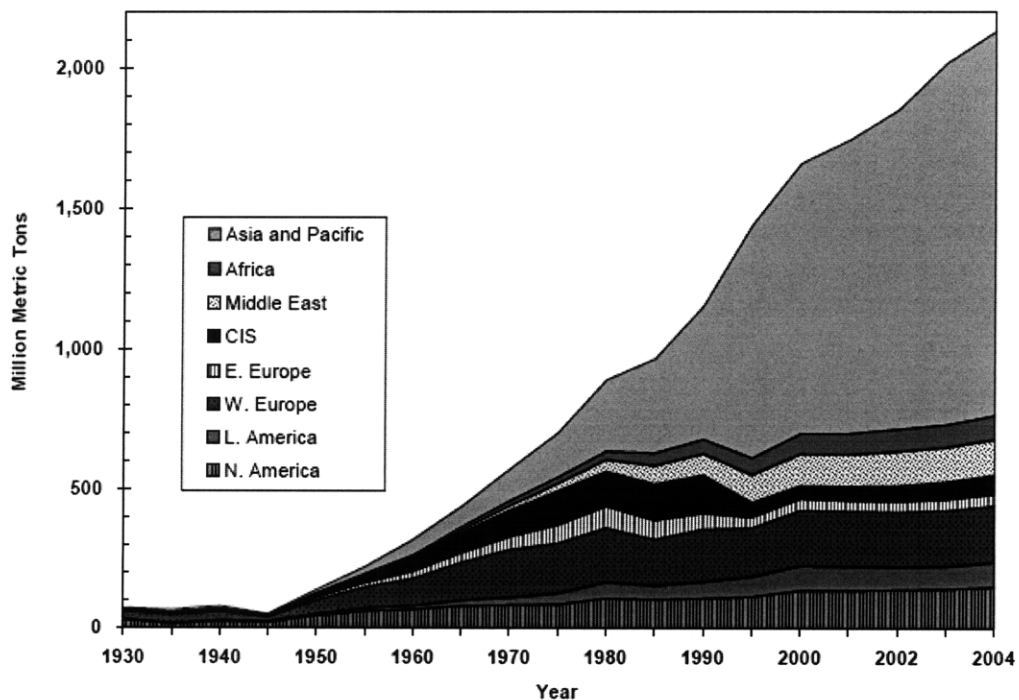


Figure 2. World Production of Hydraulic Cement by Region. Source: Van Oos, H (2005)

Cement is produced by a large number of companies all over the world, but only a few companies are global. Appendix C presents a summary of information about the largest cement producers.

The downstream component of the cement supply chain varies from country to country. Concrete (and therefore cement) demand is created in the short term by residential, non-residential and public sector construction. Cement sales are normally related to economic growth, macroeconomic factors and weather conditions. These issues have local and regional cycles.

Cement as a final product is sold in bulk or bags. Cement bulk is the normal way to distribute cement in developed economies. Bulk sales represent almost 90% of the US cement market. Concrete producers are the biggest customers. According to Cemex, bagged cement represents 80% of sales in emerging markets. Bags sales are strongly related to Do-It-Yourself (DIY) home construction.

There are two important challenges in the future of the cement industry: fuel costs and environmental regulations. Fuel concern is motivated by the high impact of fuel and energy in the cost of cement. Because of this situation, there are several research initiatives in alternative fuel sources for cement manufacturing and transportation.

Government regulations are related to carbon emissions and environmental protection.

There are three issues regarding this topic in cement production:

- Dust emissions and solid waste generated in the manufacturing process
- Air emissions generated from the kiln in the heating process
- Heavy metals in cement / concrete with the risk of leaching into drinking water

2.3 SCM in Commodity Products

The drivers that influence SCM in the commodity industry also affect SCM in the cement industry.

A commodity is a product or service that is widely available; and associated margins and product differentiation is typically low. In general, commodity prices are defined by supply and demand. According to Radetzki (2008), commodity represents “the value of output from the primary sector, comprising agriculture (including hunting, forestry and fishing), mining and utilities.” These activities provide raw and unprocessed materials for other sectors in the economy.

There are three issues related to the history of commodities that are significant to understand their current supply chain. The first issue emerges when a country moves from a lower to a higher level of economic development. The common pattern is that the relative importance of primary commodities decreases as the economy develops. Cement industry reflects this issue as shown in Figure 2.

The second issue is the impact of transportation costs in the trade of commodities. In the past, commodity price was very low compared to other products; thus the share of transportation cost in the total commodity price was high. With the entrance of technology in the rail and maritime transportation systems in the 1950s and the reduction in maritime freights, it was profitable to move commodities overseas. In some cases, it was cheaper to get commodity products from other countries than to purchase them locally. The impact of rail and water transportation development was

also extended to the cement industry. Because of this development, today it is possible to have Chinese cement with competitive prices in the west coast of the US.

The third issue is government intervention in the commodity market price and raw materials availability. According to Radetzki (2008) it is “reasonable to say that state interventionism is well past its peak” but recent geopolitical trends might change the current situation. Government intervention is also an essential factor for the cement industry. Normally, government controls cement raw materials availability through licensing and environmental regulations.

2.4 Industry Analysis Model

In his book *Competitive Strategy*, Michael Porter (1980) defines a model of structural analysis for industries. Porter (1980) suggests that a company must understand its environment to formulate a successful strategy. The term environment includes social and economic forces; some are generated within the industry and some are external to the industry.

The level of competition in an industry is determined by five competitive forces: threat of entry, rivalry among competitors, pressure from substitute products, bargaining power of buyers and bargaining power of suppliers. The level of influence of these forces controls the profit in the industry and therefore the return on capital invested by a company within the industry.

- *Threat of Entry* is generated by new entrants in the industry. They normally bring desire of market share, new capacity and resources. This force is controlled by the

barriers of entry and the reaction of current actors to new competitors in the industry. If barriers are high, the threat of entry is low. There are seven major barriers to entry in a new industry: economies of scale, product differentiation, capital requirements, switching costs, access to distribution channels, cost disadvantages independent from scale, and government policy (control by license requirements or access to raw materials).

- *Rivalry Among Competitors* occurs when one or more competitors detect an opportunity to increase margins or feel pressure from others companies. Tactics used are price competition, product introduction, customer service and warranties. The level of rivalry within an industry depends on the number of equally balanced competitors, industry growth, fixed or storage cost, product differentiation, size of capacity increments, competitor's diversity, competitor's strategic stakes and exit barriers.

- *Pressure from Substitute Products* has an effect of limiting the returns of the industry by creating a ceiling for product prices. If the substitute product price is more attractive, the industry profit based on the current product is limited. A substitute is a product that performs the same function as the industry product.

- *Bargaining Power of Buyers (BPB)* has the capacity to influence prices, product quality and services. Buyers can force competition among the industry suppliers and reduce industry profitability. Each of the following drivers increases BPB: buyer purchases large volumes relative to seller sales, seller's product importance on buyer's costs or purchases, type of product (standard or differentiated), buyer's

switching cost, buyer's profits, threat of backward integration from buyers, seller's product importance to the quality of buyer's product, and buyer's level of information.

- *Bargaining Power of Suppliers (BPS)* has the capacity of increasing prices or reducing product or service quality. BPS is affected by the following drivers: supplier industry concentration compare to the buyer's industry, availability of substitute products for sale to the buyer's industry, buyer's industry importance as a customer of the supplier industry, supplier's product as an input to the buyer's business, supplier's products differentiation and switching costs, and threat of forward integration from the supplier groups.

2.5 Supply Chain Strategy Framework

One framework was considered to analyze the supply chain strategy of companies within the cement industry. The framework was presented by Larry Lapede in 2006 in his article "The essence of excellence" based on the information of the MIT Center for Transportation and Logistics Supply Chain 2020 project. The article presents the results of the first phase of research proposing a definition about excellent supply chains. Lapede (2006) argues that an excellent supply chain is a competitively principled supply chain where there is an alignment between supply chain strategies, operating models and metrics within the strategic framework of the company.

The principles that guide excellent supply chains are grouped into two dimensions. The first dimension specifies that an excellent supply chain has to be aligned with the business strategy and has to operate within the framework that is shown in Figure 3.

The second dimension is that supply chain managers should comprehend, execute, and respect the focus and purpose of the aligned supply chain.

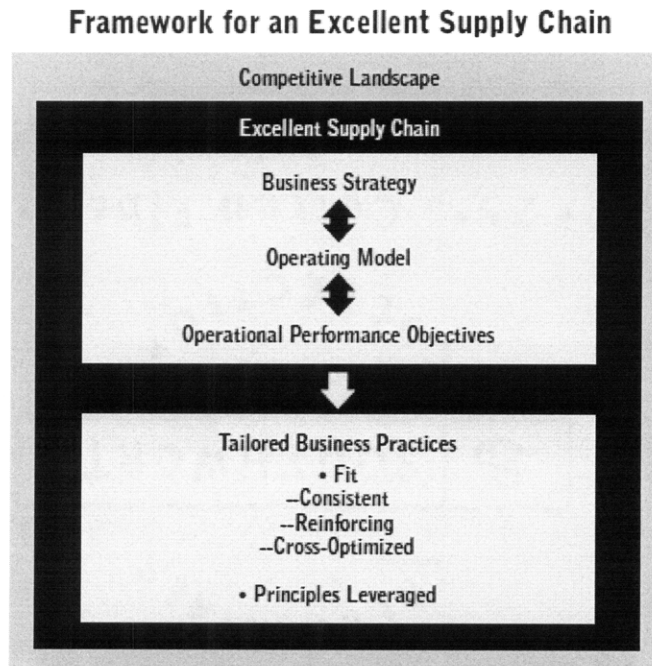


Figure 3. Framework for an Excellent Supply Chain. Source: Lapede (2006)

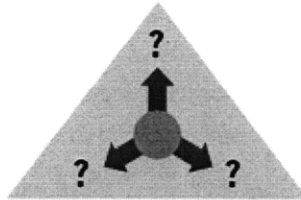
The upper box in Figure 3 reinforces the idea of supply chain alignment. In excellent supply chains, the corporate strategy is understood and shared by supply chain managers. In addition, supply chain management enhances, facilitates and evolves with the corporate strategy. In other words, supply chain fits in the corporate strategy.

Supply chain execution is also an important element in excellent supply chains. Excellence is doing well in activities that affect the firm's competitive advantage. A supply chain has to exceed the company's operational objectives. The operational objectives can be classified in three groups as shown in Figure 4. A competitive strategy requires focus on one of the groups and less on the others.

Aligning Operational Performance to Business Goals

Customer Response (Customer-Facing)

- Order Cycle Times
- Perfect Order Fulfillment
 - Quality
- New Product Time-to-Market (Not on Financial Statements)



Efficiency (Internal)

- Labor Productivity
- Supply Chain Costs (Relate to Income Statements)

Asset Utilization (Internal)

- Facility Utilization
- Inventory Turns
- Cash-to-Cash Cycle (Relate to Balance Sheet)

Figure 4. Operational Objectives. Source: Lapede (2006)

- The first set of operational objectives is gathered under *Customer Response*. An example of the metrics included in this group are order cycle time, perfect orders, new product time-to-market and product quality. These metrics generate results in customer-face operations. Companies in high margin and short life cycle industries such as fashion, pharmaceuticals and entertainment, are often concentrated in this objective.
- The second set of operational objectives is under the umbrella of *Efficiency*. The metrics included in this group are internal, for example, labor productivity, supply chain cost, or waste management cost. The data to calculate these metrics is obtained from the Income Statement. Companies in the food, beverage and basic retail goods industry which are focused in cost reductions are concentrated in these objectives.

- The third set of operational objectives is combined under *Asset Utilization*. The metrics in this group are also internal but they focus on how well the company is utilizing its assets. The information to calculate these metrics is in the balance sheet. Companies in the petrochemical and semiconductors industry are concentrated in these objectives. Typically, these companies want to maximize the return on the expensive capital investment made in their plants. Metrics such as cost, inventory turnover and fill rates are common. If a company concentrates in more than one metric, trade-offs between the metrics results are required.

The final aspect of this framework of excellence in supply chain is *tailoring practices*. Tailored practices are limited in number and are aligned with operational objectives. They have to be consistent, integrated and reinforcing. Finally, the concept of Operating Principles is introduced. Lapide (2006) argues that Operating Principles such as visibility, use of supply contracts and matching of supply and demand don't change over time. This is why supply chain managers have "to create an evolving set of tailored practices based on understanding the operating principles being leveraged by them."

In addition to the information in this article, Lapide (2008) expands this framework in a new article called "The operational performance triangles". In this article, Lapide (2008) introduces the concept of absolute or relative triangles as shown in Figure 5. The absolute triangle refers to the objectives that all companies within the industry must have, to be able to play in the industry. The relative triangle refers to the objectives where companies should focus to achieve significant differentiation from its competitors.

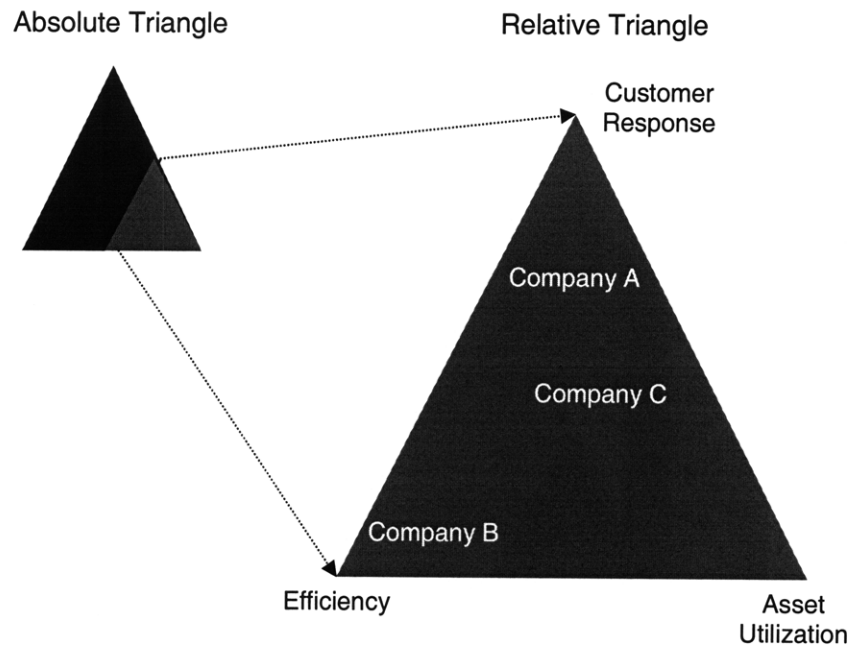


Figure 5. Absolute and Relative Triangles. Source: Lapide (2008)

2.6 Supply Chain Operating Model Characteristics

Supply Chain Operating Model characteristics are analyzed according to two perspectives: processes and products.

2.6.1 Supply Chain Processes

Two frameworks were used to analyze cement supply chain processes: the SCOR model and the Push-Pull Supply Chain frameworks.

2.6.1.1 SCOR Model

The Supply-Chain Operations Reference model (SCOR) was used to analyze the cement supply chain processes. SCOR is a cross-functional framework for evaluating and comparing supply chain activities. SCOR was developed by the Supply Chain Council as an independent global consortium of more than one thousand corporate

members. SCOR covers activities from the supplier's supplier to the customer's customer as is shown in Figure 6.



Figure 6. SCOR Model Structure. Source: Supply Chain Council (2009). [WWW Document] URL <http://www.supply-chain.org/galleries/public-gallery/SCOR%209.0%20Overview%20Booklet.pdf> (visited 2009, February 22).

There are five processes define in the SCOR Model: Plan, Source, Make, Deliver and Return.

- *Plan* includes the management processes to coordinate aggregated supply and demand. Plan generates a course of action to satisfy source, make, deliver and return requirements.
- *Source* is an umbrella for the processes that procure goods to satisfy customer requirements, from strategic roles such as identifying and selecting supply sources, to the execution of operational and tactical activities. Source also includes risk management, contracts and negotiation.
- *Make* covers the processes of transforming a product from raw material to finished good. Make includes processes such as scheduling, work in process inventory control, testing and packaging.

- *Delivery* is an umbrella for the processes that provide finished goods to meet planned or actual demand. Delivery typically includes order management, transportation management, and distribution management.
- *Return* covers two types of processes, the return of raw materials to the supplier and the return of finished goods from the customer. Return processes effectively move defective, excess or hazardous products to the appropriate destination guaranteeing final disposal.

2.6.1.2 Push-Pull Supply Chain frameworks

Two push-pull supply chain frameworks were considered to analyze the processes of the cement supply chain: Four Types of Supply Chain Design Framework (Reeve and Srinivasan, 2005) and Matching Supply Chain (SC) strategies with Products Framework (Simchi-Levi et al., 2008)

2.6.1.2.1 Four Types of Supply Chain Design Framework

The first framework was created by Reeve and Srinivasan in 2005 in their article “Which Supply Chain Design Is Right for You?” In this article the authors suggest that supply chain design is important because currently, competition is not between companies but between supply chains. There are four major supply chain designs: Built-to-Stock (BTS), Configure-to-Order (CTO), Built-to-Order (BTO) and Engineer-to-Order (ETO).

- *Built-to-Stock (BTS)*: In this design the product is manufactured before its demand appears according to a standardized bill of materials. This design offers the fastest response time to consumer because the product is normally stored in the warehouse. BTS is widely used in consumer goods and critical repair components. Product adjustments are not possible so the final product can be either over configured or under configured according to customer needs.

- *Configure-to-Order (CTO)*: In this structure, the products are assembled to order using regular components or modules. CTO is used in the computer and in the automotive industry. In CTO, customer orders are generated prior to assembly, and accordingly, replenishment orders for parts are placed as per the configuration needed by the customer. Normally, there is a trade-off in the variety of product configuration versus the time that a customer has to wait to get the final product. The main goal in CTO design is to minimize the lead time from assembly to delivery.

- *Built-to-Order (BTO)*: In this design, the product is manufactured to order according to a standard bill of materials. Two examples are the jet and the industrial machinery industry. In this option, orders are introduced at the beginning of the manufacturing process. BTO products are usually highly customized and extremely expensive to manufacture. The production process normally has to deal with expediting and exception activities.

- *Engineer-to-Order (ETO)*: In this design, the product is manufactured to order with exclusive components and drawings. ETO supplies truly customized products. The

lead time from order to final delivery is usually long. Upstream supply chain processes are more complex than downstream supply chain processes. Almost all the processes are made in units of one.

A graphical summary of the four supply chain structures is presented in Figure 7. Also, a summary of the trade-offs of each of the designs is presented in Figure 8.

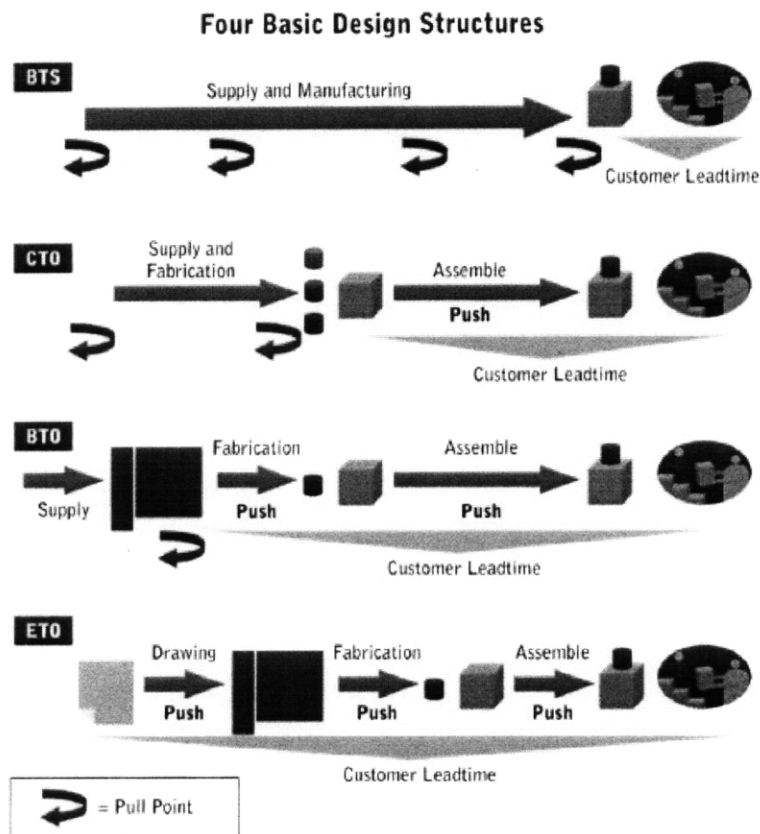


Figure 7. Four Basic Supply Chain Structures. Source: Reeve et al. (2005)

Supply Chain Design and Value Trade-off				
	BTS	CTO	BTO	ETO
Point of order entry	At point of stock	Prior to Assembly	Prior to Fabrication	Prior to Drawing
Pull point	Point of stock to upstream	Point of assembly to upstream	Point of fabrication to supply base	No pull
Inventory speculation	End-item speculation	Module speculation	Component speculation	None
Leadtime to customer	Minimal	Short	Long	Longest
Degrees of customer choice	Limited	Modularized	Semi-customized	Customized

Figure 8. Supply Chain Design and Value Trade-Off. Source: Reeve et al. (2005)

According to Reeve and Srinivasan (2005), the ideal supply chain design “is one in which a small number of components are used to configure a large variety of end products.” They introduced the concept of Raw-As-Possible (RAP), suggesting that inventories should be kept as raw as possible in the supply chain. The perfect structure according to this principle is CTO.

The application of the RAP concept is constrained by product configuration and customer lead time requirements. Product configuration is presented in the product Bill of Materials (BOM). The first step to design a supply chain is to evaluate the product BOM to identify opportunities to apply the RAP concept. Risk pooling and aggregation opportunities are also worth evaluating in the product BOM.

Supply chain should reply to consumer requirements rather than to product configurations. This is why in recent years; it is common for companies to move from BTS to CTO or from BTO to CTO. Finally, the authors argue that there is no one-size-fits-all supply chain design. Supply chain managers have to be able to assess the

current design of their supply chains and adjust it to the market requirements, as needed.

2.6.1.2.2 *Matching SC strategies with Products Framework*

The second framework by David Simchi-Levi, Phillip Kaminsky and Edith Simchi-Levi in 2008 was presented in their book “Designing and Managing the Supply Chain.” Simchi-Levi et al. (2008) argues that traditionally, supply chain strategies have been characterized as either push or pull. A new trend has emerged in the last few years with the implementation of a hybrid system, the push-pull supply chain.

Push-based supply chains are characterized by the use of long-term forecasts for production and distribution decisions. Push-based supply chains are slow to react to market changes, therefore stock outs or excess in inventory are common. Typically, push-based demands have high transportation costs, high inventory levels and / or high manufacturing costs.

Pull-based supply chains are demand driven, therefore production and distribution decisions are based on true customer demand, not on forecasts. In a pure pull system, the company doesn't need inventory because the supply process is triggered by the customer order. Typically, pull-based supply chains have lower inventory, lower variability and lower cost in the system than push-based supply chains. Pull-based supply chains have challenges such as low economies of scale in manufacturing or transportation. This is why the idea of a hybrid system is popular.

In a *push-pull strategy*, some components of the supply chain are operated in a push-based mode and other components are operated in a pull-based mode. The limit between the pull and push mode is known as the push-pull boundary.

To answer the question about the most appropriate supply chain for a particular product, Simchi-Levi et al. (2008) provide a framework for matching supply chain strategies with products as shown in Figure 9.

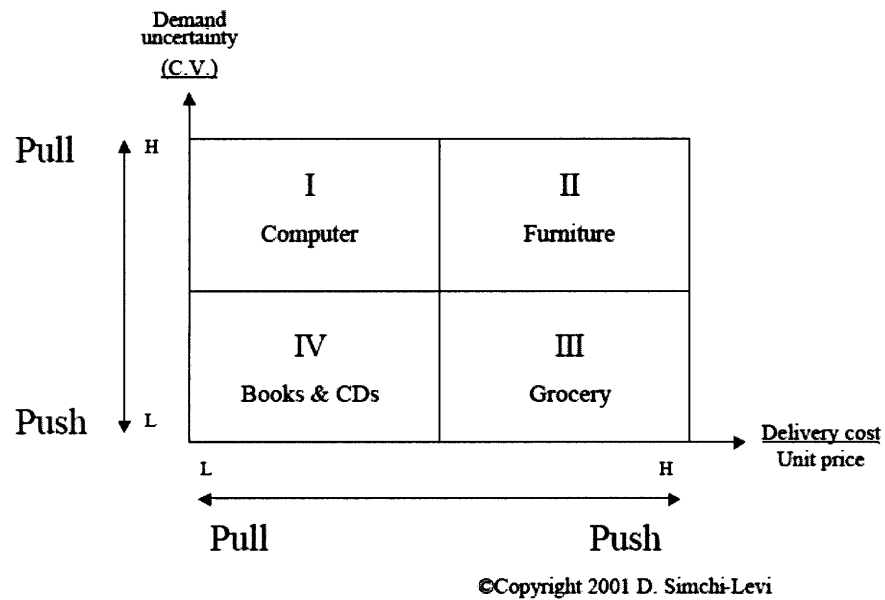


Figure 9. Matching Supply Chain Strategies with Products Framework.
Source: Simchi-Levi et al. (2008)

The vertical axis gives information about product demand uncertainty. The metric for demand uncertainty is the coefficient of variation that is defined as the standard deviation of the product demand divided by the product average demand.

Higher demand uncertainty leads to a preference for a pull strategy. Smaller demand uncertainty leads to a more accurate forecast resulting in a preference for a push strategy.

The horizontal axis gives information about the importance of manufacturing or distribution economies of scale. The metric for economies of scale is the result of dividing the delivery cost by the price per unit of a product.

The level of importance of economies of scale dictates the benefits obtained from demand aggregation and long term forecasts. As the importance of economies of scale increases, value addition from demand aggregation increases, and more preference is given to long term forecasts. This effect is generated by push-based supply chains. On the other hand, if economies of scale are low, there is no value in aggregation, so a pull-based supply chain is preferable.

In Figure 9, a 2x2 matrix is presented. *Box I* represents industries or products with high demand uncertainty and low economies of scale. One example is the computer industry. A pull-based supply chain is appropriate for products in Box I.

Box III represents industries or products, such as beer and pasta, with low demand uncertainty and high economies of scale. A push-based supply chain is appropriate for products in Box I. In this case, holding costs are minimized with the use of long-term forecast while distribution costs are minimized with the advantages from economies of scale.

Box IV represents products or industries with low demand uncertainty where a push-base supply chain is better, and low economies of scale where a pull-based supply chain is better. As a result, a push-pull strategy is more appropriate for this case. *Box II* represents products or industries with high demand uncertainty and high economies of

scale. One example is the automotive industry and the furniture industry. In this case as well, a push-pull strategy is the best option.

There are many alternatives to implement a push-pull strategy. The implementation depends on the position of the push-pull boundary. Normally, the push strategy is used in the part of the supply chain where demand is stable and the use of long-term forecast is appropriate. On the other hand, the pull strategy is normally used in the part of the supply chain where demand is unpredictable and therefore the use of real demand is recommended.

The objective on the push part of the supply chain should be minimizing cost with a focus on resource allocation, using supply chain planning processes. The objective of the pull part of the supply chain should be maximizing service level with a focus on responsiveness using order fulfillment processes.

2.6.2 Supply Chain Structure According to Product Characteristics

Three authors' various frameworks of supply chain design were used to describe the way cement supply chain structure should be.

2.6.2.1 Demand Uncertainty Framework

In his article "What is the right supply chain for your product?" Marshall Fisher (1997) proposed a framework to understand the nature of product demand and the supply chain design that is appropriate to satisfy it. Fisher proposes that products are typed, according to their demand, as functional and innovative.

Functional products normally satisfy basic needs which don't change over time. They have long life cycles. Because their demand is stable and predictable, competition is attracted and margins are low. To avoid this situation, some companies switch from functional to innovative products gaining customer loyalty.

Innovative products have high margins; short life cycles and because they are new, their demand is unpredictable. A challenge is that suppliers of innovative products have to release new products faster than their competitors to survive in the market.

Figure 10 presents Fisher's summary of demand aspects of functional and innovative products.

	Functional (Predictable Demand)	Innovative (Unpredictable Demand)
Aspects of Demand		
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin*	5% to 20%	20% to 60%
Product variety	low (10 to 20 variants per category)	high (often millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40% to 100%
Average stockout rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

Figure 10. Functional Versus Innovative Products. Source: Fisher (1997)

Fisher (1997) defines supply chain as two functions: the physical function and the market mediation function. The *physical function* extends from the transformation of raw material to the transportation to final consumers. The *market mediation function* matches the company's offer with the customer requirements.

A physically efficient process is concentrated in the physical function. A market-responsive process is concentrated in the market mediation function. Figure 11 presents Fisher's summary of differences between a physically efficient process and a market-responsive process.

	Physically Efficient Process	Market-Responsive Process
Primary purpose	supply predictable demand efficiently at the lowest possible cost	respond quickly to unpredictable demand in order to minimize stockouts, forced markdowns, and obsolete inventory
Manufacturing focus	maintain high average utilization rate	deploy excess buffer capacity
Inventory strategy	generate high turns and minimize inventory throughout the chain	deploy significant buffer stocks of parts or finished goods
Lead-time focus	shorten lead time as long as it doesn't increase cost	invest aggressively in ways to reduce lead time
Approach to choosing suppliers	select primarily for cost and quality	select primarily for speed, flexibility, and quality
Product-design strategy	maximize performance and minimize cost	use modular design in order to postpone product differentiation for as long as possible

Figure 11. Physically Efficient versus Market-Responsive Supply Chains. Source: Fisher(1997)

Supply chain for functional products has to be physically efficient. Providers of functional products have to concentrate on the physical function by minimizing costs with the use of planning tools and the proper information flow between supply chain echelons.

Supply chain for innovative products has to be market-responsive. Decisions about inventory and capacity should be made to hedge against demand uncertainty. Early information about customer trends and continuous analysis of market signals are important.

2.6.2.2 *Uncertainty Framework*

Hau Lee (2002) in his article “Aligning supply chain strategies with product uncertainties?” proposed that the right supply chain strategy has to be tailored to meet customer requirements. Lee proposes that a product with stable demand has to be managed differently from a product with variable demand and supply uncertainty. One-size-fits-all supply chain strategies are destined for failure.

Lee proposes an uncertainty framework with two components: demand and supply. The *demand component* is covered by Fisher in his classification of innovative and functional products. The *supply component* classifies supply processes into two types: stable and evolving.

A *stable supply process* occurs when manufacturing processes and their technology are mature and the supply base is well established. Manufacturing complexity in a

stable supply process tends to be low or manageable. Manufacturing processes are typically highly automated and long term supply contracts are commonly used.

An *evolving supply process* occurs when manufacturing processes and their technology are under development. Normally, the supply base is limited in size and experience. The differences between stable and evolving supply processes are summarized in Figure 12.

Stable	Evolving
Less breakdowns	Vulnerable to breakdowns
Stable and higher yields	Variable and lower yields
Less quality problems	Potential quality problems
More supply sources	Limited supply sources
Reliable suppliers	Unreliable suppliers
Less process changes	More process changes
Less capacity constraint	Potential capacity constrained
Easier to changeover	Difficult to changeover
Flexible	Inflexible
Dependable lead time	Variable lead time

Figure 12. Supply Processes. Source: Lee (2002)

The assumption that functional products always have a stable supply process or that innovative products always have an evolving supply process is incorrect.

As a result of demand and supply components, a two-by-two matrix was generated. In this matrix, products can be classified as shown in Figure 13.

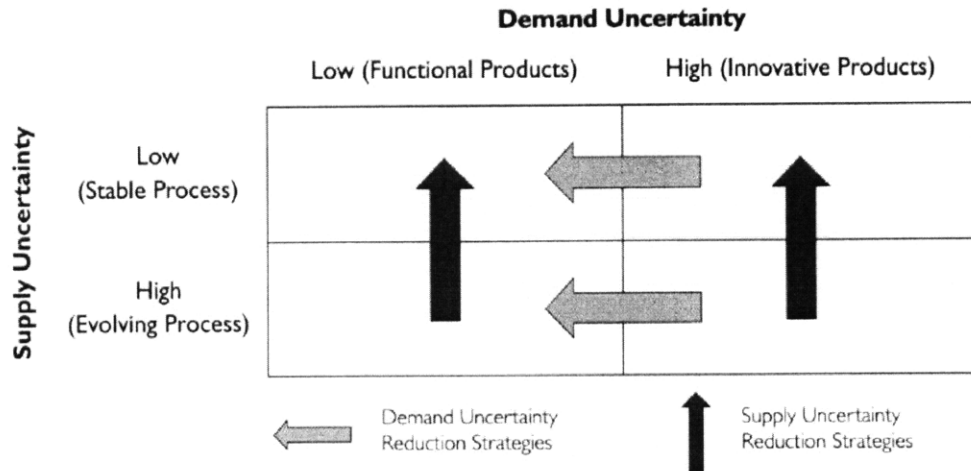


Figure 13. The Uncertainty Framework. Source: Lee (2002)

According to Lee (2002), there are four types of supply chain strategies: efficient supply chains, risk-hedging supply chains, responsive supply-chains, and agile supply chains. There is a match of these strategies with the matrix in Figure 14.

Demand Uncertainty

		Low (Functional Products)	High (Innovative Products)
Supply Uncertainty	Low (Stable Process)	Efficient supply chains	Responsive supply chains
	High (Evolving Process)	Risk-hedging supply chains	Agile supply chains

Figure 14. Supply Chain Designs in the Uncertainty Framework. Source: Lee (2002)

Lee (2002) argues “that different supply chains are need for different products.”

Table 2 present supply chain strategies in each quadrant of the uncertainty framework.

Table 2. Supply chain strategies in the uncertainty framework. Source: Lee (2002)

<p><i>Efficient Supply Chains</i></p> <ul style="list-style-type: none"> - Cost efficiency is generated by just-in-time systems, automation, lean manufacturing, facility layout or workflow streamlining. - Supply chain efficiency is generated by Full-Truck-Load (FTL) deliveries, warehouses quantity reduction, replenishment software, optimization or information sharing across the supply chain. 	<p><i>Responsive Supply Chains</i></p> <ul style="list-style-type: none"> - Responsive supply chains use strategies such as postponement, build-to-order and mass customization.
<p><i>Risk-hedging Supply Chains</i></p> <ul style="list-style-type: none"> - Risk-hedging is generated by inventory risk pooling, resource sharing, product design using the same components, multiple supply bases or market exchanges in internet. 	<p><i>Agile Supply Chains</i></p> <ul style="list-style-type: none"> - Agile supply chains are a combination of risk-hedging and responsive supply chains, therefore a mixture of both supply chain strategies is possible.

2.6.2.3 Triple A framework

The third framework was created by Hau Lee in 2004 in his article “The triple A supply chain.” In this article, Lee (2004) argues that everything else being equal, the two core concepts of supply chain management of greater speed and cost effectiveness are not enough to gain competitive advantage. The reason why efficient supply chains fail is because they are unable to respond to unexpected changes in supply or demand. Efficient supply chains are designed to maximize economies of scale with centralized manufacturing and distribution facilities. For example, when there is an increase in demand, efficient supply chain deliveries are normally delayed because they are not big enough to fill a complete truck. This delay generates stock outs affecting the company’s customer perception. Additionally, efficient supply chains are slow in making decisions to adapt to changes in market structures such as moving manufacturing facilities off-shore or outsourced manufacturing. In summary, “Supply chain efficiency is necessary, but it isn't enough to ensure that firms will do better than their rivals.”

According to Lee's research in 2004, top performing supply chains have three characteristics: agility, adaptability and alignment. Lee (2004) emphasizes that there is no need to make trade-offs among these characteristics and that the implementation of the three characteristics simultaneously is required to generate competitive advantage.

- *Agility*: An agile supply chain is able to respond to rapid and unanticipated market changes. Agility is critical because changes are frequent in the present time. Agile supply chains react both swiftly and cost-effectively. The methods to reach agility are presented in Figure 15. The ability to react and recover rapidly from disruptions such as terrorist attacks or natural disasters is a measurement of agility. This ability is particularly important in today's global supply chains.

Agility

Objectives:

Respond to short-term changes in demand or supply quickly; handle external disruptions smoothly.

Methods:

- > Promote flow of information with suppliers and customers.
- > Develop collaborative relationships with suppliers.
- > Design for postponement.
- > Build inventory buffers by maintaining a stockpile of inexpensive but key components.
- > Have a dependable logistics system or partner.
- > Draw up contingency plans and develop crisis management teams.

Figure 15. Agility Methods. Source: Lee (2004)

- *Adaptability*: Successful organizations continuously execute changes in their supply chains to adapt to changes in markets or business strategies. For these companies, it is important to anticipate changes by gathering and analyzing relevant data and by making decisions accordingly. Sometimes, adaptability forces companies to have more than one supply chain depending on the nature of the

products. Aspects such as the product stage in the life cycle and the level of manufacturing technology influences the type of supply chain that is required. The methods to reach adaptability are presented in Figure 16.

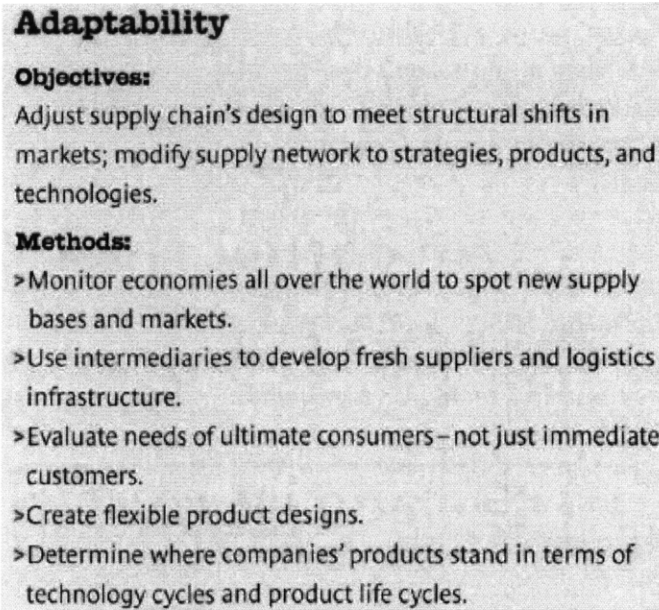


Figure 16. Adaptability Methods. Source: Lee (2004)

- *Alignment:* Great companies align the interest of its supply chain partners. If this alignment is not reached, each company will maximize its own results instead of maximizing the results of the supply chain as a whole. This misalignment can also occur among the divisions of a single company. Vendor Managed Inventory (VMI), implemented in a collaborative way, is one of the logistics practices that facilitate alignment. One way to get alignment with supply chain partners is the use of contracts where risk, cost, incentives and benefits are shared. Figure 17 presents the methods to accomplish an aligned supply chain.

Alignment

Objective:

Create incentives for better performance.

Methods:

- > Exchange information and knowledge freely with vendors and customers.
- > Lay down roles, tasks, and responsibilities clearly for suppliers and customers.
- > Equitably share risks, costs, and gains of improvement initiatives.

Figure 17. Alignment Methods. Source: Lee (2004)

Triple A supply chains do not require high technology investments. A Triple A supply chain is made by people with a full supply chain vision.

3 Characterization of SCM in the cement industry

This section is divided in three parts. The first part is a cement industry analysis using Michael Porter's five forces. The second part presents an analysis of the supply chain strategy of the four largest cement companies using Lapide's excellent supply chain framework. Finally, different frameworks are applied to analyze alternative supply chain operating models for the cement industry.

3.1 Cement Industry Analysis

Cement industry analysis was made using Michael Porter's (1980) five forces driving industrial competition. See Section 2.4 for details of Porter's model. The five competitive forces are: threat of entry, rivalry among competitors, pressure from substitute products, bargaining power of buyers and bargaining power of suppliers.

- *Threat of Entry*: Table 3 presents the analysis of the barriers to entry of the cement industry. Each barrier was qualified as high, medium or low. When barriers of entry are high, the threat of entry is low.

Table 3. Barriers of Entry of the Cement Industry.

Barriers	Barriers of Entry in the Cement Industry
Economies of scale (EoS)	Cement plants are built to get economies of scale. In general, cement plants that are owned by large companies are big, highly automated with major quality standards. This barrier of entry is high in mature markets; in emerging markets with presence of the large cement companies, the barrier is high as well.
Product differentiation	Cement is a commodity. Traditionally there were no efforts of building brand equity. Some cement companies are trying to de-commoditize cement with product innovation, branding and packaging initiatives. The barrier of entry is low .
Capital requirements	The cost of an efficient cement plant is approximately 105 millions Euros and it is expected to last 100 years. In some cases, cement companies are vertically integrated with transportation and logistics infrastructure. These investments are significant, especially in developed markets where bulk transportation is common. This barrier of entry is high , especially

	when the large cement companies are already established in the market.
Switching costs	Cement is a commodity. The switching cost from one supplier to other is low. This barrier of entry is low .
Access to distribution channels	Concrete companies can be seen as a distribution channel that is normally integrated and controlled by cement companies. This is not the case in the US. Retail and wholesalers channels are usually not controlled by cement companies and are fragmented. This barrier of entry is medium .
Cost disadvantages independent from scale	Cement companies are mature companies with years of experience. They have the know-how, access to raw materials, established locations, and high learning experience curve. On average, the age of the top 4 cement companies is 130 years and they have been focused on cement from their origin. Some of them expanded to new construction related products and new businesses as shown in the second column of Appendix C. This barrier of entry is high .
Government policy	This barrier of entry depends on country's regulations about ownership of subsoil. If subsoil is owned by the government, cement companies identify raw materials sources and work closely with the government to get licenses to exploit them. If the subsoil is owned by people, cement companies acquire the land and exploit it. Normally, there are environmental controls involved in both situations. Additionally government can also control fuel prices and freights. This barrier of entry is medium .

We can conclude that the cement industry has **medium to low** threat of entry. This is particularly true when large cement companies are in control of the country's cement production. In recent decades, large cement companies have acquired local cement companies in countries where presence of other large cement companies was limited or inexistent. Acquisitions were promoted by the following reasons:

- Desire of increased volume, revenues and market share.
- Risk diversification among different countries with different economic cycles tied to cement demand.
- Take advantage of a company's low market value in a moment of crisis.
- Benefits from the scale in the purchase of raw materials, components and energy.

- Acquisitions were possible due to the access to larger financial capital markets for cement global corporations.
- *Rivalry Among Competitors*. Table 4 presents the analysis of the drivers for rivalry in the cement industry.

Table 4. Rivalry in the Cement Industry.

Drivers for Rivalry	Rivalry in the cement industry
Numerous or Equally Balanced Competitors	In the cement industry, there are a small number of equally balanced competitors; hence, rivalry is high . There are countries where there still is local competition from small or medium size firms, but their number is limited. Some of the local competitors have small cement plants with limited automation and quality standards. They offer low prices that compete with the large cement companies, especially in emerging markets where quality requirements and purchase power is low.
Industry Growth	According to the Portland Cement Association (2006), from 2002 to 2005 world cement consumption increased by 25%. China represents 45% of world consumption and is expected to grow at a steady rate of 8.5% annually. Cement consumption growth is concentrated on emerging markets; therefore the rivalry to enter these markets is high . Even though in mature markets the consumption growth is small, companies compete to maintain their dominant positions. The rivalry is also high .
Fixed or Storage Cost	According to Lafarge (2008), its production costs (before distribution and administrative cost) are distributed as 34% for energy, 29% for raw materials & consumables, 28% for labor & maintenance, and 11% for depreciation. Assuming that the last two are fixed, their relative weight is significant and hence rivalry is high .
Differentiation	Cement differentiation is low; hence rivalry is high .
Capacity Augmented in Large Increments	Cement increments in production capacity are normally high; hence rivalry is high . In addition, capacity increments are a fixed cost investment with penalty for underutilization. The only way to reduce production (since this is a continuous process) is by turning off the plant. According to Cemex, “the cost of stopping a cement plant is significant due to lost sales. The inventories in the distribution channel are no more than 2 days; hence there is no buffer to cover supply shortages.”
Diverse Competitors	Large cement companies come from different regions and they all have many years of experience. Large cement companies have huge geographical coverage. On average,

	the top 4 cement companies are in 57 countries. See Appendix C for details. The rivalry is high .
Strategic Stakes	Cement firms normally have high stakes in the market so rivalry is high . The stakes are mostly related to capital investment required to open a new plant.
Exit Barriers	Cement firms normally have specialized assets, long term government licenses and significant capital investment, hence rivalry is high .

We can conclude that the cement industry has **high** level of rivalry amongst major competitors. The cement industry can be defined as an oligopoly; a market dominated by a small number of sellers. According to Ghemawat (2007), concentration in the cement industry has increased since 1980 where the top 5 companies owned 11% of the cement industry. By 2007, concentration increased to 25%.

- *Pressure from Substitute Products.* Cement has no direct substitutes. Modern cement was developed in the 1800s in the Industrial Revolution and today's product is essentially the same. Since cement is the major component of concrete, the substitutes of concrete are also a threat to cement. In this case, other building materials are substitutes of concrete e.g. asphalt, wood, clay bricks, stone, gypsum, fiber glass and steel. They don't represent a major challenge especially for large buildings and infrastructure projects. Therefore the pressure from substitute products is **low**.

- *Bargaining Power of Buyers (BPB):* In the case of the cement industry, there is a difference between the BPB of large construction companies and government, and the BPB of Do-It-Yourself (DIY) builders and small contractors. The relative importance of each type of buyer depends on the level of development of the

country. For example, according to the U.S. Geological Survey (USGS) (2009) in 2008 about 75% of cement sales in the US went to ready-mixed concrete producers, 13% to concrete product manufacturers, 6% to contractors (mainly road paving), 3% to building materials dealers, and 3% to other users. In underdeveloped countries, cement demand from DIY builders is approximately 70% of sales. Self builders buy cement in small quantities combined with other construction materials. Normally, wholesalers and retailers are used as distribution channels to DIY builders. The drivers for BPB are represented in Table 5.

Table 5. Bargaining Power of Buyers in the Cement Industry.

BPB Drivers	DIY Builders and Small contractors BPB	Large Construction Companies / Government BPB
Buyer purchases large volumes relative to seller sales	Market is dominated by a group of dispersed buyers; hence BPB is low .	One buyer or one group of buyers makes the purchasing decision; therefore BPB is high .
Seller's product importance on buyer's costs or purchases	Cement price is significant but the quantity that the final customer buys is small. So, BPB is medium .	Cement unit price is low but the quantity that the buyer needs is significant; hence BPB is high .
Standard of differentiated product	Cement differentiation is low; hence BPB is high .	Cement differentiation is low; hence is high .
Buyer's switching cost	Cement buyer's switching costs are low; hence BPB is high .	Cement buyer's switching costs are low; hence BPB is high .
Buyer's profits	Cement is mostly use in DIY building where profits are not an issue. Small contractor's profits are not significant. BPB is low .	Profits of large construction companies are low so there is pressure for low prices; hence BPB is high .
Buyers pose a threat of backward integration	There is no clear evidence about backward integration in the cement industry; hence BPB is low .	There is no clear evidence about backward integration in the cement industry; hence BPB is low .
Seller's product importance to the quality of buyer's product	Because of the fractioned market and the DIY building, quality is not a significant issue. This market is more price sensitive than quality sensitive; hence BPB is low .	In this market the quality of cement / concrete is very important. Buyer's prestige and future contracts are in stake; hence BPB is high .

Buyer's level of information	Because of the fractioned market and the DIY building, buyer's level of information is low; hence BPB is low .	Large construction buyers have a high level of information; hence BPB is high .
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We can conclude that the bargaining power of buyers of DIY builders and small contractors is **low**. Instead, large construction projects and governments have **high** bargaining power.

Emerging markets are dominated by DIY builders and small contractors.

Developed economies are dominated by large construction companies. A possible effect of the lack of BPB of the cement buyers in emerging economies might explain the difference in the current prices per ton of cement. The retail price in the US is approximately 110 dollars per ton versus 200 dollars per ton in Colombia.

- *Bargaining Power of Suppliers (BPS)*. Cement companies are normally the owners of quarries where major raw materials are extracted. Exploitation of quarries varies depending on country regulations about the ownership of subsoil. For example, in the US, the owner of the land is also the owner of the subsoil. In contrast, in several countries in Latin-America the subsoil is owned by the government. In these countries, the government controls the access to raw materials through medium to long-term licensing. This situation is a challenge due to the risk of continuous changes in the licensing regulations that occur in emerging markets.

There are other cement raw materials that are acquired in the spot market and are subject to significant price fluctuations. Fuel is one of the raw materials that are most important for the cement industry. The production of a ton of cement requires

about 60 to 130 kilograms of fuel or equivalent source of energy. It also consumes 150 Kwh of electricity. The drivers for BPS are represented in Table 6.

Table 6. Bargaining Power of Suppliers in the Cement Industry.

BPS Drivers	BPS in the cement industry
Dominated by few suppliers and is more concentrated than the industry	Excluding the limestone that comes from the quarries, other raw materials (e.g. gypsum, bauxite, iron, fly-ash) are highly concentrated with a small number of suppliers. BPS is high .
There are substitute products for sale to the industry	There is no clear evidence about substitute products for cement raw materials. BPS is high .
Industry importance as a customer of the supplier group	Cement industry is a major buyer of raw materials and energy. BPS is high .
Supplier's product as an input to the buyer's business.	Other raw materials and energy are very important for the cement industry. When cement raw materials and fuel prices increase, BPB increases too. According to Cembeureau (2008) energy represents 20 to 40% of the total production costs of the cement industry. BPS is high .
Supplier's products are differentiated or it has built up switching costs.	Other raw materials and energy are commodities that are not differentiated and the switching cost is low. BPS is low .
Supplier groups possess a credible threat of forward integration	There is no clear evidence about forward integration in the cement industry. BPS is low .

We can conclude that the bargaining power of suppliers in the cement industry is **medium**.

A summary of the results of Porter's five forces for the cement industry is presented in

Table 7.

Table 7. Porter's Five Forces in Emerging Markets versus Developed Countries

Competitive Force	Emerging Markets	Developed Countries
Threat of entry	Medium to low	Medium to low
Rivalry among competitors	High	High
Pressure from substitute products	Low	Low
Bargaining power of buyers	Low	High
Bargaining power of suppliers	Medium	Medium

Porter (1979) suggests that when the forces are weak collectively, there is a major opportunity for superior performance. Therefore, we can conclude that the cement industry is unattractive in mature markets, but attractive in emerging markets. Figure 18 presents the graphical summary of Porter’s five forces driving cement industrial competition.

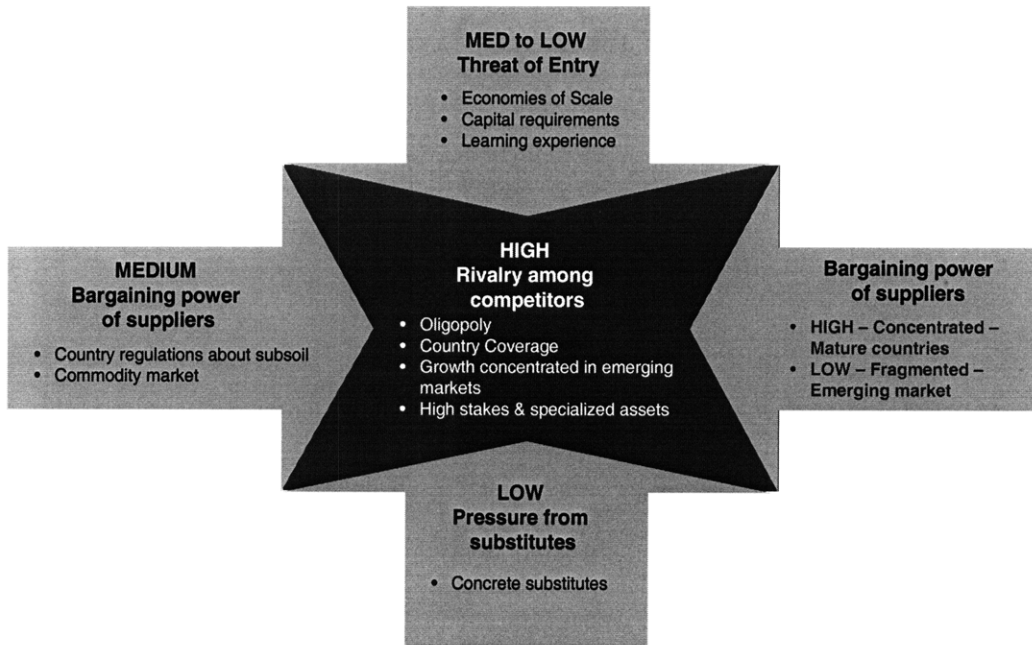


Figure 18. Porter’s Five Forces Analysis for the Cement Industry

3.2 Supply Chain Strategy in the Cement Industry

The analysis of the supply chain strategy that best fits the strategy of the four largest cement producers was made using the Supply Chain Excellence framework that was created by Larry Lapidé in 2006. See Section 2.5 for details of Lapidé’s framework.

In his article, Lapidé (2006) introduces the concept of absolute and relative operational performance triangles. The absolute triangle refers to the objectives that all the companies within the industry must possess in order to be able to play in the

industry. The relative triangle refers to the objectives which companies should focus on, in order to achieve significant differentiation from their competitors.

We believe that the cement industry is located in the corner of asset utilization with some level of efficiency in the absolute triangle as show in Figure 19. The main reason for this location is that cement companies are focused in minimizing cost based on the economies of scale generated by their investment in large manufacturing plants. This is a given condition for all large cement companies in the industry.

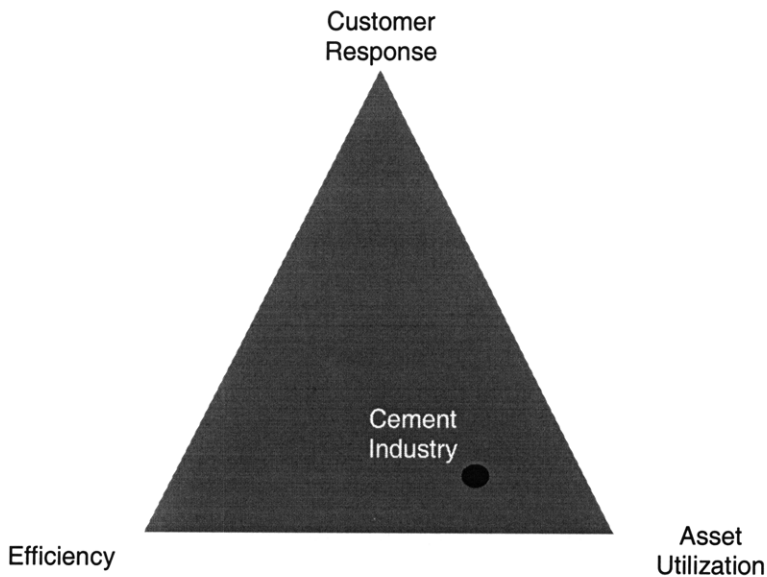


Figure 19. Absolute Triangle for the Cement Industry

The relative triangle requires a more detail analysis. The first step was to review the strategy of the four largest cement companies according to the information on their web sites and in their 2008 Year Reports. The summary of the companies' business strategy is presented in Table 8.

Table 8. Strategy of the Four Largest Cement Companies

Company	Corporate Strategy
Lafarge	<p>The Group strategy can be broken down into clear and ambitious priorities:</p> <p>2 strategic priorities:</p> <ul style="list-style-type: none"> - Continuing development on emerging markets - Accelerating innovation to reach sales of €3bn with innovative products by 2012 <p>3 operational priorities:</p> <ul style="list-style-type: none"> - Ensuring the safety of our employees and targeting 0 accidents - Continuing with cost reduction - Developing the potential of the men and women in the Group
Holcim	<ul style="list-style-type: none"> - Our strategy is based on three central pillars: focusing on the core business, geographical diversification and balancing business responsibility between local and global leadership - Holcim value chain: We focus on our core business. Cement and aggregates are at the center of our activities - Geographic diversification: Holcim is more globally active than any other building materials group, with a strong foothold in each individual market - Local management, global standards: Our success lies in striking a balance between local responsibility and global leadership
Cemex	<ul style="list-style-type: none"> - Customer focus: We're committed to providing our customers with the most efficient and comprehensive building materials - CEMEX people: Our most important asset is our people—motivated employees who can deliver consistently positive results for our customers, our stockholders, our communities, and each other - Solid business model: Our portfolio of cement, ready-mix concrete, and aggregates assets is concentrated on markets that provide sustainable top- and bottom-line growth throughout the economic cycle - Dynamic enterprise: Since we made our first batch of cement in 1906, we set in motion a philosophy that still guides us today: continuous improvement - Sustainability: Our ultimate goal is sustainable growth and development for our company and our industry
Heidelberg	<ul style="list-style-type: none"> - Besides the traditional core business of cement, aggregates (sand, gravel and crushed rock) have become a second strategic pillar - Our strategy is clear and convincing: Concrete, the building material for which there is most demand worldwide, is by far our most important end product - Heidelberg Cement is pursuing a clear dual external growth strategy: expansion of the cement business in growth markets and North America; and focus on aggregates and downstream activities in mature markets and North America.

The second step is to build a relative triangle for the cement industry. Based on the strategy information in Table 8 and the information gathered in the interviews, we allocate a dot corresponding to each one of the four companies on the relative triangle. We position Lafarge predominantly in Customer Response because of its focus on innovation and emerging markets. We position Holcim and Heidelberg in the middle of Customer Response and Efficiency because they are focused in emerging markets and are also concentrated on their core businesses to gain efficiency. We place Cemex in the corner of Efficiency with some degree of Customer Response. Cemex is also concentrated in emerging markets but with special focus on continuous improvement.

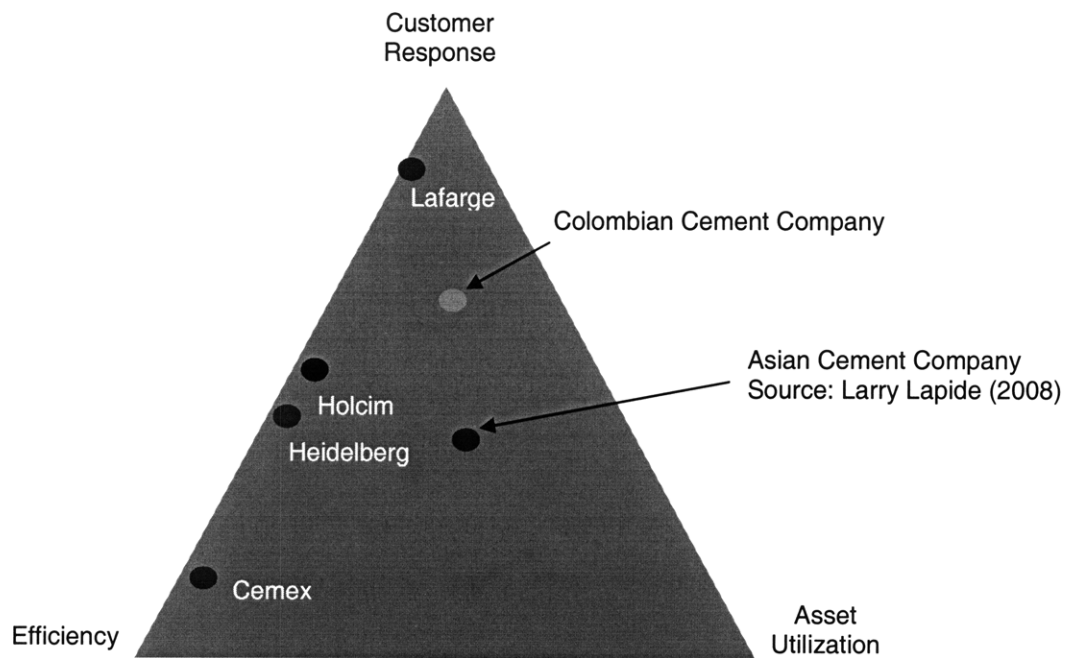


Figure 20. Relative Triangle for The Cement Industry

It is important to acknowledge that in the information gathered, there is no clarity about the strategy that the companies are going to use in the emerging markets. So, an additional understanding of the companies' strategy is recommended, using multiple relative triangles for domestic or international markets, or as per country or region.

3.3 Supply Chain Operating Model of the Cement Industry

Supply Chain Operating Model characteristics are analyzed according to two perspectives: processes and products.

3.3.1 Supply Chain Processes of the Cement Industry

Two frameworks were used to analyze the processes of the cement supply chain: the SCOR model and the Push-Pull Supply Chain frameworks.

Figure 21 presents the diagram with the summary of the cement SC characteristics.

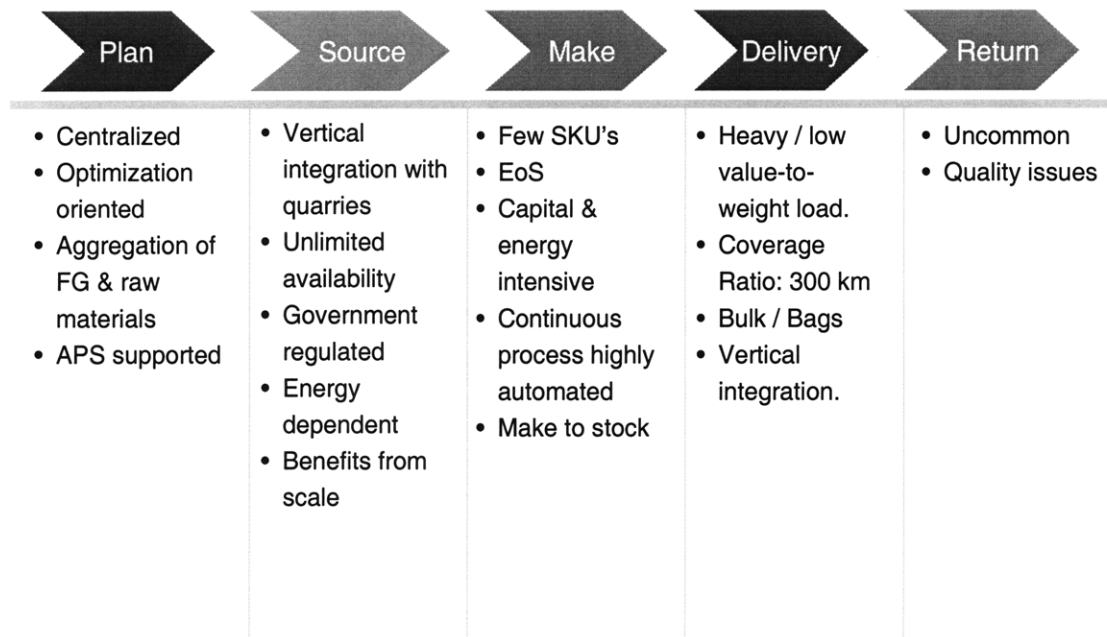


Figure 21. Summary of Cement Supply Chain Characteristics

3.3.1.1 SCOR Model

The supply chain processes of the cement industry were described using the logistics processes in the SCOR Model: Plan, Source, Make, Deliver and Return. See Section 2.6.1.1 for details of SCOR Model.

3.3.1.1.1 Plan

- Currently, supply chain planning processes in large cement companies are centralized. Centralization was promoted by the desire of identifying and integrating SCM practices that were independent before the acquisitions made during the last three decades.
- There was also an opportunity to optimize supply chain processes and to significantly reduce costs by analyzing the cement supply chain as a whole and not as independent companies. SC integration was not only for cement as a final product, but also for raw materials and fuel.
- Optimization projects motivated the implementation of APS (Advance Planning System) tools in large cement companies and the creation of centralized groups of supply chain planning.
- Even though, there are variations on a company-to-company basis, optimization in the cement industry is concentrated on minimizing logistics cost.
- A current trend in the cement industry in emerging markets is the use of S&OP (Sales and Operations Planning) processes to align sales, manufacturing and supply chain activities to guarantee the required service level. S&OP meetings are normally weekly and some of them include coordination among different countries.

3.3.1.1.2 Source

- Limestone is the principal cement raw material. Limestone comes from quarries. Cement companies normally own the quarries or get license agreements with the government to exploit them. There is no clear evidence about limitations in the availability of limestone but some countries have more potential than others.

- In a majority of the countries, governments control cement and mining industries with environmental regulations related either to the exploitation of raw materials or to the environmental impact of the process. Cement is a highly controlled industry.
- Cement companies purchasing items organized by cost are coal, electricity, other raw materials, packaging, production elements and maintenance elements. There are benefits from scale in large cement companies but only for components that are common among many cement plants e.g. coal, refractory materials used in kilns or computers. Some components vary depending on the country so there is no opportunity for aggregation e.g. trucks.
- There is no evidence of collaboration among competitors in the cement industry even though it is easy to find similarities among the cement companies that operate in the same country or region.

3.3.1.1.3 Make

- Cement has low proliferation of SKU's. For example, Cementos Argos, which is mainly concentrated in emerging markets, has 27 SKU's, 8 of which are cement in bulk and 19 are cement in bags.
- Cement manufacturing process is capital and energy intensive and is designed to generate economies of scale. It is a highly automated continuous process. Because of the cost that is generated by stopping a plant, traditionally all the logistics processes were subordinated to avoid this situation, no matter the costs. Now, cement companies are committed to optimize the logistics costs along with avoiding stops in production.
- A cement plant is normally located near the quarries. Quarries have to be large enough to support a cement plant that is designed to last about 100 years on

average. One of the challenges of cement companies is to maintain an appropriate reserve of raw materials by exploring the soil.

- Cement production process is make-to-stock. This means that production is made to satisfy a sales plan; final products are kept in warehouses and wait for demand to be delivered.
- Cement manufacturing process is dependent on fuel and electricity. This is one of the major future concerns of the cement industry. It also has a very strong environmental impact especially in carbon emissions.

3.3.1.1.4 Deliver

- There is a natural boundary of action of a cement plant given by how competitive is the cost of transporting cement by truck. According to Cembeureau (2008) because of the weight of cement, it is not profitable to move it in by truck over distances longer than 300 kilometers. Maritime, river and railroad transportation enable the expansion of plants coverage by reducing the transportation cost per ton.
- There are physical characteristics of cement that challenge the distribution process. Cement is a heavy load with low value-to-weight ratio which promotes practices such as FTL and the use low cost transportation modes such as sea, rail and river. Cement hardens with water which also creates a challenge in water transportation.
- Cement shelf life is approximately 60 to 90 days. If the product is stored for longer periods, its physical properties might be affected and need to be tested for quality.
- Cement is distributed in bulk or bags. Bulk distribution requires a dedicated and expensive fleet that is owned or outsourced by cement companies. See picture in Figure 22. The load of a bulk truck varies depending on whether the distribution

region is mountainous or plain. If is mountainous, the load has to decrease to compensate the motor effort.

- Other challenge in cement bulk deliveries is that specialized equipment is needed to unload the product. The equipment has to travel with the truck or it has to be present at the customer site when the truck arrives.



Figure 22. Bulk Cement Silos and Truck. Courtesy of Cementos Argos.

- Bags are more flexible, they can be moved in normal trucks with the advantages of backhauling. In emerging markets, distributors such as retailers and wholesalers are the distribution channel for cement in bags. Distributors require small and frequent orders because storage space and financial capital is limited. This situation creates a challenge for the logistics processes of ordering, picking and design of an efficient urban transportation routing process.
- Bags are also hard to load and to unload, especially under the circumstances of emerging markets. Loading is done in the cement plant where palletizers and lift

trucks are available. Unloading is done in the customer location. In general, customers don't have appropriate equipment, so unloading is done manually. Unloading is expensive and time consuming and affects the health of the workers in charge. There are initiatives from cement companies in emerging markets to introduce mechanization in the unloading process.

- The distribution process in emerging markets requires balance. On one side, cement characteristics limit the distribution process and promotes certain practices (e.g. FTL, use of sea, river or train). On the other side, bag buyers require cement companies to formulate a logistics process that is similar to consumer product goods (CPG) logistics process (e.g. small orders, high frequency, urban deliveries). Cement companies in emerging markets have to be able to cope with the challenges of both worlds.
- Vertical integration with logistics providers and infrastructure is common in the cement industry. This decision depends on the company strategy, the political situation of the country, the competitor's strategy and the size of the market. In a period of steady or growth in demand, vertical integration has advantages that can become disadvantages in periods of demand contraction. Outsourcing, or a mix of private fleet and outsourcing, are the alternatives used by large cement companies. If logistics contracts are flexible, this could be an interesting tool to convert fixed logistics cost to variable costs and reduce the impact of a decrease in demand during a crisis.

3.3.1.1.5 Return

Cement returns are uncommon. Returns can be generated by problems with the quality of the product (e.g. wet product) and they are normally resolved by replacing it.

3.3.1.1.6 SCM in the concrete industry

Concrete is a mix of cement, aggregates, water and sand. Concrete can be made and sold as a ready-mix formula that is transported in a specialized fleet of in-transit mixers to the construction projects. Concrete can also be made by hand mixing the components in a concrete mixer in the construction site. This option gives time to the construction workers to use concrete before it hardens. In emerging markets where labor is cheap, this process costs less than ready-mix concrete.

Ready-mix concrete distribution has particular challenges. Concrete is a perishable product that has to be used within 90 minutes after introducing the materials in the mixer; therefore in-transit mixers generally do not travel far from their plant. Another issue emerges from concrete needs of the construction companies that have tight schedules that they have to comply with. Ready-mix concrete logistics requires high coordination between supplier and buyer to get a quality product on time at the construction site.

Ready-mix concrete and cement industry are normally integrated. There are several reasons that might explain the integration. First, ready-mix concrete industry can be seen as a distribution channel of the cement industry. Ready-mix concrete customers are more loyal than cement customers. They are normally large construction companies in charge of large construction projects that are looking for service and product guarantee. Second, integration was a trend in the cement industry back in the 1980s that was followed by many of the large cement companies. Third, it could also be motivated by a desire of increase in revenues because one ton of cement produces approximately three cubic meters of concrete that is sold at a higher price than cement.

Cement and ready-mix concrete SCM are normally separated. There are some areas of integration that can be explored in maintenance of trucks in case of private fleets, routing optimization and truck tracking technology among others.

3.3.1.2 Push-Pull Supply Chain Analysis in the Cement Industry

Figure 23 represents the cement supply chain. Different colors were used represent each of the product flows in the cement supply chain: raw materials, clinker, cement in bulk, cement in bags and concrete.

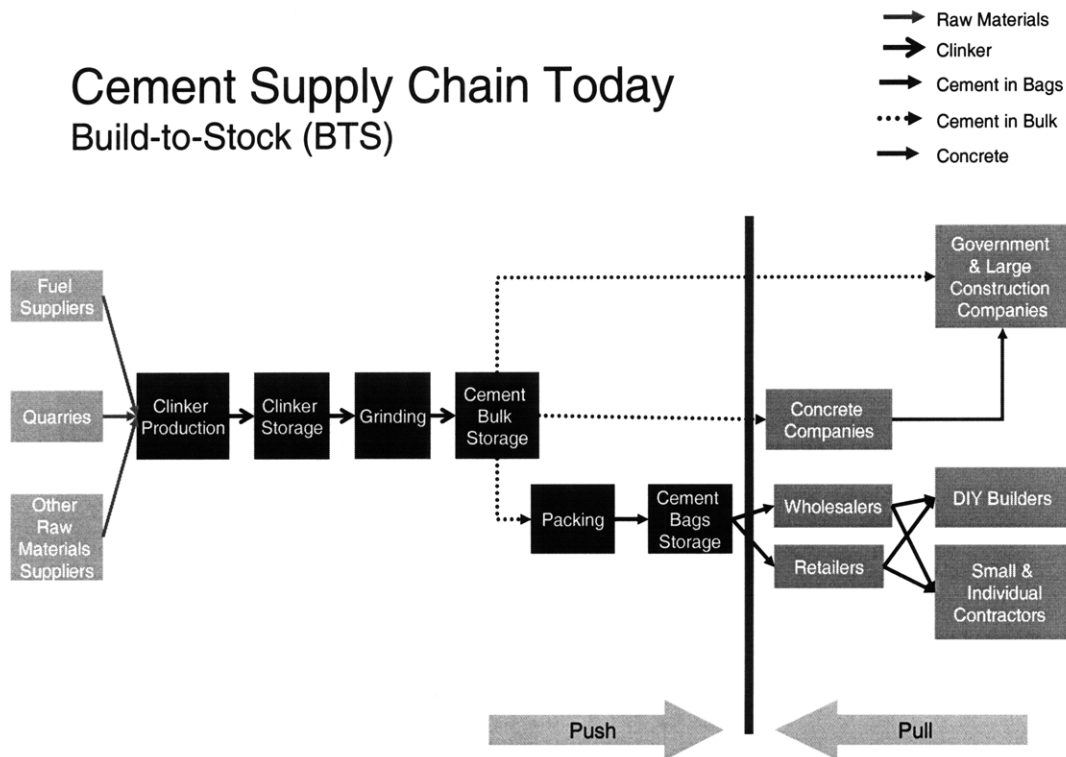


Figure 23. Cement Supply Chain

According to Reeve and Srinivasan (2005) there are four major supply chain designs: Built-to-Stock (BTS), Configure-to-Order (CTO), Built-to-Order (BTO) and Engineer-to-Order (ETO). See additional details in Section 2.6.1.2.1. At present, the cement industry supply chain has a BTS design where purchase orders are delivered

from storage, the lead time to consumer is just the transportation time and the degrees of customer choice are limited. Cement BTS is shown in Figure 23.

According to Reeve and Srinivasan (2005), CTO is the most appealing of the supply chain designs because CTO maximizes the benefits of the Raw-As-Possible (RAP) principle. CTO usually increases the customer lead time but offers flexibility in product configuration. Additional analysis should be made to confirm cement customers' willingness to wait for the product and how cement / concrete configuration requirements justify the implementation of the CTO model.

Simchi-Levi et al. (2008) push-pull supply chain concept is similar to Reeve et al. (2005) CTO design. See details of Simchi-Levi et al. framework in Section 2.6.1.2.2. In Reeve's framework, the RAP principle is used to define the push-pull boundary that is more appropriate for the product. To evaluate how feasible it is to move from BTS to CTO in the cement industry, an analysis of the cement BOM was made according to the RAP principle. Cement BOM is composed of clinker, gypsum, other mineral raw materials and paper bags (only for bagged products). Based on the cement BOM, we proposed two CTO alternatives: Grind-to-Order and Pack-to-Order.

- *Grind-To-Order (GTO)*: Clinker is an intermediate product of the cement manufacturing process. GTO might be possible using clinker as a base, grinding it according to customer orders as shown in Figure 24. A trade-off analysis between the costs of storage and ordering from clinker versus the reductions of final product inventory and the benefit in cement / concrete configuration flexibility. Also, technical aspects related to the grinding machines have to be evaluated.

Cement Supply Chain

Grind-to-Order

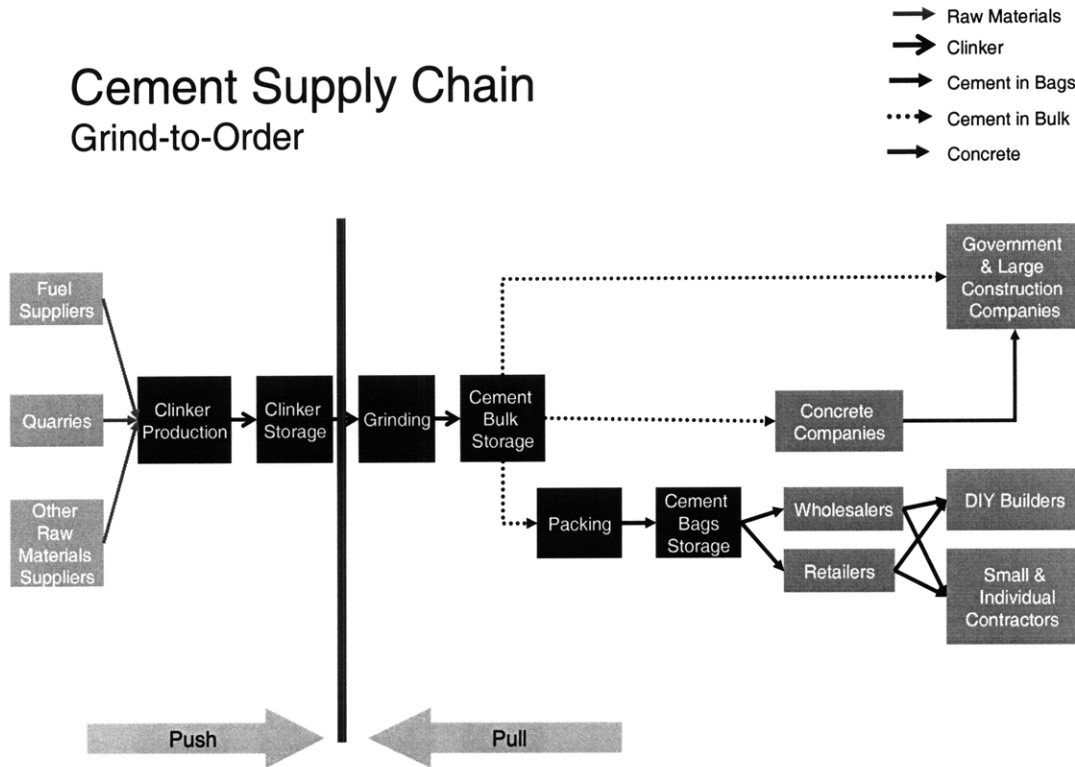


Figure 24. Grind-To-Order Cement Supply Chain

- *Pack-to-Order (PTO)*: PTO is an opportunity in emerging markets where cement is sold in bags and where DIY builders and small contractors have the highest market share. Today, there are just a few variations in bag sizes in the cement industry in emerging markets. In the future, the number of bag size variations might increase. Therefore, there is an opportunity for postponement in the packaging process. Cement packaging is a simple and highly automated process. The average speed of a cement bagging machine is 100 tons per hour. The packaging process is not a bottleneck. In this case, postponement can be used by keeping cement in bulk stored in silos until purchase orders arrived specifying the bag size that the customer needs as shown in Figure 25. A trade-off analysis between the carrying costs of cement in bulk versus the carrying cost of cement in bags is required.

Cement Supply Chain Pack-to-Order

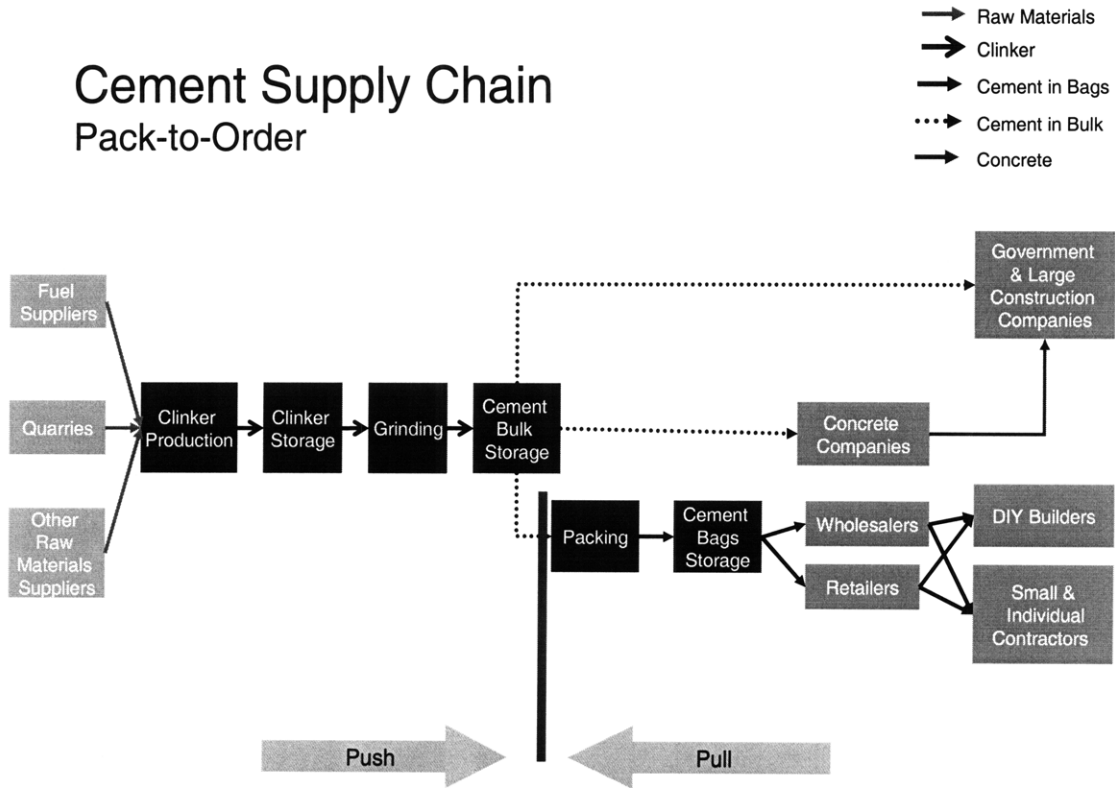


Figure 25. Pack-To-Order Cement Supply Chain

GTO and PTO aggregate demand in the manufacturing process reducing variability and improving forecast accuracy. Their implementation requires a continuous information flow and close coordination between order processing and manufacturing.

A minor opportunity for postponement is in packaging printing processes. In this case, plain bags can be stored and when purchase orders are received, the bag printing process starts. A trade-off analysis between the carrying costs of printed bags versus the benefits of print by demand is required.

3.3.2 Supply Chain Structure of the Cement Industry

Cement supply chain operating models were analyzed according to three frameworks: the Demand Uncertainty Framework (Fisher, 1997), the Uncertainty framework (Lee, 2002) and the Triple A framework (Lee, 2004).

Fisher (1997) proposes that there are two types of products according to their demand: functional and innovative. See Section 2.6.2.1 for details of Fisher's framework. Cement should be analyzed as two different products: bulk cement and bagged cement. Bulk cement is the cement configuration that is normally sold to ready-mix concrete companies or to large construction companies and governments. Cement bulk is dominant in developed countries. Bagged cement is sold to wholesaler and retailers. Its final consumers are DIY builders and small contractors. Cement bags are dominant in emerging markets.

Table 9 presents the quantitative analysis comparing bulk cement and bagged cement according to Fisher's aspects of demand.

Table 9. Cement Classification According to Fisher's Aspects of Demand

Aspects of Demand	Bulk Cement	Bagged Cement
Product Life Cycle	Modern cement is more than 200 years old. The product is in mature stage.	
Contribution Margin	In general, cement margins are 25 – 35% depending on the country and the type of cement. According to the information in Appendix C, developed countries (bulk cement is dominant) account for 30-40% of the company's operational income.	In general, cement margins are 25 – 35% depending on the country and the type of cement. According to the information in Appendix C, emerging markets (bagged cement is dominant) account for 60-70% of the company's operational income.
Product Variety	Low. For example,	Medium. For example, Cementos

	Cementos Argos has 8 types of bulk cement.	Argos has 19 types of bulk cement.
Forecast error	According to Cementos Argos, the average forecast error for bagged cement is 17%.	According to Cementos Argos, the average forecast error for bagged cement is 12%.
Stock out Rate	N.A.	It is estimated by the author that is higher than bulk cement.
Lead time for MTO	According to Cementos Argos, the MTO manufacturing process of a ton of cement is 62 minutes. This time doesn't include extraction.	

N.A.: Not Available

Based on Fisher's characteristics of functional and innovative products presented in Figure 4, we can conclude that bagged cement is more innovative than bulk cement. Therefore, a cement company that produces these two varieties of cement should have different supply chains.

Table 10 presents the analysis comparing Fisher's recommendations for functional products with current characteristics of cement supply chain.

Table 10. Cement Supply Chain Analysis

SC Characteristics	Current characteristics of cement SC
Primary purpose	Based on the information gathered, supply chain areas in cement companies are in the process of taking a strategic role in cost reduction. According to Lafarge "SCM potential for cost reductions is recognized in the cement industry. Optimization processes were quickly adopted by all large cement companies." In the case of bagged cement, it is important to gain the ability to respond quickly to unpredictable demand to reduce stock outs for cement wholesalers and retailers. Cement companies collaboration with wholesalers and retailers is very low. There are significant opportunities for improvement, especially in emerging markets.
Manufacturing focus	Cement companies are committed to high utilization rates. Cement plants are built to generate economies of scale and they work 24x7 only stopping for maintenance or due to extreme falls in demand. In the case of bagged cement, it is important to create excess buffer capacity. One opportunity to get this capacity is by the use of postponement in the packing process where a buffer is created in bulk cement avoiding the possibility of not having inventory in the bag size that the customer is requiring.
Inventory strategy	Given the 60 days of cement shelf life, cement companies are committed to generating high turns and minimizing the inventory of finished goods (FG).

	For bagged cement, it is necessary to create buffer stocks of finished goods close to the market given that cement plants are normally close to the quarries. According to Cementos Argos “We maintain 3 days of FG inventories in the warehouses” According to Cemex “The bagged cement business is about turnover”.
Lead-time focus	Cement industry is make-to-stock. According to Cementos Argos, the local delivery lead time is approximately one day since product is normally available in inventory. For bagged cement, it is important to invest in practices to reduce the lead time even further. Practices such as moving the inventory closer to the customers or specialized software to optimize urban routing are interesting.
Approach to choosing suppliers	Cement is a commodity that is selected primarily by price, availability and quality. Availability is a key element in bagged cement. If the product is not available in the shelf in the purchasing moment, the final consumer easily switches to a different product. Collaboration with downstream partners is a key element to get the desired level of product availability in shelves.
Product-design strategy	Cement manufacturing process is highly automated and continuous. Cement companies are focused in maximizing performance and minimizing cost. Postponement ideas of grinding to order or packing to order might help in the case of bagged products.

Lee (2002) proposes an uncertainty framework with two components: demand and supply. Demand uncertainties are covered by Fisher (1997) in his classification of innovative and functional products. Supply uncertainties classify supply processes into two types, stable and evolving. See Section 2.6.2.2 for details of Lee’s framework

Cement supply process can be characterized as stable. Cement manufacturing is stable with high production yields, low product quality problems, relatively unlimited supply sources, easy changeover because of the small number of references using just a few raw materials, and fixed cement production lead times.

Given that bulk cement is a functional product and that cement supply process is stable, bulk cement is located in the upper left corner of in Figure 27. According to Lee (2002), the right supply chain for bulk cement is an efficient supply chain.

Given that bagged cement is an innovative product and that the cement supply process is stable, bagged cement is located in the upper right corner of in Figure 26. According to Lee (2002), the right supply chain for bagged cement is a responsive supply chain.

		Demand Uncertainty	
		Low (Functional Products)	High (Innovative Products)
Supply Uncertainty	Low (Stable Process)	Efficient supply chains Bulk cement	Responsive supply chains Bagged cement
	High (Evolving Process)	Risk-hedging supply chains	Agile supply chains

Figure 26. Uncertainty Framework in the Cement Industry. Source: Fisher (1997)

In recent years, cement companies are significantly improving their abilities to master an Efficient Supply Chain for their bulk products. The extensive implementation of optimization supply chain software in the cement companies is one of the key elements of progress in the cost efficiency aspect.

In the case of the Responsive Supply Chain that is necessary for bagged products, Fisher (1997) and Lee (2002) agreed on the importance of collaboration with upstream and downstream supply chain partners. Functional products like cement are price sensitive; therefore negotiations with upstream and downstream partners are difficult. Collaborative programs between supply chain partners are the best way to avoid this situation, creating higher profits for the supply chain as a whole. Based on the information gathered, the level of collaboration in the cement industry is relatively low. In the upstream component, there is collaboration with the suppliers of raw

materials with medium to long-term contracts but there is no evidence of continuous information sharing initiatives. In the downstream side, low level of collaboration between cement and concrete companies is evidenced. According to Cemex, “There is a belief in the cement industry about the difficulty in combining cement and concrete supply chain processes. We believe that there are benefits in combining the two and we started this process by joint truck maintenance initiatives.” The long-term relationships of concrete companies with large construction companies are the best example of collaboration in the cement / concrete industry.

Traditionally, the supply chain of the cement industry has been classified as an efficient supply chain. The cement supply chain was designed to maximize economies of scale with relatively centralized manufacturing and to minimize transportation costs with the use of FTL and low cost transportation modes. Efficient Supply Chain is effective for bulk cement, which is common in developed countries, but as we have discussed, it is not appropriate for emerging markets.

According to Lee’s research in 2004, top performing supply chains have three characteristics: agility, adaptability and alignment. See Section 2.6.2.3 for additional details about the framework. In Table 11, bulk cement supply chain and bagged cement supply chain were assessed as high, medium or low in each SC characteristic.

Table 11. Cement Supply Chain Assessment in Triple-A Framework

SC Characteristics	Bulk Cement Supply Chain	Bagged Cement Supply Chain
Agile	<p>Medium</p> <ul style="list-style-type: none"> – Medium flow of information with customers. – Medium level of development of collaborative relationship with suppliers. 	<p>Low</p> <ul style="list-style-type: none"> – No flow of information with customers. – Medium level of development of collaborative relationship

		with suppliers.
Adaptable	Low <ul style="list-style-type: none"> – Limited use of intermediaries in logistics services. – High concern about final consumers. 	Medium <ul style="list-style-type: none"> – High use of intermediaries in logistics services. – Medium concern about final consumers.
Aligned	Low <ul style="list-style-type: none"> – Limited flow of information with suppliers and customers. – Limited use of supply contracts sharing risk, costs or gains. 	Low <ul style="list-style-type: none"> – Limited flow of information with suppliers and customers. – Limited use of supply contracts sharing risk, costs or gains.

In general, we identified opportunities in collaboration and information sharing with raw materials, energy suppliers and distribution channels, focus in final consumers and use of equitable supply contracts in supply chain processes such as logistics services (e.g. infrastructure, transportation or warehousing).

According to Fisher (1997), two additional elements should be addressed in functional products that are worth to analyzing for the cement industry.

- Aggressive cost reductions have been made in some functional product industries and after some point, diminishing returns were reached. For many years, cost reductions in the cement industry were concentrated on the manufacturing process. Now, large investments are required to significantly reduce the cement manufacturing cost. In recent years, cement companies identified the benefits of SCM practices and used them as an opportunity for significant cost reduction. Present and future SCM potential savings are considerable and they can be extended to the mineral extraction commodity industry in general.

- One cause of lack of effectiveness of functional products' supply chain strategy is forward buying. In general, forward buying is a game where everybody loses because buyer's carrying cost increase while supplier's manufacturing and distribution processes are disrupted by fictional peaks of demand. Forward buying is a common practice in the cement and commodity industry. It has been used for many years and customers are used to buy under this practice. Further research is required to establish the benefits and barriers of moving to an every day low prices strategy that companies in other industries have implemented successfully.

4 Cases Studies

Three case studies are presented to support the idea that SCM can add value to the corporate strategy of cement and mineral extraction commodity companies. The first case is the implementation of a single 3PL (Third Party Logistics Provider) by three of the largest oil companies in Colombia. The second case is a collaboration project between concrete and cement supply chain in Cemex Colombia. The third case is collaborative port operation contract in the steel industry.

4.1 Single 3PL for the oil industry

The first case study is the implementation of one single 3PL provider to serve three of the most important oil companies in Colombia. The project's name was "Integrated Logistics Operator" (OLI – Spanish acronym). The name of the companies are Petrol A, B and C¹. These names are fictional.

Traditionally, supply chain management leaders in the oil companies in Colombia don't work collaboratively. In 2002, after an evaluation about the potential benefits that collaboration in supply chain management might bring to the oil companies, Petrol A supply chain leader promoted a meeting with his counterparts. This meeting was facilitated by a third person that was independent to the oil industry. The purpose of the meeting was to have a brainstorming session to identify potential areas of collaboration. As a result of the meeting, two areas of collaboration were identified. The first area was Materials, Repair & Operations (MRO) parts visibility among the oil

¹ One of the three oil companies was public. In Colombia, public companies are forced to follow the government contracting law in all their purchasing processes. This law requires companies to follow strict guidelines to guarantee transparency. The other two companies evaluated the requirements of the government contracting law and agreed on adopting its guidelines as the group purchasing process.

companies. The second area was developing common 3PL providers for the oil industry.

The first area of collaboration was motivated by the fact that oil companies have significant MRO inventories generated by the parts that are not used in the perforation of oil wells. The value of the industry inventory of MRO parts represents millions of dollars. Because the lack of inventory visibility, an oil company might buy a part that another company has in its inventory. This project was postponed because the significant IT integration investment that was required to consolidate the MRO inventory information of the companies in the oil industry.

The second area of collaboration was motivated by the opportunities of consolidating the purchasing processes of logistics services of the oil companies. During the brainstorming meetings, the oil companies noticed that they were acquiring products from the same origins (US, mainland Europe and UK). They noticed that they normally bid for the same type logistics services (freight forwarding services, transportation and customs clearance services) but at different times during the year. For example, Petrol A bids transportation in February, while Petrol B bids in May and Petrol C bids in June. They also noticed that they were bidding for the same type of logistics services with different 3PL providers. 3PL providers for the oil industry were not developed at that time; they were specialized as per service type.

Additionally, an opportunity to get benefits from the demand aggregation of the oil companies from a logistics and financial perspective was also identified. All the companies in the oil industry were invited to participate, but only three were

committed to develop common 3PL providers. The three companies managed, handled, transported and delivered USD 140 millions per year worth of international purchases of materials, equipments and spare parts accounting for at least 60% of the Colombian oil industry.

The first step of the process was demand aggregation per logistic service. As a result, three aggregated purchasing processes were made, one for freight forwarding services, one for transportation and one for custom clearance service. The main reason for not moving to a single 3PL provider was a bad past experience by one of the oil companies with a 3PL provider covering the three logistics services. To reduce the risk from unreliable suppliers, the three oil companies decided to select two providers per logistics service for a two years period.

The individual logistics service contracting mode generated excellent results, but the supply chain leader of Petrol A insisted in the importance of the single 3PL provider. Due to the large scope of the three logistics services required by the oil companies, a consortium of suppliers was required. Then, the bidding started and 11 consortiums quoted. Finally, two consortiums were selected; one for Petrol B, the largest of the three oil companies, and another for the remaining two companies.

An interesting innovation was the three oil companies' involvement in the details of the contract's costs and rates. This level of involvement requires the 3PL provider to open its accounting books and to support all the expenses specified in the contract. The contract was flexible enough to use the 3PL provider current tariffs for a certain period of time but after that period, if a component of the logistic service could be outsourced

for better tariffs in the market, the 3PL provider has to work with these outsourcing companies. The motivation for this arrangement was to guarantee that the 3PL provider tariffs were always competitive. The oil companies were involved directly in the selection of the outsourcing company. This process was particularly valuable in the case of freight consolidation service where maritime and air tariffs were hidden in the general tariffs, and for customs brokerage services where ports operations costs were hidden too.

In the first 4 years of the implementation of the ILO, the cost savings were approximately 4 million dollars per year for the three oil companies. This figure represents a 20% reduction from the figure that the companies were paying for ILOS services before integration. Further savings are possible with the entrance of other oil companies and continuous improvement from the partners involved.

Based on the information gathered, these are the key success factors in the implementation of the single 3PL provider in the Colombian oil industry:

- Long term contracts (at least 5 years) allowing the 3PL provider to build the learning curve in the oil business and exploit it in the execution of the contract.
- One manager per company exclusively dedicated to the execution of the contract with significant knowledge about supply chain operations in the oil industry.
- Oil companies' involvement in the details of the contract cost and rates to unhide cost components and reveal additional savings opportunities.
- Use of key performance indicators and continuous performance reviews to assess the results of the ILO and adapt to changing environment.

- Training and exposure of ILO employees to logistics knowledge and continuous improvement in ILO logistics practices based on the requirements of the oil companies.

There were also challenges in the execution of the project such as changes in the renewal contract conditions from internal decisions of the oil companies or differences in the internal structures to manage the contract.

4.2 Collaboration between of concrete and cement supply chain

Traditionally, cement and ready-mixed concrete supply chains have worked independently from each other. This situation holds true even when they are part of the same company.

Cemex started operations in Colombia in 1996 by acquiring two local cement producers: *Cementos Diamante* and *Cementos Samper*. Cemex Colombia now produces bulk cement, bagged cement, aggregates and ready-mixed concrete. Cemex Colombia cement supply chain leaders have been committed to value generation. They have also been interested on extending these value generation practices to their ready-mixed concrete operations as well.

In April 2008, Cemex Colombia ready-mixed concrete operations had a private fleet of 319 mixer trucks but only 74% of them were operational due to mechanical problems. Taking into account that ready-mixed concrete lasts fresh for about 90 minutes, concrete mixer trucks availability is a crucial element to guarantee adequate customer service level.

Cemex cement operations had a very efficient maintenance facility for bulk and bagged cement trucks that was not utilized by concrete mixers. In one meeting, concrete leaders asked for help to cement maintenance managers to fix concrete mixers mechanical availability problem. Additionally, there was a problem with ten large ready-mixed concrete trailers that were pulled by third party contractors that were very old and usually broken/unavailable. To solve this problem, cement maintenance leaders reassigned ten of their own trucks to immediately eliminate the need of the old third party trucks.

The result was outstanding. In six months, mechanical availability of mixers increased from 74% to 93%, 109 mixer trucks were completely overhauled and total maintenance costs were reduced by 25%. Also, a state-of-the-art maintenance facility was built and a specialized team of engineers was hired to solve the maintenance needs of both; bulk cement trucks and ready-mixed concrete trucks.

This project started as a pilot but currently the maintenance function is fully integrated across the company; generating value for Cemex supply chain as a whole.

Cemex also provides an example on how cement companies can create value through end-user innovation, effectively de-commoditizing a traditional product like cement. According to Flores et al. (2003), Cemex "*Patrimonio Hoy*" project facilitates access to emerging markets that are characterized by low-income large population. Flores et al. (2003) propose that customers in emerging markets are producers rather than consumers. The producers approach means that companies have to provide producers

“a refinement of abilities that they can appreciate and from which they can profit.” In the case of the Cemex, the company is concentrated in selling homes rather than selling cement. Because DIY building is dominant in emerging markets, Cemex is promoting building a house one room at a time. Cemex DIY customers are part of groups of three that are responsible for weekly payments. The payment covers the construction materials of one room. The customers are also members of a club where they get information about designing and construction. By 2003, *Patrimonio Hoy* has 39,000 members with a rate of complete payment of 99.6% after the materials are received. Other benefits are that DIY builders built at a rate that is three times the traditional rate and four-fifths of the traditional cost.

Cementos Argos, a cement company in Colombia, is also using end-user innovation projects, similar to Cemex *Patrimonio Hoy*, in collaboration with cement distributors and financial institutions.

4.3 Collaborative Supply Chain Contracts in the Steel Industry

Steel Inc. is a Latin-American manufacturer of flat and long steel products (e.g. semi-finished steel, flat-rolled products, welded tubes and beam, and roll-formed products). Steel Inc.’ customers come from diverse industries such as automotive, construction, agriculture and household electric products.

Steel is an alloy composed of iron mixed with carbon and other mineral elements. Steel supply chain extends from the extraction of iron ore from mines, the transformation of raw materials into steel and its final products and the delivery to customers by sea, truck or river.

Steel Inc. mostly uses sea transportation to export its products to final customers. Normally, sea freights have three components: loading cost, sea freights and unloading cost. These costs are composed of vessel waiting time and fuel. The vessel waiting time is estimated with loading and unloading rates provided by port operators. The speed of loading and unloading is a critical element of cost; it reduces sea freight tariffs and penalties for vessel delays.

Before 2005, sea freight costs accounted for 20% of the total logistics cost of the company. Of this 20%, 18% was the cost of the vessels loading in port; this percentage represents approximately 10 million dollar per year. The port operator at that time had a loading rate of 2,400 tons per day.

The main goal of the project was to select a new port operator. One major challenge was the specialized equipment required to load steel final products into vessels. To minimize this challenge, Steel Inc. made an up-front payment of several million dollars to purchase new equipment as a part of the five year contract. It was also agreed that Steel Inc. was the owner of the equipment.

The project was won by a multinational firm which operates other ports in Latin-America and Europe. The company reached a 40% increase in efficiency in one year, stabilizing on an average rate of 4,600 tons per day from 2006 to 2008. With this rate, the cost of the vessels waiting in port was reduced to 5 million dollars compared to the original 10 million dollars.

One element in this contract was the inclusion of an incentive model to foster the port operator to increase loading rates. The five year contract involved incremental yearly goals loading rates. The monitoring of real time data to calculate the inputs for the incentive model was made by a third party which was the last entity in contact with product before the loading process. The incentives model took into account the differences in loading efficiencies from different steel products. In addition, the port operator had full access to the planning and production systems and was part of the weekly review meetings.

The contract included the following processes: transportation from warehouse to dock (*Manejo* and *Caleta* in Spanish), unloading of raw materials, loading of finished goods (*Izaje* in Spanish), palletizing and product accommodation inside the vessel (*Trincado* in Spanish). See Figure 27 for details of the port process.

Significant improvements were collaboratively implemented such as: use of tractors and trailers in port internal movement to gain speed, new security procedures to use several docks in the loading process at the same time, new tools to accelerate product accommodation inside the vessel keeping a safe environment for workers, flexible shifts to guarantee continuous operations and mobile dining rooms to reduce worker's walking distance. The contract main goals were security, quality and productivity.



Figure 27. Steel Port Operations. Courtesy of Steel Inc.

In summary, four elements were crucial in the success of this contract: risk sharing in the initial steel port equipment, information sharing among the company, the union and the port operator, and an incentive model to promote continuous improvement.

5 Conclusion

The purpose of this thesis was to understand the evolution of supply chain management in the cement industry, to propose the right supply chain for cement and to demonstrate that supply chain management can generate value for cement companies. The conclusions below present the key findings on these objectives.

- From an economic perspective, the oligopoly or monopoly that characterized cement industry might explain the lack of importance of SCM. Compared to a free market, oligopolies and monopolies have low pressure to reduce costs, low pressure from customers and limited number of competitors. The focus of companies in oligopolies or monopolies is concentrated on pricing and competition monitoring. Traditionally, SCM is not a priority for these companies.

- Cement is a mature industry. On average, the four largest cement companies are 200 years old. Change management processes for these companies require time and resistance may be found. SCM importance within the companies might take time to be incorporated in the strategy but it could be an excellent opportunity for innovative managers to create value. The case studies presented were from companies in emerging markets; maybe this is a coincidence, but one can conclude that innovation in SCM is possible when the pressure from headquarters was relaxed because of local market situations.

- Traditionally, cement supply chain is driven by asset utilization. Assets are represented by production plants, infrastructure and transportation equipment. Asset utilization is a given for the largest companies in the cement industry. This is

why they are moving to Efficiency and / or Customer Response objectives to differentiate and to gain competitive advantage in the market. This change in strategy requires cement companies to build supply chain management capabilities that traditionally asset utilization companies don't have, in order to succeed in the new competitive environment.

- Given the asset utilization focus of cement companies, there were significant investments to improve cement manufacturing processes. As a result, a highly automated and continuous production process was developed. Today, large investments are required to improve manufacturing capabilities, so SCM may be seen as the new frontier of cost reduction in the cement industry.

- The low price-to-weight ratio, which is a characteristic of cement, limits the geographical coverage of a production center. This situation reduces supply chain management to an operational role because it is solely responsible for moving the product by truck in a ratio of 300 kilometers. The use of maritime, rail and river transportation expanded the coverage of a production center allowing SCM to increase its scope facilitating the access to new markets and reducing costs significantly. Additionally, SCM costs are normally hidden in the company financial statements. Detailed cost analysis is required to uncover the potential of savings of SCM.

- Cement companies face a major challenge in emerging markets where bulk and bags coexist. To gain competitive advantage, these cement companies have to build two different supply chain strategies, one for each type of product. The bulk

cement supply chain has to be focused on efficiency to obtain benefits from optimization processes and maximize utilization. The bagged cement supply chain has to be responsive and focused in availability. Bagged cement is more similar to a consumer good product than to bulk cement. To cope with the bulk and bagged challenge, supply chain leaders in the cement companies in emerging markets need a team which is able to work in these supply chain environments.

- Practices such as collaboration and information sharing with upstream and downstream supply chain partners are a significant opportunity to gain alignment for cement companies. Other elements such as the use of equitable contracts and the elimination of forward buying practices might generate value and increase the agility of these supply chains. One additional opportunity is supply chain collaboration with local or regional competitors in the purchasing of common components, equipment and services. Collaboration with competitors requires a significant change in the mind-set of the cement companies.

This set of conclusions can be expanded to the mineral extraction industry. SCM relevance varies significantly by commodity. It seems that for some products, SCM has to be more responsive like oil, and for other products more efficient like bulk cement or coal. Some mineral extraction companies outsourced to contractors most of their supply chain processes many years ago. In this process, some companies lost their SCM know-how and they have to start from scratch to rebuild it.

A major concern in the commodity industry is the variability in the implementation of advance SCM practices within the companies in the same industry. This thesis

project is an invitation for lagging commodity companies to evaluate the potential benefits of SCM and implement them in the near future.

A natural next step stemming from this research would be to repeat this analysis with other commodity products to understand their particular supply chain complexities.

From a strategic perspective, it is important to go deep in the supply chain strategy required to succeed in emerging markets. In this thesis emerging markets are treated as a single market with homogeneous characteristics for the sake of simplicity. Additional research at regional or country level in particular emerging markets is required to understand its particularities and define an appropriate supply chain strategy.

In this thesis, cement was characterized as two types of product, bulk cement and bagged cement; and a right supply chain was recommended for each of them. It is important to acknowledge that there are several types of bulk cement and bagged cement. Further research should be done in order to confirm if all the types of bulk cement or bagged cement should have the same supply chain structure.

At an operational level, further research has to be done to confirm if the proposed alternatives of Grind-To-Order and Pack-To-Order generate value for the cement supply chain. Also, a comparison could be made between bagged cement supply chain and consumer products supply chain to identify practices that might generate value in the cement industry.

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Appendix A. Respondent companies

Company	Position	Commodity Type
Lafarge North America	Logistic Manager	Cement
Holcim North America	Logistic Manager	Cement
Cemex Colombia	VP Supply Chain	Cement
Cementos Argos	VP Supply Chain & Functional Directors	Cement
Cerrejon Coal	Director of Logistics and Trade	Coal
Ecopetrol	Purchasing Manager	Oil
Empresa de Energía de Bogota	Supply Chain Director	Electricity
Ternium	VP Supply Chain	Steel

Appendix B. Questionnaire

Plan

- What is the company strategy?
- What is the role of SCM in the business strategy of your company?
- Where is SCM in the organizational chart? Has the position evolved over time? Why?
- Which are the activities/areas that fall under SCM? Have they evolved over time? Why?
- Which are the priorities / Key Performance Indicators of the SCM organization?
- How do you plan the network design of your company?
- What is the impact of the internationalization of your company in SCM?
- What are the benefits of M&A in your industry? Are these benefits related to SCM?
- What is the ideal SC for your product?
- How important is SCM in your industry? What is the level of development in SCM in your industry?
- Is the SCM organization global or regional? How much does it vary from region to region?
- Which are the future challenges that your industry is facing? How will these challenges be supported by SCM?
- What are the challenges in sustainability in your industry? Are these requirements different depending on the country? How?
- Why cement companies decided to integrate with concrete producers? Are there any benefits in SCM? (This question applies only to cement companies).

Source

- Which are the priorities / Key Performance Indicator of the Sourcing process?
- What are the components that are more significant for your company?
- Who are the major suppliers of your company? Are they short term / long term relationships?
- Is the sourcing centralized or decentralized?
- How do you plan the sourcing of your company?
- Do you use any IT in the sourcing process?
- Is there any limitation in raw materials availability in your industry?
- Do you have inventory of raw materials / components in your company? How large is this inventory?
- What are the challenges in sustainability in the sourcing process?

Make

- Which are the priorities / Key Performance Indicator of the Manufacturing process?
- How do you plan / schedule production in your company? MTO? MTS?
- Do you use any IT in the production planning / scheduling process?
- What is the size of a typical production batch?
- How many SKU's do you manufacture and how difficult it is to change from one product to the other?
- Does your plan have an excess of capacity at this moment? How do you manage this situation?
- What are the challenges in sustainability in the manufacturing process?

- Which is the future challenges that manufacturing is facing?

Deliver

- Which are the priorities / Key Performance Indicator of the Distribution process?
- How do you describe the demand of your product? Is it variable / seasonal / trend?
- Which are the clients of your company? Which are the most important from a SCM perspective? Why?
- What is the difference between the distribution of cement in bags versus the distribution of cement in bulk? (This question applies only to cement companies).
- How do you plan the distribution in your company?
- What is the transportation modes preferred in your company? Why?
- Is your company vertically integrated in the logistics process? Transportation? Warehousing? How the integration has evolved over time? Why?
- Are there any physical characteristics of your product that limit the distribution process?
- Is it common for your product to be used as backhaul load?
- Do you have inventory of finished goods?
- Which are the future challenges that Distribution is facing?

Return

- Are there any returns in your industry? What are the causes? How big they are?
- Is the return cost significant?
- Is there any return in the concrete industry? What are the causes? How big they are? What do you do with the returned product? (This question applies only to cement companies).

Appendix C. Comparative Table of Largest Cement Producers (Information of 2008)

Company	Business Units (% of Sales)	Sales	EBITDA Margin	Production Sites ¹	# of countries	Allocation of Sales & Operating Income	SCM Position
1. Lafarge France 1833	Cement (57%), Concrete & Aggregates (35%), Gypsum (8%)	€19 billion	24.2%	2,187	79	Sales: EM ² (46%), DM ³ (54%) Op. Income: EM (60%), DM (40%)	COO is one of the Executive Officers. Country or Regional & Corporate Supply Chain Directors ¹¹
2. Holcim Switzerland 1912	Cement (57.6%), Other Construction Materials (33%), Aggregates (9%)	US\$ 23.2 billion	21.2%	2,000	70	Sales: EM (50.8), DM (49.2%)	Procurement functional leader is member of the Executive Committee.
3. Cemex Mexico 1906	Cement (44%), Concrete (40%), Aggregates (15%) ³	US\$ 21.6 billion	20.0%	2,427	50	Sales ⁵ : EM (32%), DM (67%) Op. Income. EM (72%), DM (28%)	Operations technology and IT is one of the cited responsibilities of one of Executive Management Team. Country Supply Chain Vice-presidents.
4. Heidelberg Germany 1873	Concrete & Aggregates (46%), Cement (43%), Construction Materials (11%)	€14 billion	20.7% ⁶	N.A. ⁶	50	Europe and the US represent 78% of sales.	Logistics is one of the cited responsibilities of one of Managing Board members
5. Italcementi Italy 1864	Cement (71%), Concrete & Aggregates (23%), Others (5%)	€5.8 billion	19.3% ⁸	690	22	Europe and the US represent 90% of sales	COO is one of the Executive Officers ¹¹
6. Taiheiyo Japan 1881	Cement, Mineral Resources, Environmental, Real estate, Construction Materials, Ceramics & Electronics, and International Businesses	US\$ 9.2 billion	6.8% ⁹	21 ¹⁰	3	US West Coast, China, Southeast Asia.	In the Professional Staff Division there is a General Logistics Department.
7. Buzzi Italy 1907	Cement & clinker (64%), ready-mix, aggregates (36%)	€3.5 billion	N.A. ⁶	565	11	Europe and the US represent 94% of sales	N.A. ⁶
8. Votorantim Cimentos Brazil 1936	Cement, concrete, aggregates	R\$5.6 billion ⁴	28.6% ⁴	295	3	Brazil, US and Bolivia	N.A. ⁶

1. Include cement and concrete plants
 2. Emerging Markets (EM)
 3. Developed Markets (DM)
 4. Data from 2007 in Brazilian currency
 5. For Cemex analysis, EM is composed Mexico, South / Central America and the Caribbean, Africa and Middle East and DM is the US, Spain, United Kingdom, Rest of Europe, Asia and Australia.
 6. Operating Income before Depreciation (OIBD)
 7. N.A. (Not Available)
 8. Recurring EBITDA
 9. Income from cement operations
 10. Including four at domestic and ten at overseas subsidiaries, affiliates.
 11. It is assumed that SCM is part of COO responsibilities.
- Source: Lafarge (2008), Holcim (2008), Cemex (2008), Heidelberg (2008), Italcementi (2008), Taiheiyo (2008), Buzzi (2008), Votorantim (2008)