Implementing Supply Chain "Best Practices" in the Construction Value System

By

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ABSTRACT

The construction industry, with a $4.2 trillion worldwide market, is highly fragmented with innumerous players in its value system. Supply Chain Management involves management of inter and intra company resources (personnel, inventory, transportation, facilities) in order to efficiently deliver products and services to the market place and boost profitability. Different industries have utilized supply chain management practices in their own ways to achieve this objective. From a preliminary study, it seems that the Construction industry has only utilized Supply Chain Management practices in a limited way and there still remains a huge opportunity in improving efficiencies in the Construction Value System.

This thesis examines some of the supply chain best practices that have been successfully implemented in other industries (Ex: Aviation/Defense, High Tech, Process, Consumer Goods, etc) and discusses how some of those can be applied to the construction industry.

This study, oriented towards improving the Construction Value Chain may be used by academia and industry as a reference when implementing supply chain practices, processes and systems. Researchers may also use this study and develop detailed implementation strategies on how some of these best practices could be implemented in the Construction industry.

Thesis Supervisor: Prof. Jerome J. Connor
Title: Professor, Civil and Environmental Engineering

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1. INTRODUCTION

1.1 U.S. Construction Industry

The construction Industry is a large business with important links to the rest of the economy with a total dollar value more than $856 billion (1997). Totally more than 7.9 million people are employed directly or indirectly by the construction industry, which accounts for nearly 8% of U.S. gross domestic product. The U.S. exports of construction services totaled over $4 billion in 1998.

The construction industry is highly fragmented with about 667,000 construction companies in the U.S. (1997). Most construction establishments employ fewer than 10 people. According to a survey of 5,214 establishments, 58% of construction firms hold industry assets between $500,000 and $5,000,000. Only .01% of all firms have net industry assets over $50,000,000.

7.9 million people work in construction in 2000
$856 billion in construction business done in 1997
$565 billion in new construction in 1999
$4 billion in U.S. construction exports in 1998
667,000 U.S. construction companies in 1997

Table 1: Statistics in the Construction Industry

The mainstream construction industry first began in a sort of mom and pop way. Single-office based operations, which worked on single projects at a time were how today's large corporations in the industry started. Unlike other industries, the construction industry has not seen change as frequently. The original expansion of the industry can be credited to

technological advances, but the recent introduction to e-commerce has further helped globalize the construction industry. In addition to expanding their commerce throughout the world, today's major construction companies are always trying new and innovative projects. The top five net grossing construction companies in the world are all companies that have established a network of e-commerce opening doors that might not otherwise have been available.

1.2 Supply Chain Management in Construction

The industry today can be described as a high cost industry with low productivity. The state of the market and the productivity in the construction industry have a strong link; in an upward economic trend, the productivity becomes worse when companies are busy making fast profits on the temporary markets having no time to try to reduce project costs. The opposite is seen during a recession in the economy. At harsh times, companies have been forced to ponder on ways of increasing efficiency and effectiveness but then there is no money to implement and experiment with new strategies and technologies.

Supply Chain Management involves management of inter and intra company resources (personnel, inventory, transportation, facilities) in order to efficiently deliver products and services to the market place and boost profitability. Construction industry has only utilized these practices, if at all, in a limited way and there still remains an enormous potential in improving efficiencies in the Construction Value Chain.

Today, the actions related to the flow seldom seem be coordinated with the initiatives of the others involved in the supply chain. By limiting coordination to node-to-node communication, the supply chain is unable to flexibly meet the demands of the end customer.

There is a need for a new, simpler information and material transaction business model (Taylor and Bjornsson, 1999). There is a clear gap between the supply chain and logistics management practices between the manufacturing and construction industry.

As the economy changes, as competition becomes more global, it is no longer company vs. company, but supply chain vs. supply chain (Henkoff 1994). The construction supply chains also will be affected by this trend. Construction supply chains have to be reconsidered by measuring the value-added at each node and new ways have to be found to decrease waste and latency (Taylor and Bjornsson, 1999).

1.3 Purpose and Objective

The purpose of this research is to identify supply chain management processes that can improve efficiency and reduce costs in the construction value chain.

The objective of the thesis is achieved by accomplishing three sub-objectives:

- The first sub-objective is to identify basic problems caused by the current practices used in the construction industry.
- The second sub-objective is to examine some of the supply chain management best practices that have been successfully implemented in other industries.
- The third sub-objective is to is to determine what supply chain management practices from other industries can be applied to the construction industry and discuss how these best practices can benefit the construction value chain and the different players in this chain.

1.4 Focus

The focus in this thesis is on the supply chain in the construction value system. SCM involves effectively defining and utilizing process, material and information flows to achieve

higher output/revenue at lower costs. This thesis is a visionary research, which is confined to identifying supply chain best practices that could be applied to the construction supply chain. Future researchers can take any of these identified areas and perform detailed implementation research.

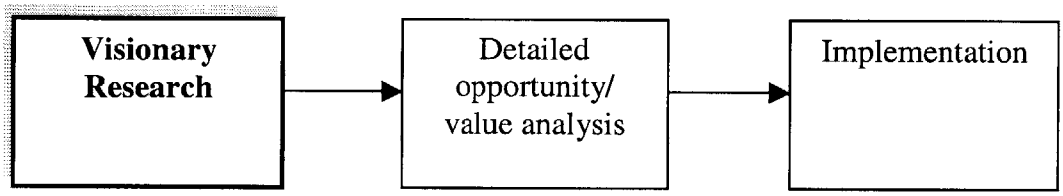

Figure 1: Progress of a research

1.5 A Guide to the Thesis

To achieve the objectives of the thesis a three-step approach will be used.

First, the construction value system with its current practices and methods will be studied. The following will be identified:

- Stakeholders
- Challenges in construction supply chain
- Key areas of opportunities in the construction supply chain
- Differences between the supply chains of a traditional industry and the construction industry

This is presented in *Chapter 2, The Construction Value System.*

Next, some of the supply chain best practices that have been successfully implemented in other industries are examined. These would include the Aviation/Defense sector, High Tech

industry, Process, Consumer Goods industry, Retail industry, etc. This is discussed in *Chapter 3, Supply chain "Industry Best Practices".*

Finally, analysis and discussion of how some of these practices can be applied in the construction industry to improve its productivity is presented. A high-level implementation plan is discussed and how this plan would affect the construction industry is analyzed.

This analysis is in *Chapter 4, Improving Supply Chain Management in the Construction Industry.*

Figure 2 contains the basic outline of the report, and the associated chapters.

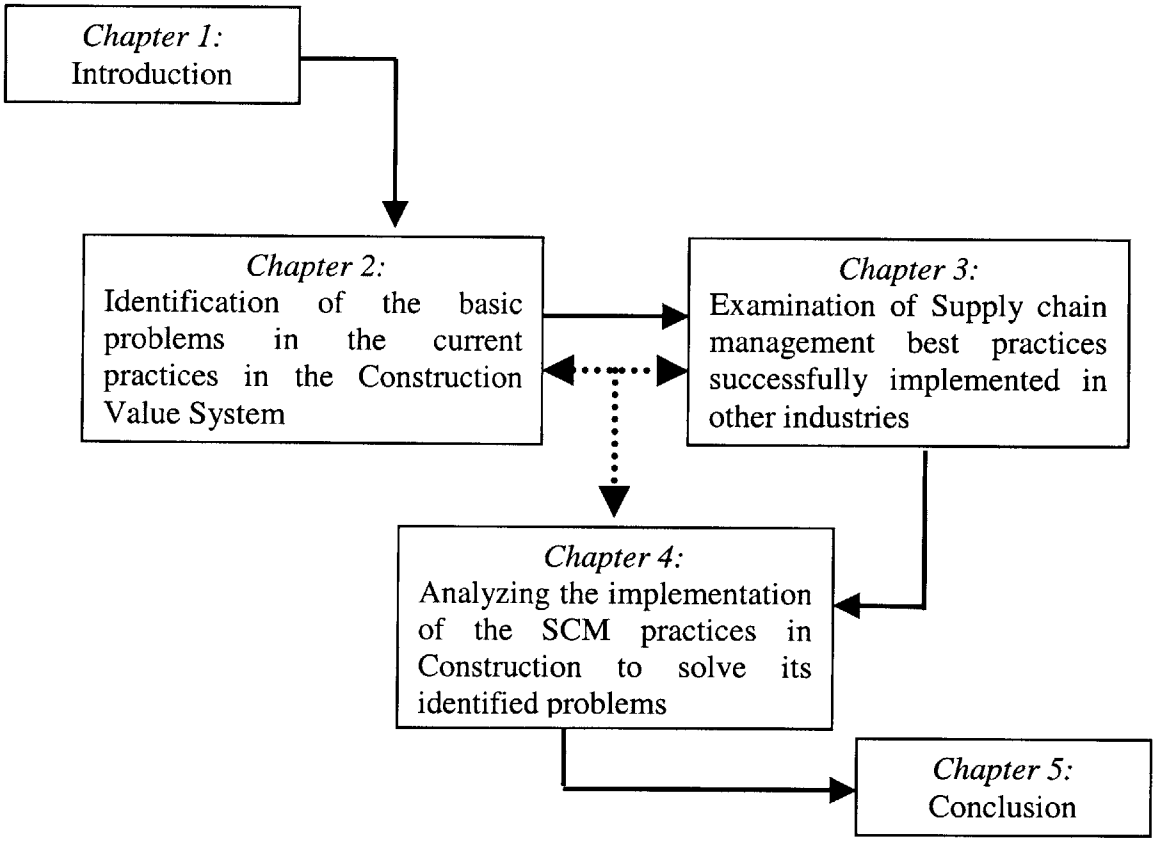

Figure 2: Outline of the report

2. THE CONSTRUCTION VALUE SYSTEM

2.1 Value system

According to Porter, a value system is a multiple series of supplying and buying firms, purchasing inputs from and delivering outputs to each other. Such a value system can be compared with a supply chain. A supplier in the system is not only delivering a product or a service to a buying firm, but also influencing the buying firm's performance in many other ways. The other way around, the supplier's business is dependent on the buying firm's delivery performance to the next buying firm in the value system. This interdependence necessitates considering the integral performance of the collective system rather than the separate performances of the individual firms (Vrijhoef, 1998).

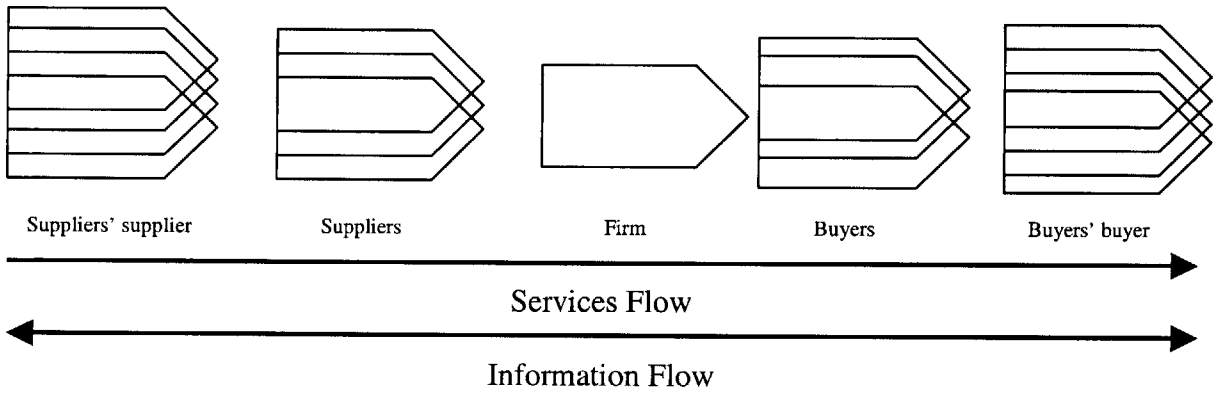

Figure 3: Firm Value System

2.2 Construction Value System

The construction value system consists of a series of interdependent entities that provide their services and products to realize a construction project - a building, road/highway, dam, etc. The multiple stakeholders in the system are owners, developers, designers, contractors, sub contractors, equipment, material and raw material suppliers, and lenders and insurers.

Figure 3 shows the construction value system, its different players and the relationship between them.

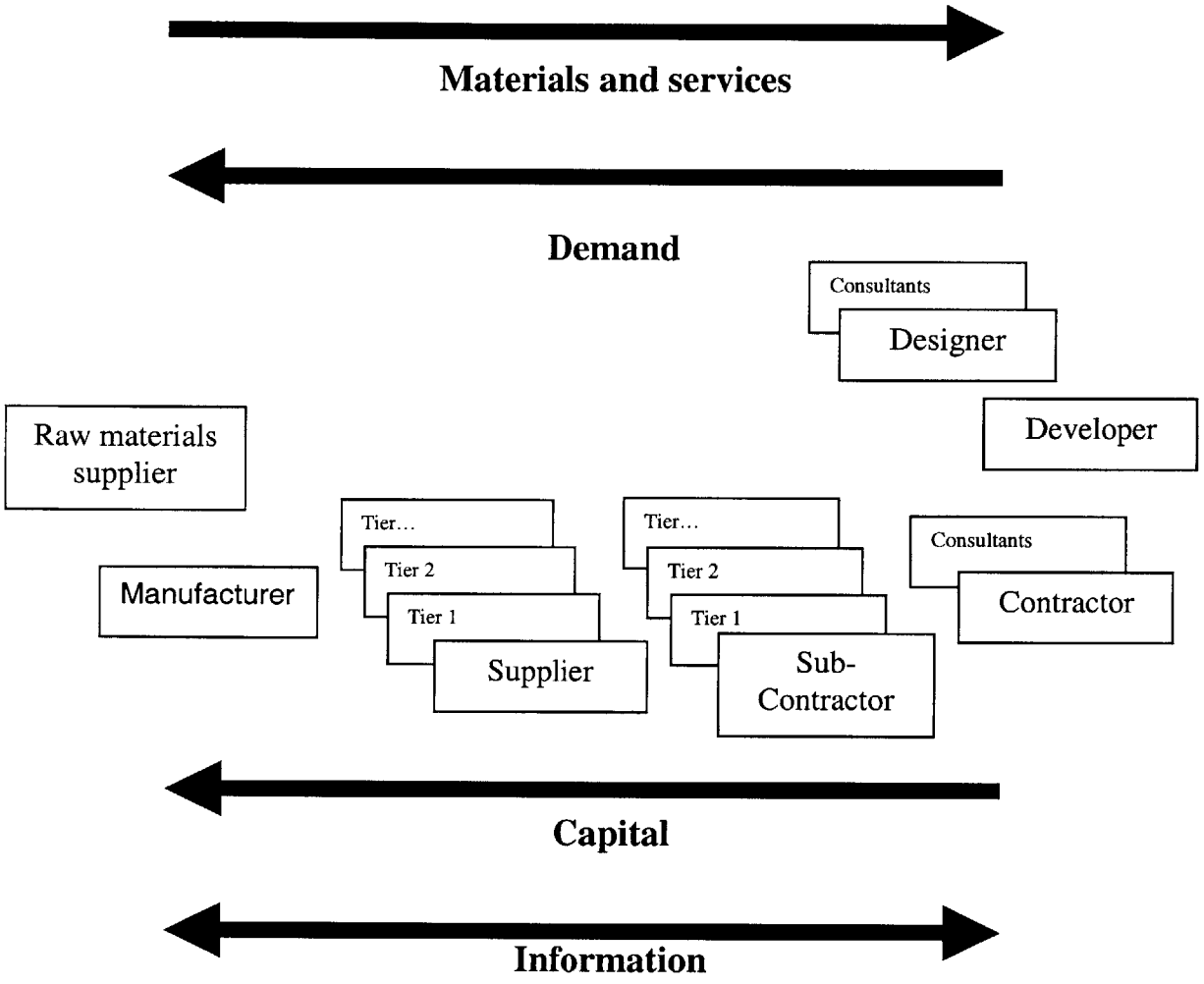

Figure 4: Construction Value system

2.3 Stakeholders

2.3.1 Owners

The construction project is initiated by the owner of the project. The owner is either the developer himself/herself or hires a developer for his project.

2.3.2 Developers

The developer is responsible for the acquisition of the property, arranging the financing for the project, contacting and hiring the designers and selecting the contractor.

2.3.3 Designers

The designers are the architects and the engineers who execute the design for the construction of the project based on the owner's/ developer's requirements. They collaborate with many different specialty consultants for technical advice.

2.3.4 Contractors

The contractor is the entity in charge of managing and executing the actual construction of the project. The main (general) contractor is responsible for hiring subcontractors, consulting specialty consultants, managing the project construction and procuring material, labor and equipment.

2.3.5 Sub contractors

The subcontractors are hired by the general contractor to manage different activities. Most of the construction work now is subcontracted out to different subcontractors specializing in their field. For example, there are subcontractors for the geo-technical works, civil works, millwork, mechanical works, electrical works, plumbing works, etc. The number of sub contactors on a project depends completely on the size and scope of the project.

2.3.6 Equipment and material suppliers

The general and sub contractors rent or buy the equipment such as cranes, hydraulic pumps, needed to perform the construction activities. The individual sub contractors who need the material and equipment generally buy and arrange for it themselves.

2.3.7 Manufacturers

The manufacturers manufacture or fabricate the required material that is bought by the suppliers who supply these to the general and sub contractors. Often the material is bought directly by the contractor from the manufacturer, in which case the manufacturer is also the supplier.

2.3.8 Raw material suppliers

Further upstream in the value system are the raw material suppliers who supply the raw material to the manufacturers for the manufacture of the finished goods used in the construction of a project.

2.3.9 Lenders and insurers

The owner/ developer approach lenders and insurers for financing and insuring the project respectively. Insurance of the entire project can be done by the owner or can be handled separately by the owner, developer and contractor.

2.4 Progress of a Construction Project

The construction activities are mapped with a focus on the stages in the design phase and production phase, but the connection to the production of materials, inbound logistics, e.g. in terms of warehousing, supply chain management or logistics in general, is nearly never included.

The following shows and example of a typical construction process and its different stages: plan, design, construction, use and maintenance.

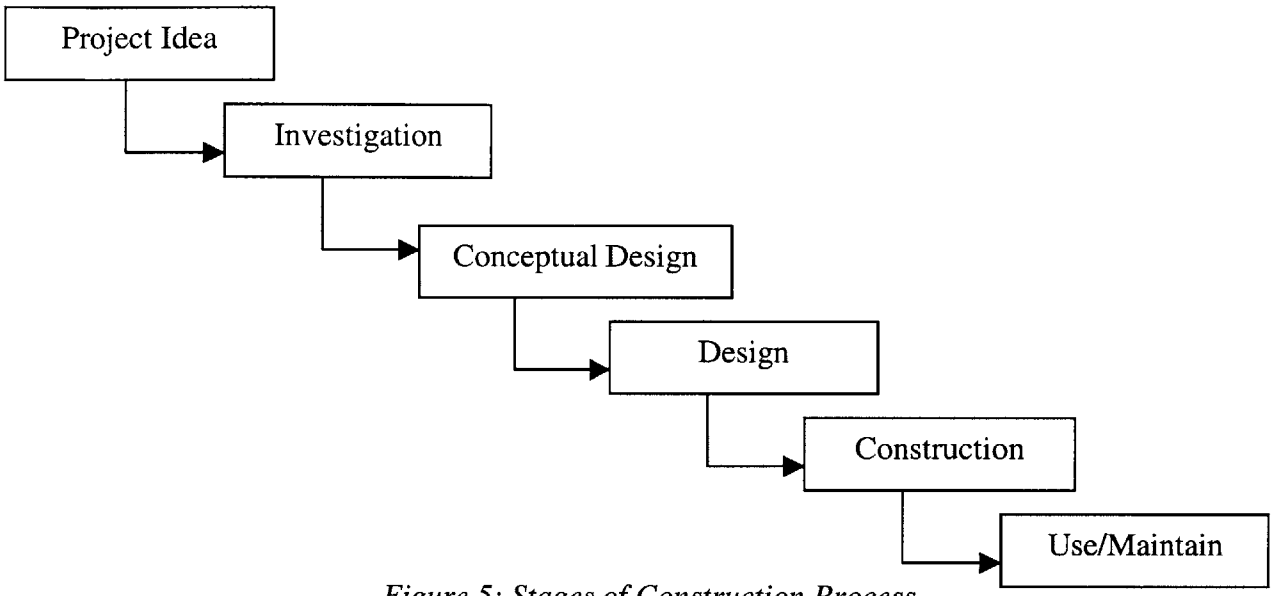

Figure 5: Stages of Construction Process

From the figure it can be clearly noted, there is no mention about the logistics, procurement or warehousing anywhere in the chain of activities. It is evident these areas of the construction process are not planned and thought about in much detail. Some might argue that these are taken into account in the design stage but design to availability is not a very common practice.

2.5 Characteristics of the Construction Value System

The following are a few of the main characteristics found to be prevalent in the Construction Value System and at the Construction Project Site.

2.5.1 Project oriented

Construction industry is a typical one-of-a-kind industry working in projects (Burbridge et al., 1993; Cutting-Decelle, 1997). A special characteristic of a construction supply chain is that the production is carried out in projects. A new organization with new players is set up for every new project. During the production, projects are relatively independent from the

rest of the contractor's own organization. The project focus is a limitation that restrains the companies' abilities to develop themselves (Olsson, 2000).

2.5.2 Decentralized

The business is decentralized and shortsighted having immediate goals of making each project profitable. The focus on efficiency in individual projects could be an explanation to why we do not see more integrating routines in the business relations (Olsson, 2000).

2.5.3 No knowledge base

Considerable knowledge is lost as companies move from one project into the next as the construction sector generally sees its own environment as "one-offs" with little repeatability (Olsson, 2000). What has to be realized is that products are different from project to project but the information and material delivery processes are almost the same in all construction projects (Wegelius-Lehtonen and Pahkala, 1997).

2.5.4 Dynamic environment

A construction site is a dynamic and fast changing environment with many actors in complex relations. Complications, which would be termed as crisis in other industries, have become a part of the construction process. This is because the focus is on the proceedings of the construction activities and not the manner in which it proceeds. The actors on the construction site are so used to chaotic handling of materials on site, that they do not experience the situation as a problem.

2.5.5 Variability

There is a lot of variability and uncertainty in the supply chain because each company in the supply chain does its own forecasting, scheduling, inventory control and material

requirements planning. This effect is compounded by the fact that ordering is typically based on the immediate needs of the downstream customers (Taylor and Bjornsson, 1999).

2.5.6 Dis-aligned incentives

There are no common strategic objectives, lacking incentives or funds for innovations, price sensitiveness instead of cost consciousness, lack of fairness and willingness to share, and lack of understanding of the own and other participants' processes (Vrijhoef, 1998).

2.5.7 Myopic Control

The construction supply chain is characterized by independent control of each stage of the chain. This cause wastes and problems, which mostly, are caused in another stage of the construction supply chain than where detected. Myopic control of the construction supply chain, combined with traditional trading and non-cooperative relationships, reinforces the problems, and complicates their resolution (Vrijhoef, Koskela, Howell, 2001).

2.6 Traditional versus Construction Supply chains

On comparing the supply chains in a traditional industry and the construction industry we find a number of differences, which help in explaining the lack of supply chain management in the construction industry. A few characteristics of the construction supply chain make it difficult to apply the Supply Chain Management practices used in traditional supply chain in this value system. Table 2 lists out a few of the major differences between the two industries and their working.

Traditional/ Manufacturing Supply Chain	Construction Supply Chain
Build to Stock is the widely used model. Ex: Apparels, Automotive, Consumer Goods etc.	Build to Order is the widely used model.
Wider and less specific end product.	Specific and defined end product
High degree of standardization with repeatability.	Project-unique design and material specifications with little or no repeatability.
Reliable demand forecast and planning can be done.	Uncertain demand forecast and inadequate tools make forecasting/planning a huge challenge.
Generally one organization responsible for the production process.	Multiple organizations with different objectives involved in the production process.
Predefined supplier and distribution networks	Project-specific suppliers and distribution networks.
Many suppliers supplying to a wide range of end users	Many suppliers supplying to a specific end user , i.e. a converging supply chain

Table 2: Difference in the industries

2.7 Challenges in the Construction Supply Chain

2.7.1 High costs and low margins-

Cost is one of the major factors where applying supply chain management can help greatly. Reducing costs and increasing revenues can be called the main drivers to the implementation of new tools and techniques. By improving the overall efficiency and effectiveness of the material flow, not only the end product can be more worth its price, also the revenues for the players involved in the work can increase. The industry today is marked with high procurement costs and limited storage space.

2.7.2 Long lead time/cycle time

For non-standard elements the total preparation time before processing elements on the building site can take about half a year: three months for the preparation of the drawings and three months for the production of the elements. Because of the long lead preparation time, manufacturers are sometimes already involved into the preparation process, without being chosen as the final supplier. Shorter lead-time would imply less cost of the project. For example tied up capital, cost due to inflation, etc is saved. Logistics control and management could help significantly in reducing the cycle time.

2.7.3 Low productivity

The productivity increase in building construction has been slow. Lagging productivity development has been a challenge as important as the increased economic weight in the construction supply chains.

2.7.4 High wastes, variability and uncertainty

High wastes are typical of construction projects and uncertainty and variability of demand does not help optimize the supply. Like mentioned earlier the variability arises from separate and individual forecasts and planning taking place at each node of the supply chain.

2.8 Key areas of Opportunity

Despite the many differences between traditional and construction supply chains there still are opportunities in the construction industry, already tapped in other industries, which can be focused on to improve the overall working of the supply chain. A few such areas of opportunities are listed below.

2.8.1 Knowledge Management

Due to the one-of-nature of the Construction Industry, knowledge is lost when the firm moves form one project to another. A key opportunity is to tap the applied knowledge on previous projects, which could help in the implementation of future projects.

A building is generally organized in sequential stages, bringing together a large number of firms that rely heavily on subcontractors. This means that the various interests in the industry operate disjointedly and have different economic characteristics and capacities to innovate. Furthermore, the amount of feedback from the industry's workforce and markets is lowered, and the industry's organizational learning capacity reduced.

Also, multiple entities are involved in the production of the final product in this industry and these entities may very well change from project to project-based on requirement, specialty, location, etc. Having a database of the past experiences with the different entities, such as general contractors, subcontractors, and suppliers could help in global growth and also initiate strategic alliances.

2.8.2 Centralization

Centralization of construction activities can benefit the supply chain by advantages gained by pooled procurement, optimum material ordering, efficient resource management, etc.

The way asset (labor, material, equipment, etc) management, currently, is done in construction there seems to be no benefit of economies of scale or centralized planning, which could help in expanding into new markets. This would help increase profits not only from the margins but also the volume.

2.8.3 Availability of key decision making data and Systematic feedback mechanism

One of the major challenges in construction is poor availability and bad accessibility of accurate performance data. This is can be considered a huge obstacle in improving performance of the supply chain.

'A challenge facing the construction industry is the ability to measure performance across projects and organizational boundaries' (Fisher et al., 1995).

Keeping performance registers, for instance, is a rare event. Achieving understanding of current performance is an absolute necessity to be able to improve it effectively (Vrijhoef, 1998).

2.8.4 Information exchange

Lack of understanding and willingness, mistrust and adversarial, non-collaborative work relations, among the players are some of the reasons, which make the ability to distribute and exchange data ineffective and insufficient. Exchange of important and beneficial information and providing feedback along the supply chain can prove to have many advantages.

2.8.5 E-Procurement

Procurement of resources such as material, labor, equipment can be done electronically which could prove to have many advantages. Main problem of procurement is related to schedule delays and lack of specified quality for the project. To prevent this situation it is often necessary to dedicate important resources (money, personnel, time, etc.) to monitor and control the process. A great potential for improvement is possible if state of the art technologies are applied to the procurement process. These technologies could help to eliminate the root causes for many types of wastes in construction.

2.8.6 Logistics and information systems

There are clear potential benefits to be seen in the construction industry, if the logistical competence increases. The construction industry as talked about earlier is a slow moving industry with not many changes in years. This is a factor, contributing to the lack of new technologies in the industry, which can help increase efficiencies greatly. Information technology has great potential to be implemented in the industry paving way to opportunities never explored before.

Information system can help promote internal relationship of several subsystems of a firm. And also promotes external data and information exchange.

2.8.7 Process transparency

The Construction Supply Chain can be called a closed system with a 'fog' over the methods and processes of the different players use to perform their parts. Process transparency can help reduce 'bottlenecks' during the construction phase, which could significantly reduce costs and lead times of different tasks.

2.8.8 Design to availability

In the current industry practices there is no concept of 'design to availability' as the design is almost complete before it is even viewed by the contractor or subcontractors who are upstream in the supply chain and responsible for procuring the material, equipment and labor.

2.9 Barriers to implementation of new techniques

The major source of obstacles to implement supply chain management to construction is the necessity to address the entire supply chain. This is particularly complicated in a fragmented supply chain like the construction supply chain. Another problem is the apparent

impossibility to implement long-term arrangements in a construction supply chain due to its limited existence only during one-off construction projects (Vrijhoef, 1998).

Some of these factors affecting the implementation of new tools and techniques in the construction supply chain are listed below.

- Traditional contracting practices
- Lack of logistics skills
- Risk aversion
- Implementation at all levels; strategic, tactical and task
- Local project versus global focus
- Lack of forecasting and planning tools
- Lack of defined processes
- Minimum use of web-based processes and systems
- Lack of intra and inter company collaboration

This chapter gave an overview of the current practices in the Construction Industry, some of the challenges being faced by it and a few key areas of opportunity that have been identified. Supply Chain Management solutions to these areas can greatly help increase efficiencies in the Value System and make the entire construction process smoother.

3. SUPPLY CHAIN MANAGEMENT "INDUSTRY BEST PRACTICES"

3.1 Supply Chains

During recent years, the supply chain has become a major subject of management research and manufacturing theory. The supply chain has previously been defined as:

'The network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer' (Christopher, 1992).

For Example: Supply Chain for a detergent soap might comprise of Raw Material suppliers, Packaging suppliers, Proctor & Gamble as the manufacturer, Ryder/Walmart as the distributor and Walmart as the retailer.

In its broadest sense, a supply chain includes the entire sequence of firms and activities from the extraction of raw materials at the initial source (supplier's suppliers, etc.) to the delivery of the end product to the ultimate consumer in the marketplace (customer's customers, etc.) until the service of the product through it's lifecycle. The objective of the supply chain is to maximize the overall value or profits generated. Given below is a representation of the different flows that take place in a supply chain:

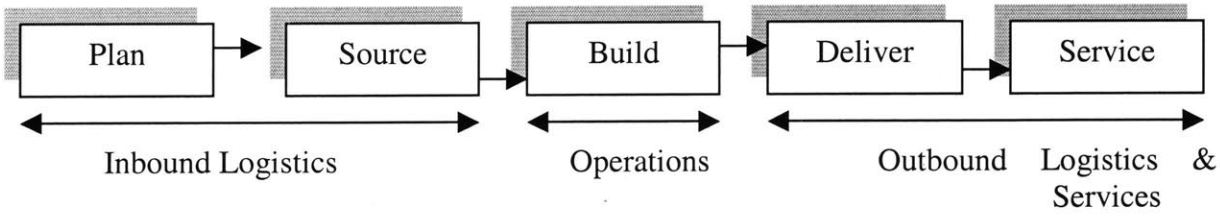

Figure 6: A schematic action chain

3.2 Supply Chain Management

Supply Chain Management (SCM) is the management of flows between and among different stages of a supply chain in order to maximize total profitability. Profitability is improved through reducing costs and boosting revenues for the entire supply chain.

Supply chain management can also be defined as the integration of material, labor, information and financial flows in a network of companies that make and deliver products and services from the source to the consumer.

3.3 Drivers for Supply Chain Management

The application of Supply Chain Management concepts has grown many folds during the last 5-6 years. In late the 1980's, Quality was the key for an organization to compete and be successful in the marketplace. Today, quality is a standard and is a requirement to even enter the market place. Companies today are competing on the effectiveness of their supply chains. Nokia, for example gained a significant amount of market share from rivals Motorola and Ericsson. Nokia attributes a significant portion of that gain to its supply chain capabilities that helped the company launch products in the market on time and consistently meet demand. Almost 90% of the Manufacturing organizations within the Global 1000 list now have supply chain organizations within them. Some of the key reasons that have driven the growth of supply chain management are:

1) Cost Reductions – Increasing competition has resulted in demanding customers asking for similar quality products at lower costs. Also, with the rapid growth of Internet, the competitor now is only a click away. In order to meet Wall Street expectations and margin goals, companies have to cut costs.

2) Market Share growth – Companies who can deliver the right product at the right time at the right place at the right price can rapidly gain market share. The efficiencies in the Wal-Mart supply chain resulted in lower costs for the end customer. On the other hand, Kmart reduced its costs in order to compete but could not sustain them due to poor supply chain management. Kmart was forced to file for Chapter 11, Bankruptcy protection in 2002.
3) Computing Advances – Internet has brought the world closer and has helped companies work on a global basis. Supply Chain Management software solutions that use mathematical optimization algorithms to solve business problems are now available in the marketplace. Most of these tools are now Internet based and can be accessed globally. Cisco Systems for instance has its material planners in different geographies plan the same product collaboratively and order it from the most cost effective source in the world using a single instance of supply chain planning solution. Many companies now engage in electronic procurement of materials and services over the Internet. With Internet standards like XML, sharing and transferring data has become much easier than before.

3.4 Decision types within Supply Chain Management

Supply Chain Management can also be classified into three sub categories by the types of decision made:

Supply Chain Design: This phase involves designing the structure and strategy of the supply chain i.e. defining the number of stages and associated roles, selection of business partners, manufacturing capacity, number of plants and warehouses, location of plants and warehouses, types of information systems, etc. These decisions are usually longer-term

decisions and are based on factors like company's future strategy, anticipated market conditions, competitive landscape, etc. Ex: Dell's decision regarding the location and capacity of manufacturing facilities, warehouses, and supply sources are all Supply Chain Design decisions.

Supply Chain Planning: This phase involves forecasting demand, planning, replenishing and deploying inventories, assigning customers to locations in the supply chain in order to optimize costs and revenue/service. The decisions made during this phase consider the supply chain design as fixed and attempt to optimize performance. The decisions here are usually tactical and consider factors like lead times, demand uncertainty, supply uncertainty. Ex: Aviall's decision for inventory levels to be stocked a location are driven by the Service Level commitment with the customers in addition to the factors described above.

Supply Chain Operation: This phase involves making day-to-day decisions like regarding how to fulfill individual customer orders. During this phase, individual orders are allocated to inventory or production, set order fill dates, generate pick lists at a warehouse, allocate orders to shipping mode and shipment, set delivery schedule of trucks and place replenishment orders. These decisions being very short term (minutes, hours, days) have little uncertainty. At the operational level, the supply chain design is fixed and planning policies are already defined. Ex: As the inventory levels for a detergent SKU fall below Safety Stock at a Walmart store, a pick ticket is generated at the closest P&G distribution center to ship inventory.

3.5 Supply Chain Best Practices

In this section, we examine how different organizations in a variety of industries have successfully implemented supply chain management and achieved benefits. Also, we

summarize the successfully used best practices, tools and solutions under different process/functional areas within supply chain management.

3.5.1 Forecasting and Planning

Accurate Forecast is a key element of effective supply chain management. A wrong forecast can result in wrong orders being placed or wrong products being manufactured thereby creating excess inventory situations. Companies have significantly improved forecast accuracy by utilizing Demand Forecasting solutions that apply statistical model to historical data. With the development of a common platform like Internet, more and more companies are now moving towards collaborative forecasting models. Companies are now working closely with their customers and using customer's outlook as an input in addition to historical demand. Consensus forecasting is being used more and more. Companies like Rayovac involve their Supply Chain Management, Sales, Marketing, Finance and Operation groups to develop a forecast. Rolls Royce, the aircraft engine manufacturer for instance conducts a global planning meeting with all its major customers and distributors to develop a forecast and a manufacturing plan. Aviall, the aerospace/defense aftermarket services provider utilizes feedback from Sales Managers at its 43 depot locations when developing forecast for a Product. Many Global 1000 companies are now sharing yearly forecasts and plans with their suppliers on an ongoing basis. All these factors have helped companies optimize assets, improve revenues/service and boost productivity.

In summary, forecasting and planning has been streamlined through process and system improvements in the following ways:

- Demand forecasting software solutions
- Collaborative or Consensus Forecasting

- Factory planning software solutions
- Forecasting/Planning information exchange

3.5.2 Purchasing/Procurement

The purchasing function has seen significant improvements over the last decade. Companies have worked with their suppliers to streamline purchasing by developing partnership type relationships and utilizing Internet and EDI technologies. Harley Davidson Motor Company for instance has used "Supplier Councils" to effectively cross-pollinate supply intelligence through the company's supplier base. These councils meet several times a year to discuss key strategic initiatives where participants critique on new process and technologies in an effort to produce best possible solutions for the entire supply chain. Another example is the famous SCORE program pioneered by Chrysler. SCORE was about sharing savings with a supplier when supplier identified an area where costs can be reduced. The program generated enormous cost savings making Chrysler the most profitable car manufacturer. Many organizations now view suppliers as their business partners and work with them to improve profitability of the entire supply chain. Internet and Web Technologies have also added tremendous efficiencies into the purchasing process. Companies can now download price quotes from supplier web sites into their systems, place orders electronically and transmit them to suppliers in real time. Suppliers can also provide feedback in real time. Once an order is placed, the status of the orders can be checked as well. These technologies have helped companies significantly reduce the administrative lead times associated with purchasing. E-Procurement is another example of application of Internet to gain efficiencies. Electronic procurement systems have been used to reduce paperwork, streamline process, speed up supply delivery and boost productivity; saving businesses, both time and money.

Bell South for instance successfully uses an E Procurement system to procure parts from its suppliers. Once the quantity to be purchased is determined in the planning system, a request for proposal (RFP) is sent to a select group of suppliers. Suppliers are notified through an email who then log on to the same E-Procurement system. Suppliers like Lucent, Nortel, Cisco and others submit bids by the bid closing date. Once the bidding process is complete, the Bellsouth buyer logs onto the system to review the bids. Orders are then awarded based on the factors like Price, Promise Dates, Supplier's past performance, etc. Cisco Systems uses a company wide E- Procurement system that is used to procure office supplies.

In summary, Purchasing has been streamlined through process and technology improvements in the following ways:

- Collaborative supplier partnerships
- Collaborative process improvements
- E Procurement processes and systems
- Web based purchasing systems.
- Electronic data interchange with suppliers
- Purchase from suppliers web catalogs
- Real time communication with suppliers
- Supplier negotiation
- Real time vendor price quotes

3.5.3 Inventory Management

One of the most costly aspects of supply chains is the management of inventory. Inaccurate inventory management can result in excess inventories on unnecessary products while shortages on critical components. Companies have realized the importance of inventory

management, introduced new systems, reengineered processes and have worked closely with suppliers and customers over the last few years. Many Global 1000 companies now use web based inventory planning and inventory management systems. These systems provide visibility to inventories in the entire supply chain. Also they have helped companies in keeping the inventory levels low, reducing overall holding costs, and still meeting production or customer service targets. IT tools like web-based agents have been also implemented at some companies to trigger inventory changes as they occur in the supply chain. Cisco Systems for example uses an inventory management system that provides it World Wide inventory planning and inventory visibility capabilities. Companies now are using mathematical optimization based inventory models that balance supply and demand generating inventory recommendations for the inventory managers. Techniques like Economic Order Quantity, Postponement, etc are being used to improve inventory management.

Companies are also deploying Vendor managed inventory (VMI) models that allow suppliers to manage the company's inventory. VMI addresses the questions of how to use shared sales and inventory data among supply chain partners and who is responsible for supply chains and inventory levels. Proctor and Gamble (P&G) manages inventories for Walmart for the products it supplies. As inventory is sold at a Walmart, the Point of Sale data is transmitted to P&G. As soon as the inventories go down below the Reorder point level at a store, P&G replenishes it to the Target Inventory level.

In summary, Inventory Management has been streamlined through process and technology improvements in the following ways:

- Web Based inventory management systems

- Electronic data interchange programs with suppliers
- Collaborative Inventory Management
- Vendor Managed Inventories
- Point of Sales data tracking
- Hand held devices
- Agents based triggers to communicate stock outs

3.5.4 Information Exchange and Collaboration

Many companies have now developed infrastructure that helps them track data, convert data into information and share key information internally and externally. UPS for instance transmits information about receipt of a package to its central information system in real time with the use of a wireless hand held device. The receipt information can then be accessed through it's website from anywhere in the world. Many companies have used similar tools to track demand/usage and have successfully used them to optimize their supply chains. Within organizations, different functions like Sales, Marketing, Production, Logistics, Finance, etc have realized that efficiencies in the supply chain directly affect them and have started to exchange information and collaborate. Similarly on the external side, companies are sharing forecasts, production schedules etc with suppliers in order to ensure material availability. Some best practices companies like Cisco and Dell give significant weight to the supply chain capabilities of suppliers before selecting them. Common platforms like Internet, languages like XML have made sharing data much easier than ever before.

In summary, Information Exchange has been streamlined through process and technology improvements in the following ways:

- Hand Held devices

- XML based formats
- Web Based systems
- Electronic data interchange capabilities

3.5.5 Some more Supply Chain Enablers and Best Practices

- Benetton, who delay the dyeing of their jumpers until the very end of the supply process. Thus, with standardized jumpers, customized as late as possible, a degree of customer choice is achieved without long lead-times and the risk of obsolescence (Gattorna and Walters 1996).
- Originally Hewlett-Packard produced printers for a global aggregate demand and customized them for local markets prior to their shipment to regional distribution centers. Unfortunately, demand forecasts were seldom accurate, so obsolescence risks were high. The solution was to postpone the decoupling point as late as possible and customize the printers in the regional distribution centers when the order was 'pulled' by the customers (Davies 1993, Lee and Billington 1992).
- A European personal computer (PC) producer has moved from a mass production system to a lean and agile one (Berry et al. 1995, Berry and Naim 1996). This involved the implementation of just-in-time (JIT) systems that reduced total lead-times by 46%, the development of a holistic approach to supply chain management via the utilization of a global material logistics system and finally the integration of its suppliers into its total supply chain concept.

3.6 IT applications across different industries

Some of the Information Technology applications in different industries are listed below.

- Data Capture- Keyboard, Bar coding, RFID

- Data Collection- Hardwired, RFDC, Satellite, GPS
- Data Base Management- Portable, Front-end controllers, ERP systems
- E-Commerce- EDI, Internet web-based systems between business partners
- Decision making tools- Supply chain planning, Supply chain execution, Data Warehouse

The above best practices studied are some of the key concepts of Supply Chain Management that have been applied in various industries. However, other best practices in areas such as Order Processing, Warehousing, Returns Management, etc. can be studied under a broader study of Supply Chain Management.

4. APPLYING SCM BEST PRACTICES IN THE CONSTRUCTION INDUSTRY

4.1 Introduction and Approach

The previous chapter gives an insightful view of how effectively Supply Chain Management Concepts are being used in many industries for their benefit. Efficiencies and effectiveness of Supply Chains can increase many folds if latest, advanced tools and techniques, which impact the Supply Chain positively, are used. Construction Industry with its many Supply Chain problems could definitely use some of these techniques.

After having understood the roles of different players in the Construction Value System and the classification of entities in Supply Chains the first step is to integrate the two phenomena into one. Figure 7 below represents this integration and depiction of the construction supply chain, its players and different flows clearly.

Having categorized the different aspects of the Construction Supply Chain, the next step is to identify which of these tools can be applied to and will be beneficial for the Construction Value System. The approach to be taken to address the problems in the industry has to be decided.

There are two ways of approaching and tackling the challenges found in the construction supply chain. The problem can be solved by:

1. Optimizing the whole supply chain by treating it as one entity, or
2. Individually optimizing different entities in the supply chain.

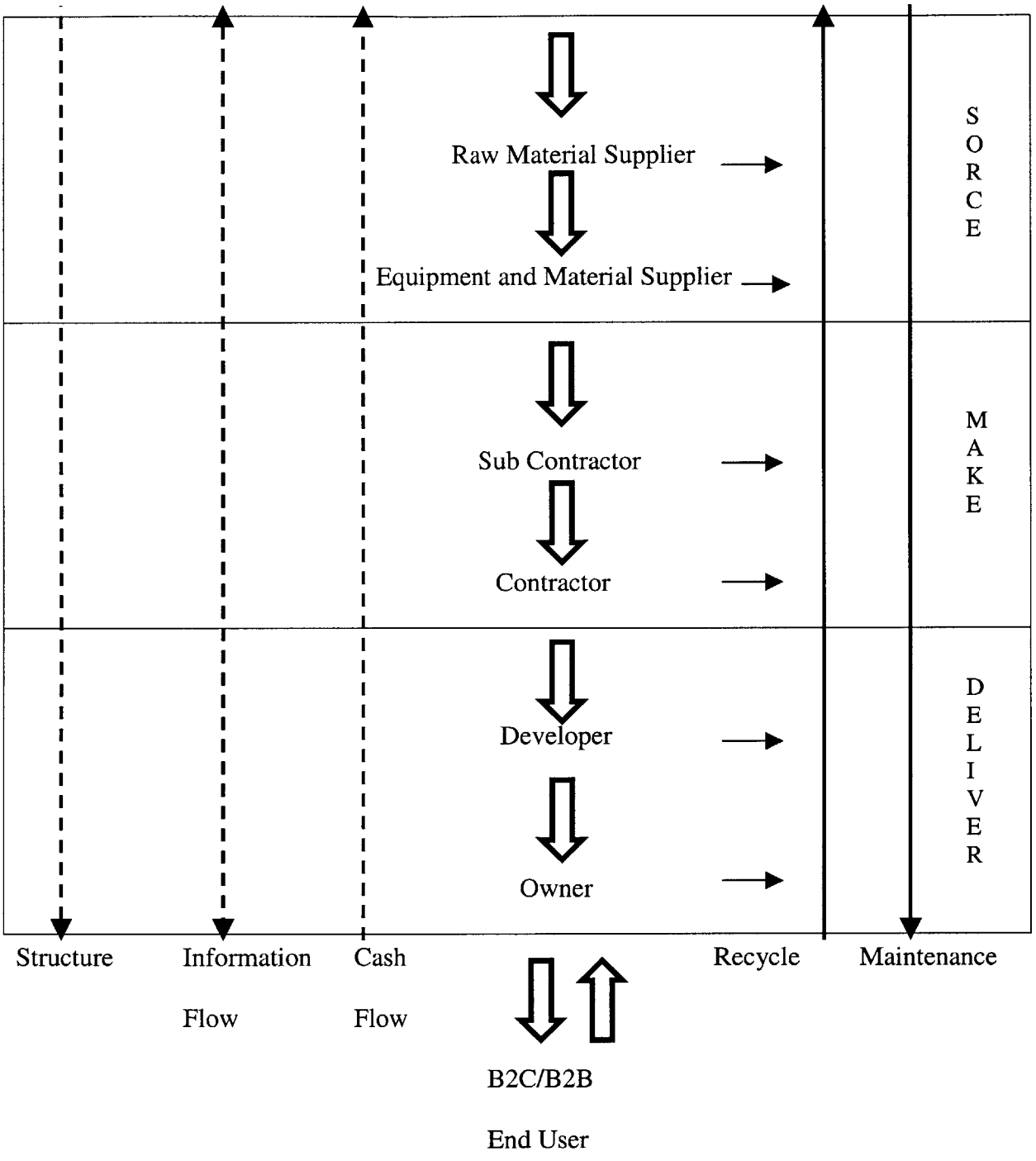

Figure 7: Supply Chain of the Construction Value System

On studying the Supply Chain best practices across different industries, it is found that the first approach is practically less feasible. Stated below are some key reasons.

a. All the different companies in the supply chain are structured differently with different organizations.
b. The various companies have unique business processes and systems, which make them, operate differently for each other.
c. The short-term and long-term goals of the companies are also different
d. Depending on the type of supplier and customer, a company can have multiple supply chains.

Due to the above reasons it is decided that in this thesis the second approach with be taken. A key player in the construction supply chain will be identified and implementation of supply chain management techniques would be focused around that player. These Supply Chain Management concepts would result in not only optimizing the key player's business but will also have a positive impact on other participants of the Supply Chain.

Hence, the primary task is to identify one of the key players in the supply chain. In the construction supply chain the relationships between the players can be categorized into two major types:

- The relationships of the general contractor with the owner and the design team, and
- The relationship of the general contractor with the sub contractors and the different tiers of suppliers.

Thus, the main contractor appears to be a key player in the construction supply chain, standing on the borderline between demand and supply. This position obviously makes the main contractor a "key solver" of problems in the supply chain (Vrijhoef, 1998).

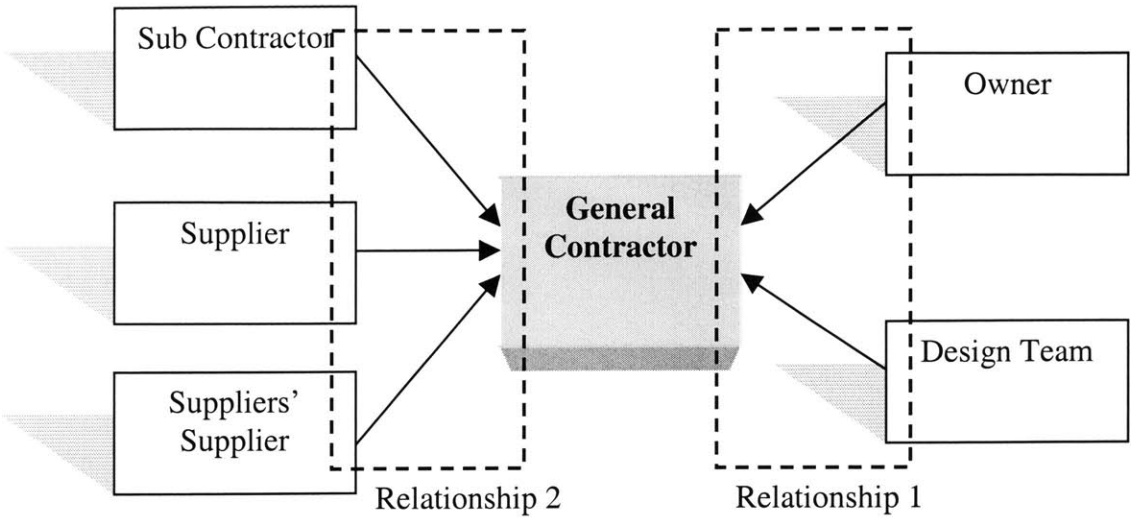

Figure 8: Relationships of the general contractor in the value system

4.2 Identifying SCM best practices in the Supply Chain

The different supply chain best practices that can be applied in the construction industry are described as under.

4.2.1 Centralization

Centralization, as mentioned earlier, involves centralized planning and logistics to achieve economies of scale, improve visibility and management thereby leading to improved efficiencies in the supply chain. A model is proposed to better explain the application of a centralized system.

In this model, a centralized logistics and warehousing system part of the contractors firm is utilized for ordering and procurement of material that is required for all the different projects awarded to the contractor. An information exchange system helps the central logistics department have complete, accurate, real-time information of the progress and requirements

at the project sites. This information helps the department to order optimum and on time material and resources.

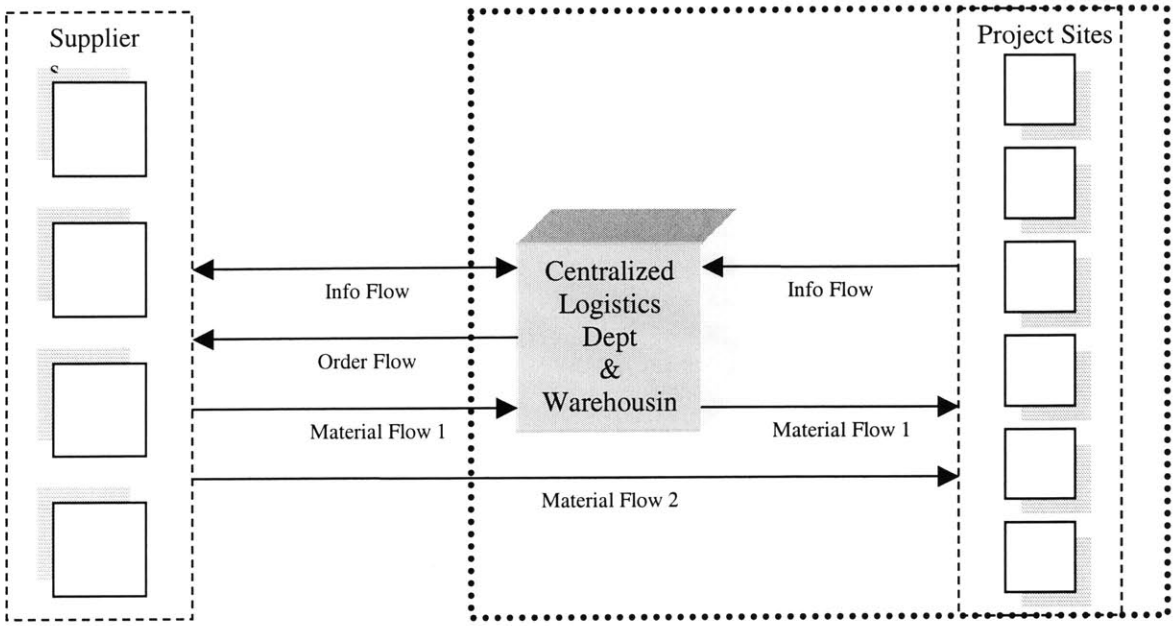

Figure 9: Centralized supply chain

The material, which is ordered by the central department, can then be delivered by two methods, 1) to the central warehouse and then to the sites 2) directly to the sites, depending on the need.

The benefits of this system are:

1. Economics of scale due to pooled procurement.
2. Improved asset utilization, as there is visibility of all the sites to one central point.
3. Lower lead times for projects by stocking critical and common inventory in the central warehouse.

4.2.2 Availability of key decision making data and Systematic feedback mechanism

Data should be collected and maintained in an information system common to project sites and the general contractor's central department, with restricted access to sub contractors and developers. Common information systems installed across the contractors firm could help collect data on a large scale and use it to make decisions.

A mechanism for systematic feedback to the headquarters is by having scanners or hand held devices on site, which record the receipt and use of material. As in the case of Wal-Mart and Procter and Gamble, at the construction site too low levels of inventory can then trigger the central logistics department to place new orders. It is well understood that scanning every material used in the construction of a project might not be feasible (such as each brick) in some cases manual entering of such information might be required to have the system updated. The different devices can be synchronized with the central information system on a frequency basis, hourly, daily, weekly, depending on need.

Collecting supplier data that can help measure performance can be useful. Order data for suppliers can be collected and analyzed to make business decisions. For example, supplier performance can be tracked if you have all original order due dates and actual receipt dates in the system. EDI/Web Order Confirmations can be utilized by suppliers to provide Order Confirmation. This information if available in the GC Info system can be compared to the actual order receipt date to measure Supplier Delivery Performance.

As seen in the earlier chapter in the case of UPS, as soon as a package is delivered the signature from a customer updates the UPS website and tells the company that a task in complete. A similar technique can be implemented with sub contractors and within the general contractors firm. Sub Contractors can utilize an information system or site computer

to provide a daily weekly update on tasks and a confirmation on completion. This information if synchronized with the central information system. This system can also help quantify the effects or damages produced due to delayed or early procurement of resources. The benefits of having these systems to make important information available to the parties who need it are

1. Accurate Forecast Projections
2. Better asset management in terms of labor, material, equipment
3. On- time delivery of material
4. Reduced project delays
5. Better supplier and sub contractor quality information

4.2.3 Knowledge Management

Project closeouts generally require detailed documentation of important knowledge gained on the project, which could help performance and facilitation of future projects. Rarely is this seen to happen in the field. A simple reason being no incentive for the project manager to share his knowledge or lessons learnt with the rest of the firm or other entities of the supply chain.

Another important source of knowledge lose is the knowledge of the different players, suppliers, subcontractors in the supply chain. With key data available and the central department getting systematic feedback the performance data of the other players is easily accessible. Having this knowledge is extremely beneficial as it could help evaluate the best choice of contractors and suppliers during the awarding of the contract.

A database of suppliers also helps during procurement (Detail analysis presented in 4.2.5 E-procurement). Continuous working with and identifying quality subcontractors and suppliers could facilitate strategic partnerships and alliances. This in turn would help reduce inhibitions in information exchange making that process smoother.

As the information of subcontractor and supplier quality is already in the centralized system obtained by the systematic feedback mechanism there is no future need of documentation or filing records keeping lists of the past upstream entities. This partially could help solving the 'no incentive' problem for the project manager or site supervisor to feed in information at project close outs. Similar processes will be have to found to tackle the problem of lack of incentive for extra work being done as post project learning to share information such as resolutions of problems during construction, innovative practices, etc.

In summary knowledge management can benefit by:

1. Strategic partnership and alliances with upstream supply chain members.
2. Help global growth by having a history of work in different locations with different players.
3. Help in evaluation and selection process of right entity to award the contract to.
4. Post project learning by all members of the firm (also those not involved in the project) and other players involved in the project.

4.2.4 Information Exchange

A critical part of supply chain collaboration, information sharing seems to be negligible in the construction supply chain owing to its adversarial nature. Looking at some of the other industries it is found that a few common practices in other industries related to information exchange could be beneficial to this industry as well.

In the planning stage the contractor can provide the forecast for their material demand to their regular suppliers in order for the suppliers to be able to better manage their material production for the future. In exchange the supplier provides its production capacity information to the contractor, which would help the contractor make his ordering strategy. This kind of collaborative planning is often seen in automotive, aviation and high tech industry.

Systems such as EDI and more recently XML/Rosetta net are used as information exchange in many industries. XML has started to replace EDI because it can be used to automate business documents, serves as a rich messaging format for inter-process communication and has lower costs. Industries which are involved in adopting XML in their supply chains include not just the Automotive, but also the Aerospace (Boeing, Raytheon, Lockheed Martin) and Computer industry (Hewlett-Packard, Hitachi, IBM, Intel, Lucent, Motorola, Philips, Rockford.

Electronic order placements by the contractor and electronic order confirmations by the suppliers can help reduce the administrative lead times significantly. Order Transmission, Order Confirmation, Advanced Ship Notice, Forecast, Capacity data can be exchanged between Suppliers and General Contractor.

ASN is a technique practiced by the suppliers who send the notice of a shipment on its departure to the customer with the information of the transport time. This helps the customer prepare for the arrival of the product. If the supplier informs the contractor about the departure of its material to the contractor's warehouse by an ASN, it helps the contractor plan

his warehousing activities accordingly which would help avoid delays by lack of resources for its receipt, as an example.

The benefits of these planning and implementation processes to exchange information can be summarized as follows:

1. Better management of production for the supplier and order placement for the contractor.
2. Reduced administrative lead times
3. Better planning for receipt of material and equipment.

4.2.5 E-procurement

Electronic Procurement can be used in the Construction industry to procure products and services in a more efficient way. Examples such as Cisco Systems and Bell South are great inspirations for considering e-procurement in business. Based on the a similar model as in the case of Bell South, the construction business can minimize problems in procurement such as delays in requests for material/equipment, delays on delivery of supplies, and more.

The tendering and bidding process for subcontractors and suppliers can be done electronically. On acquiring a project, the request for proposals would be sent to the subcontractors/ suppliers through an electronic system installed in the contractors firm. The list of subcontractors and suppliers is obtained either from the knowledge database created by the contractor or by e-content management programs.

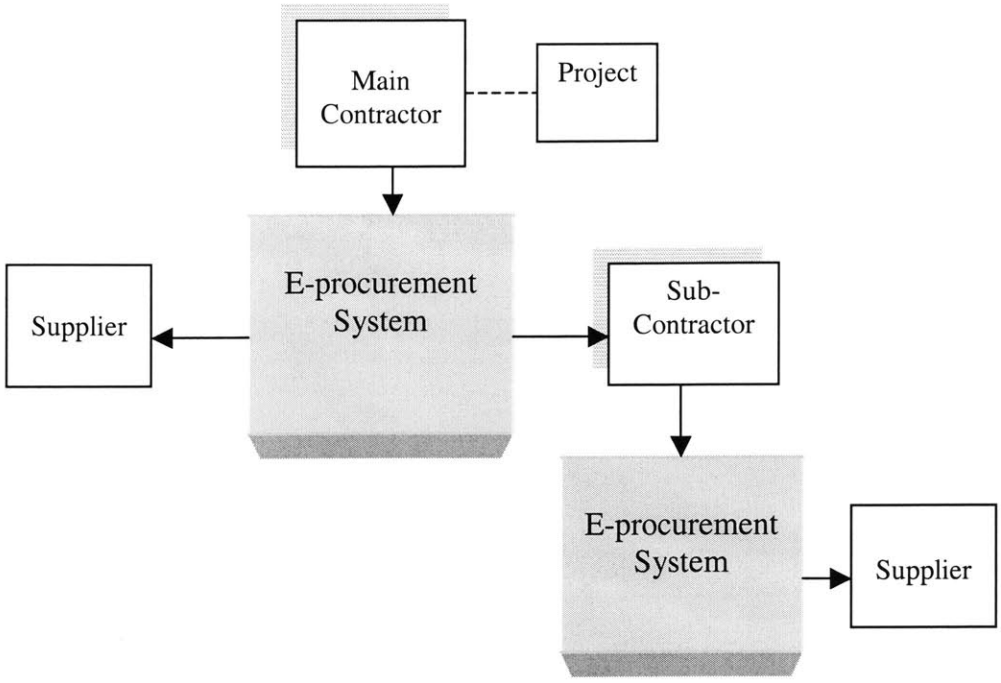

Figure 10: E-procurement of bids

On receipt of the Request for Proposals from the main contractor, the sub contractors and suppliers respond back to the requests on the same system, which now they can log on to.

The same process is followed in the subcontractors firm to receive bids from the suppliers.

E Procurement system database will also have past information. This information may be referred by contractors/sub contractors to evaluate suppliers.

Bid evaluation and selection now can be done based on the bids received through this system and the use of the created knowledge base of the organization. Different factors may be considered before a contract is awarded to a particular subcontractor, like, price, historical delivery performance, quality, ability to meet due dates, etc.

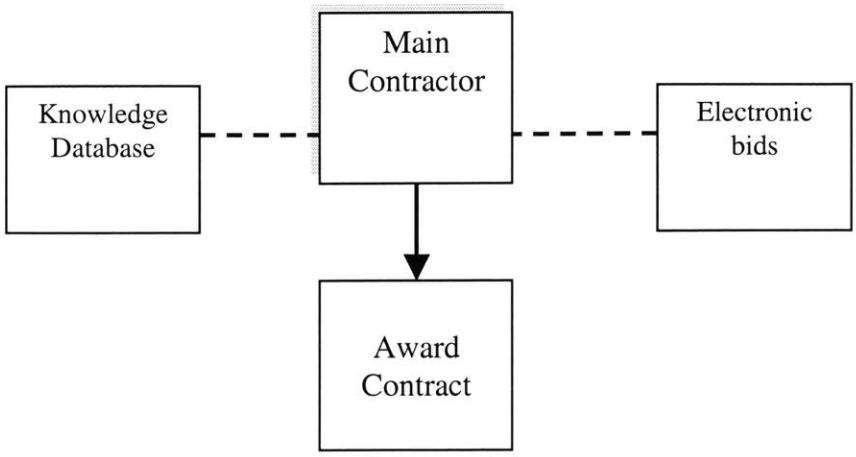

Figure 11: Evaluation and selection process

Material procurement can also be done online in a similar fashion as online biding. This would help increase efficiency and provide a higher negotiating power for the contractor by quickly being able to locate qualified, reliable suppliers in new or unfamiliar markets. Organizations such as contractorhub.com now offer similar services online. There was a sudden increase in e-procurement 2000 in many industries, which then crashed because the market was not ready for accepting and performing business transactions in this new method. But slowly e-procurement is creeping back in and has become and will continue to become an increasingly accepted form of business.

The benefits of e-procurement can be summarized as below:

1. Reduced administrative lead times
2. Lower costs and higher efficiency for the Value Chain by replacing time-consuming, costly, labor-intensive ordering and bidding systems with fast, highly efficient, money-saving e-commerce tools.
3. Expanding the network of suppliers while maintaining existing supplier relationships.

4. Collective buying at volume prices
5. Provides seamless, fast, accurate transactions
6. Provides low cost searching and information

Some key areas of opportunities have been identified in this chapter and high-level process and systems solutions have been proposed. A detailed feasibility study on these could help tackle the challenges in the Construction Industry identified in Chapter 2.

5. CONCLUSION

Conclusions from the study are drawn and the three-step thesis approach is summarized and scope for future research is discussed in this chapter.

Logistics and Supply Chain Management knowledge in general is found to be in its initial stage at present in the construction industry. Prior initiatives on construction Supply Chain Management have had only limited impact on the industry, and their wider application has been slow. It can be argued, some of these initiatives can be slow to grow in their early phases. The reasons for the lack of developed applied logistical concepts are more than one. The companies in the construction industry are hence not used to flow models or supply chain models. A better understanding of construction supply chains is clearly necessary in order to comprehend the reasons for the difficulties of Supply Chain Management's advance within construction. But, now with Beck Group's DESTINI which aims to dramatically reduce the costs and duration of a project by integrating technology with an improved delivery process, and Turner's new subsidiary- Turner Logistics the companies in the Construction Industry are beginning to realize the benefits of Logistics and Supply Chain Management. The fact that companies such as these are moving towards implementing such techniques in their management implies that they see an advantage for them in doing so.

The absence of Supply Chain Managers and Logisticians results in logistical incompetence and makes Supply Chain related problems difficult to overcome. Flow-related problems are frequent because the possibilities to pro-actively manage material flows are not seen. Yet, often these are not considered to be problems and treated as part of the normal production conditions on site.

Proactive logistics can improve effectiveness and efficiency and thus reduce costs, and this insight has caused a clear trend in the stationary industry towards pro-active approaches as supply chain management as seen in many cases in Chapter 3. The application of supply chain management to construction can be very beneficial, and offers substantial opportunities to solve basic problems in construction supply chains. This awareness though has been seen in the research field for a while now, is lately beginning to take shape in the practicing firms as well.

5.1 Summary

The summary of the research conducted is presented below.

Supply Chain Management involves management of inter and intra company resources (personnel, inventory, transportation, facilities) in order to efficiently deliver products and services to the market place and boost profitability. Construction industry has only utilized these practices, if at all, in a limited way and there still remains an enormous potential in improving efficiencies in the Construction Value Chain. Construction supply chains have to be reconsidered by measuring the value-added at each node and new ways have to be found to decrease waste and latency.

The Construction Supply Chain is a fragmented, project oriented and temporary Supply Chain. The activities in the chain are marked by decentralization, myopic control, variability and uncertainty. In spite of this (or maybe because of this) planning of logistics, procurement or warehousing is most of the time neglected in the chain of activities in a construction process. Significant differences in the Manufacturing Supply Chain and Construction Supply Chain make it hard to implement widely used Supply Chain Concepts of the Manufacturing Industry into the Construction Industry.

Nevertheless, opportunities and need for the application of Supply Chain best practices is immense in the Construction Industry. Centralized work and procurement models, use of information technology and the internet for fast and cheaper communication and collaboration, data update and information exchange with the help of advanced technologies (scanners, hand held devices, etc.) are some of the many ways of improving the Construction Supply Chain's efficiency and effectiveness.

5.2 Future Research

As stated earlier this study represents a visionary research. Construction Supply Chain has been studied, areas of opportunity have been identified and high-level process and systems solutions are suggested. Future research needs to focus on detailed feasibility study in these areas. This can be followed by development and implementation of the solutions proposed.

In the current state of the construction industry, there are enormous challenges being faced by the different participants of the supply chain and many areas of opportunities present to apply and utilize the benefits of Supply Chain Management in. In this thesis more such key areas of opportunity are identified than the visionary Supply Chain solution is provided for. As an example, Design to availability seems to be a big area of opportunity in which the owner's and designer's collaboration with the contractor is essential. How can their incentives be aligned and goals be formed in a manner that they are congruent?

Questions such as how long-term framework agreements with subcontractors and suppliers can be established and contracts modified in a way so it benefits the working of the different players as a team are still to be answered.

The scope of this research can be widened to be applied globally. Difference is the working and functioning of the construction industry in other nations can be studies and how these

models and tools can be applied internationally can be studied. Comparisons between functioning of the same industry could be very difficult but nevertheless new insights can be gained.

Supply Chain Management application in construction should not remain on a strategic or tactical level only. Addressing the operational level of the supply chain is extremely critical, though challenging, to success.

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