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**Facilitators and Impediments in Moving Firms Toward Supply Chain
Management: A Qualitative Field Study**

**A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville**

**DeWayne L. Searcy
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DEDICATION

This dissertation is dedicated to my wife, Shelley, whose unwavering support and constant encouragement provided me the strength to cross the goal line.

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ABSTRACT

Competing at the supply chain level, instead of at the individual firm level, is widely recognized today as a potential source of competitive advantage (Christopher 1992, Spekman et al. 2001). To compete on a supply chain level implies firms within a supply chain must develop and enhance internal, as well as, external competencies.

Intuitively, firms must have some degree of internal integration before they can reap significant benefits from engaging in supply chain management (SCM). As firms become more efficient and effective coordinating their internal processes and operations they soon realize significant improvements are possible by coordinating and linking their processes and operations with their suppliers and customers (i.e., forming competence alliances). At a supply chain level, firms within the supply chain may form competence alliances that link each firm's competences and/or resources to other firms of the supply chain in order to, "draw on a broader range of competences, to acquire desired competences more quickly, or to extend the reach of current competences into new competitive domains (Sanchez and Heene 1997, 307)."

Studies aimed at investigating the implementation process should be fruitful in further developing the theory of SCM. This study seeks just that aim, by qualitatively investigating how a direct supply chain attempted to implement SCM. In moving toward supply chain management this study identifies six supply chain management execution antecedents that individual firms in a supply chain must address, 1) proper alignment of management support, 2) funding of verbal commitment, 3) proper motivation, 4) training, 5) visioning, and 6) internal/external integration linkage. In

addition, the study revealed the reinforcing linkage between internal integration and external integration. If the supply chain is the next source of competitive advantage then understanding how to progress towards managing the supply chain is crucial. The results of this study add to that understanding.

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GLOSSARY OF ACRONYMS

DOD	Department of Defense
EMD	Engineering Manufacturing Development Phase
FTS	First Tier Supplier
IMA	Institute of Management Accountants
IPT	Integrated Product Team
LESA	Lean Enterprise Site Assessment
LIS	Lean Infusion Score
LRIP	Low Rate Initial Production
MC	Major Component
OEM	Original Equipment Manufacturer
SCIW	Supply Chain Integration Workshop
SCO	Supply Chain Orientation
SCM	Supply Chain Management
SMA	Statements on Management Accounting
STS	Second Tier Supplier
TTA	Tools and Testing Associate

I. INTRODUCTION

Supply chain management is the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.

Mentzer et al. 2001

Competing at the supply chain level, instead of at the individual firm level, is widely recognized today as a potential source of competitive advantage (Christopher 1992, Spekman et al. 2001). To compete on a supply chain level implies firms within a supply chain must develop and enhance internal, as well as, external competencies. A firm achieves competency “when it has an ability to sustain coordinated deployments of resources (tangible and intangible) in ways that help that firm to achieve its goals (Sanchez and Heene 1997, 306).” At a supply chain level, firms within the supply chain may form competence alliances that link each firm’s competences and/or resources to other firms of the supply chain in order to, “draw on a broader range of competences, to acquire desired competences more quickly, or to extend the reach of current competences into new competitive domains (307).”

According to the Mentzer et al. (2001) definition of supply chain management (SCM) presented above, SCM involves internal integration (internal competency), as well as, external integration (external competency). In other words, there is a shift from an internal-only focus to an internal-external linkage focus. Additionally, Spekman et al. (1998) find firms in a supply chain move toward more collaborative arrangements as the firms coordinate their processes and operations across each other (i.e., begin to create external integration).

Intuitively, firms must have some degree of internal integration before they can reap significant benefits from engaging in SCM. As firms become more efficient and effective coordinating their internal processes and operations they soon realize significant improvements are possible by coordinating and linking their processes and operations with their suppliers and customers (i.e., forming competence alliances). This shift of thinking, called supply chain orientation by Mentzer et al. (2001) is necessary for a firm to move towards SCM.

Several studies have discussed this shift from an intra-firm perspective to an inter-firm perspective of SCM (e.g., Stevens 1989; Cooper and Ellram 1993; Metz 1998; Cavinato 1999; and Poirier 1999); in particular is Stevens' four-stage process model (see Table 1). According to Stevens, firms evolve from an inefficient collection of independent operations and processes (Stage 1), to limited functional integration within the firm (Stage 2), to internal integration across all functions within the firm (Stages 3), and, finally, to external integration and coordination of the supply chain (Stage 4). SCM occurs when firms in a supply chain evolve from internal integration to external integration (transition from Stage 3 to Stage 4).

The success of SCM will depend largely on the internal competency realized in Stage 3, as well as, the external competency realized in Stage 4. In other words, the maximum performance capabilities of a supply chain are a function of the operating efficiencies of the individual firms comprising the supply chain. Therefore, it is crucial to understand how the individual firms in a supply chain move toward increasing their operating efficiencies. If SCM is an evolutionary process, then

understanding the performance of individual firms within a supply chain will lead to understanding the performance of the supply chain itself.

As firms progress toward linking their processes and operations, the nature of the relationship between the firms changes. Spekman et al. (1998) describe this change in the relationship between supply chain firms as transitioning from an arm's length (open market) relationship to a more collaborative relationship. In other words, the intensity of the relationship between firms increases as firms begin to evolve to SCM.

Figure 1 displays Spekman et al.'s (1998) model of relationship intensity. They present four levels of relationship intensity, 1) Open-Market Negotiations, 2) Co-operation, 3) Co-ordination, and 4) Collaboration. As firms in a supply chain work together toward SCM, the intensity of the relationship should increase. Firms within a supply chain transitioning from internal integration to external integration should increase the intensity of the relationship with each other. Spekman et al. (1998, 634) state that, "co-operation is the starting point for SCM and has become a necessary but not sufficient condition." Other researchers also recognize the higher levels of relationship intensity that need to be reached in SCM (e.g., Day 2000; Mentzer, Foggin, and Golobic 2000). This leads to the research question for the proposed study:

What are the facilitators and/or impediments for firms moving toward Supply Chain Management (i.e., moving from co-ordination to collaboration)?

To-date there have been limited empirical studies examining true supply chains (Mentzer et al. 2001). Spekman et al. (2001) comment that this area of research is still in the early development stage. As such, there are calls for case-based and

longitudinal research in SCM¹. Based on those calls, this study is a longitudinal (one-year) field investigation of a supply chain. The primary unit of analysis is a direct supply chain comprised of three firms (Mentzer et al. 2001). The study begins with the participation of several individuals across three contiguous companies² in a Supply Chain Integration Workshop. The workshop provides the starting point for the firms to work together as a supply chain. Shortly after the workshop two of the tiers in the supply chain continued to work together, while the third tier declined to participate.

One year after the workshop interviews were conducted to investigate why the two firms continued working together on supply chain issues, while the third abstained. The interviews were the primary data collection device for the study. The outcome of the study provides some refinement to the theory of SCM. The study identifies five SCM execution antecedents 1) proper alignment of management support, 2) funding of verbal commitment, 3) proper motivation, 4) training, and 5) visioning. In addition, the study revealed the reinforcing linkage between internal integration and external integration.

The importance of SCM should not be underestimated. SCM affects every discipline from marketing to accounting. For example, it was important enough to the managerial accounting discipline that the Institute of Management Accountants (IMA) issued two Statements on Management Accounting (SMA) in 1999 dealing with SCM

¹ Mentzer. (2001, 460) state, "Studies that cut across three or more companies in the supply chain should bring us insights into [SCM] that have not been reported previously. By the nature of this challenge, such research probably will be within the realm of case study. Additionally, longitudinal research is needed to explore the evolution of supply chains over time and the myriad of cause-and-effect relationships in supply chains."

² Three companies directly connected in a supply chain (i.e., three tiers of a supply chain).

issues (SMA 4II and 4JJ). As the authors of SMA 4II commented, “Supply chain management is not just the wave of the future. It is a tsunami that will engulf everything in its path...For financial professionals and others working in the field, the issue is not so much whether to become expert in the art and science of supply chain management but rather, how fast (47).”

Section II discusses the relevant literature in the operations and logistics disciplines examining firm operations, as well as, SCM and related antecedents. Section III details the research’s methodology. Section IV contains the results of the study, while Section V discusses the results within the theoretical model of SCM. Finally, Section VII concludes the study.

II. LITERATURE REVIEW

Supply Chain Management

To build a research stream around the SCM phenomenon, researchers must agree on a common definition. Mentzer et al. (2001) review, categorize, and synthesize the various definitions on SCM found in the literature with the goal of developing one comprehensive definition of SCM. They classify the various definitions into one of three categories: a management philosophy, an implementation of a management philosophy, and a set of management processes. Tables 2a and 2b list several definitions of SCM found in the literature and classifies the definitions into one of those three categories³.

Mentzer et al. (2001, 11) classify the definitions relating to SCM as a management philosophy as supply chain orientation (SCO). They define an SCO as, “the recognition by a company of the systemic, strategic implications of the activities and processes involved in managing the various flows in a supply chain.” SCO is the philosophical underpinning of supply chain management. In other words, firms must be oriented toward managing their supply chain before they can implement SCM activities. In their review of the literature, they state that an SCO is associated with the following three characteristics (7):

1. A systems approach to viewing the channel as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer,
2. A strategic orientation toward cooperative efforts to synchronize and converge intra-firm and inter-firm operational and strategic capabilities into a unified whole, and

³ A significant portion of Table 2 is adapted from Mentzer et al.'s (2001, 6) Table 1 and Croom et al.'s (2000, 69) Table 1.

3. A customer focus to create unique and individualized sources of customer value, leading to customer satisfaction.

They also state that a willingness to address the SCM antecedents by a firm is an SCO. Before a company can move to SCM it must first have an SCO. In other words, a company must have a philosophical awareness of the implications of managing a supply chain before the management of that supply chain can occur.

The authors also mention that a firm with an SCO might be able to implement some “disjointed supply chain tactics (such as just-in-time delivery or electronic data interchange with suppliers and customers), but this is not SCM unless they are coordinated (a strategic orientation) over the supply chain (a systemic orientation) (11).” However, those “disjointed supply chain tactics” should help an SCO spread throughout the supply chain. As the interactions increase across firms and the successes of those “supply chain tactics” improve, the firms should begin to recognize the implications of managing the various flows across a supply chain.

If SCM is not a management philosophy, then what is it? SCM revolves around the other two categories listed in Tables 2a and 2b, a set of activities to implement an SCO and a set of management processes. Mentzer et al. (2001) identify seven SCM activities, 1) integrated behavior, 2) mutually sharing information, 3) mutually sharing risks and rewards, 4) cooperation, 5) having same goals and focus of serving customers, 6) integration of processes, and 7) having partners to build and maintain long-term relationships. Underlying those SCM activities is a more-encompassing view of the relationships between firms in a supply chain. The move is

away from arm-lengths relationships to more collaborative arrangements (Spekman et al. 1998).

Lambert et al. (1998) suggest in successfully implementing SCM firms must move away from the traditional silos and move toward a process approach. They suggest several key processes to organize around, to include; customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, procurement, and product development and commercialization. It appears SCM encompasses firms having a more collaborative arrangement across an integrated (internally and externally) set of key processes.

Mentzer et al. (2001, 18) state, “that supply chain management involves multiple firms, multiple business activities, and the coordination of those activities across functions and across firms in the supply chain.” As such, in their attempt at developing one comprehensive definition of SCM, they define SCM as, “*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across business within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.*”

The success of SCM depends on the extent of inter-functional coordination and inter-corporate coordination (Min 2001a, 2001b). Inter-functional coordination is a measure of the extent of internal integration. Inter-corporate coordination measures the functional shifting between firms in a supply chain, as well as, the structure and relationships (relationship intensity) between firms (Mentzer et al. 2001). Min also

states that both are necessary but neither of the two is sufficient to successfully manage a supply chain.

Performance Frontier and SCM

Examining Schmenner and Swink's (1998) performance frontier theory helps one to understand a firm's performance capabilities and its impact on SCM. They define a performance frontier as, "the maximum performance that can be achieved by a manufacturing unit given a set of operating choices (108)." There are basically two factors that the firm can change, 1) structural factors and 2) infrastructural factors. Structural factors include items relating to the plant design and investment, while infrastructural factors include those items formed by operating decisions. Since structural factors relate to the fixed-asset portion of the balance sheet, Schmenner and Swink identify those factors with the asset frontier. The other frontier is called the operating frontier and applies to the operating choices made by a plant, given a set of assets (i.e., infrastructural factors). Figure 2 displays the two performance frontiers, as modified by Vastag (2000)⁴.

There are two types of positive movements within the operating frontier, improvement activities and betterment initiatives. Improvement activities are defined as, activities that "increase plant performance in one or more dimensions without degradation in any other dimension (this definition is analogous to Pareto optimality in

⁴ Schmenner and Swink originally placed cost on the vertical axis and performance on the horizontal axis (109); however, Vastag (2000) correctly states that, "cost is considered as one of the competitive priorities and as such it is a function of investments in equipment (structural factors) and manufacturing systems (infrastructural factors), so I argue that it belongs to the performance dimension (354)." Thus he includes cost as a component of performance and moves it to the vertical axis and places

microeconomic theory).” Betterment initiatives are defined as, “altering manufacturing [systems] in ways that move or change the shape of the operating frontier (Schmenner and Swink 1998, 109).”

A firm that is not operating on its operating frontier is inefficient and underutilized (A_0 in Figure 2). This firm is similar to a Stage 1 firm in Table 1. As the firm implements improvement activities (e.g., increasing training), its utilization and/or efficiency improves and the firm moves closer to its operating frontier (A_1 in Figure 2), i.e., begins transitioning to higher stages of integration. The utilization and/or efficiency gain of an improvement activity stops once a firm reaches its operating frontier. It takes betterment initiatives to further increase the performance of the firm, assuming no change in the asset frontier.

Betterment occurs when a firm changes its operating policies and systems to improve operational efficiency. One proven method of accomplishing this goal is through lean production techniques (e.g., Schonberger 1982; Ohno 1988; Fullerton and McWatters 2001). A successful betterment program shifts a firm’s operating frontier up, where additional improvement activities can resume in order for the firm to reach its full potential. A firm operating on or near its operating frontier resembles a Stage 3—internal integration firm⁵. In addition, if a betterment initiative elevates a firm’s operating frontier higher than a competitor’s operating frontier, that firm is able

manufacturing inputs, investments and choices on the horizontal axis. Also note, the operating frontier is concave due to the law of diminishing returns, while the asset frontier follows a step-function.

⁵ Another possible movement is a firm moving along the operating frontier. A movement along the operating frontier represents an increase in manufacturing inputs (i.e., materials, labor, overhead). Since the firm remains on the operating frontier it is still operating at its maximum capabilities. The increase in manufacturing performance is due only to increasing the manufacturing inputs.

to compete based on the superiority of its operating frontier. The Japanese car manufacturers, using lean production techniques, did just that and created a competitive advantage against the American car manufacturers (Flaherty 1996, as cited by Vastag 2000).

The discussion on performance frontiers can also be used to evaluate the supply chain itself. Figure 3 displays a hypothetical supply chain and the operating and asset frontiers for the supply chain as a whole. The operating frontier is the operating systems and policies of the supply chain, given a set of assets. It is a function of the internal operating systems of each firm, as well as, the external processes and operations across firms of the supply chain. At time 0, the supply chain is not on or close to its operating frontier (SC_0). Improvement activities are needed by the individual firms to move the supply chain closer to its operating frontier. As with individual firms, as the supply chain moves closer to its operating frontier there is an increased need for betterment initiatives. Successful improvement activities and betterment initiatives (e.g., SCM) will move the operating frontier upward and the supply chain closer to it (SC_1). It is only at this stage the supply chain has created internal and external competencies (moved to Stage 4—external integration) and can leverage those competencies to create and sustain a competitive advantage.

The movement of the supply chain within its operating frontier is dependent upon the individual firms comprising the supply chain. The same holds true for the movement of the operating frontier, itself. As firms improve their internal processes and increase their level of internal integration (i.e., develop internal competency), they

should begin examining the processes external to the firm but interconnected with it (i.e., develop an external linkage focus) and proceed to implement activities aimed at integrating those external processes (i.e., develop external competency).

Supply Chain Relationship

As firms begin successfully working together in integrating externally, the firms should progress toward a collaborative relationship. While there exists several theories that attempt to explain the nature of relationships between firms, the network approach (Johanson and Mattsson 1987) and resource-based view (Penrose 1959) appear to best explain relationships between firms implementing SCM. The resource-based view, “considers vertical cooperation as bundles of resources and capabilities. The individual firm in the supply chain should focus on its core competencies and [develop competency alliances] with the other parties in the value chain (Skjoett-Larsen 1999, 51).” The resource-based view maintains firms should focus on developing internal competencies and rely on its supply chain partners for those resources and competencies it does not have, but requires.

The resource-based view helps explain why firms migrate through the first three stages of supply chain integration—to develop internal competencies. It also explains why firms need to develop closer relationships with other firms in the supply chain—to form competency alliances and achieve external integration. The resource-based view also helps identify which firms in a supply chain should develop closer relationships with their suppliers and/or customers. According to the theory, a firm should develop closer relationships with those firms having the requisite competencies

needed that cannot be easily duplicated in-house. In other words, firms should attempt external integration with those firms who are vital to the success of the individual firm and the supply chain as a whole. Not every supplier-customer relationship requires high levels of external integration.

If the resource-based view tells us why supply chain relationships are formed, the network approach tells us how supply chain relationships are formed and strengthened. A network includes three components (activities, actors, and resources) and their mutual relationships. At a supply chain level, the actors are the individual firms that control the resources of their respective firm. The network approach focuses on the “exchange and adaptation processes between [firms] in a supply chain (Skjoett-Larsen 1999, 51).” Exchange processes include all inter-firm exchanges to include, operational, administrative, and social exchanges. Adaptation processes are the mutual modifications to the exchange processes. External integration activities between firms are adaptation processes. It is through adaptation processes (i.e., external integration activities) that the relationships between firms are strengthened and made more stable (Skjoett-Larsen 1999).

According to the theory of performance frontiers, successful SCM is a function of the operating frontiers of the individual firms comprising the supply chain. Using the supply chain as a competitive advantage (i.e., operating on or near the supply chain’s operating frontier) requires the firms to concentrate on their core competencies while working together in integrating their exchange processes across the supply

chain. The extant literature identifies several antecedents that should be present across firms attempting to successfully manage their supply chain.

Supply Chain Management Antecedents

Mentzer et al. (2001) identify eight antecedents to SCM; trust, commitment, interdependence, organizational compatibility, vision, key processes, leader, and top management support (Figure 4). The first two, trust and commitment (what Spekman et al. 2001 call part of an alliance spirit) are widely recognized as necessary pre-conditions to any successful long-term relationship (Morgan and Hunt 1994).

Spekman et al. (2001, 9) define trust as, “the belief that one’s partner will act in a predictable manner, will keep his word, and will behave in a way that will not negatively affect the other.” To progress to SCM, firms must believe their supply chain partners will act in a way that benefits all of the supply chain partners and not act in an opportunistic manner, what Spekman and his colleagues call a win-win orientation.

Closely related to trust is commitment and it is a vital aspect for successful supply chain relationships. Commitment is one’s willingness to devote time, energy, and/or resources to the supply chain relationship (Spekman et al. 2001). There is zero probability for firms to engage in SCM without commitment to the endeavor. Firms must be willing to devote, for the long-term, the time, energy, and resources to SCM to have any chance of transforming their supply chain to a competitive weapon (i.e., shift the supply chain to its operating frontier).

A recent study found a higher probability of success for trading partners willing to devote resources to sustain a longer-term interaction (Monczka et al. 1998). Trust and commitment go hand-in-hand and lead directly to cooperative behaviors necessary to implement SCM. Spekman et al. (2001) comment that the presence of commitment almost necessitates some level of trust; however, firms can trust their supply chain partners without committing resources to a mutual endeavor.

The third antecedent identified by Mentzer et al. (2001) is interdependence. Companies that do not recognize some level of dependence on other companies in their supply chain have little motivation to work with those companies. To move to SCM, all companies must acknowledge dependence among the firms (Bowersox and Closs 1996). Dependency relates back to the earlier statement that not every supplier-customer relationship requires high levels of external integration. Firms will recognize a high amount of dependency with those key suppliers and customers that are vital to its success.

The next two antecedents are organizational compatibility and vision. The overriding theme is that firms in a supply chain should have similar operating philosophies and corporate cultures and visions (Cooper et al. 1997), as well as decision-making style (Spekman et al. 2001). A shared vision among all member firms of a supply chain provides each firm with the directions, objectives and strategies in how to manage the supply chain (Mentzer et al. 2001). To work together successfully, the member firms must have similar operating philosophies and corporate cultures. Cooper et al. (1997) argue the importance of similar operating

philosophies and corporate cultures should not be underestimated. Spekman et al. (2001, 12) advocate a “flexible, adaptive, and open organization” and a culture “supportive of trusting behavior, openness, inquiry and experimentation.” Haas and Kleingeld (1999) mention the design of the control structure plays a crucial role in fitting organizational behavior to organizational goals. The authors appear to advocate a more “organic” organizational control system, as opposed to a “mechanistic” organizational control system (Burns and Stalker 1961).

Mechanistic systems are highly bureaucratic and rigid. Centralization of control and authority and a high level of task specialization and standardization characterize the mechanistic structure. In addition, communication is formalized vertically; decisions, rewards and punishment flow down, while information, often in the form of exceptions flow back up. The role of line managers is simply to operate the established facilities, systems, and personnel according to senior management’s rules, regulations, and pre-determined targets (Burns and Stalker 1961).

In contrast, an organic system is adaptive and reflexive. A continuous reassessment of tasks and assignments occurs in order to deal with new problems and/or opportunities facing the organization. Organic systems are much looser organizations with more decentralization of control and authority. Communications flows horizontally and diagonally, as well as vertically, and are dependent upon where the requisite knowledge resides. Organic systems have a participative style of management, with much more reliance on group processes (i.e., teamwork) to achieve integration and adaptation in managing functional interdependencies (Burns and

Stalker 1961). Organic organizational control systems appear the best fit across firms attempting to successfully implement SCM.

The sixth antecedent is identifying key processes. Member firms should agree on the key processes of the supply chain (Lambert et al. 1998) from which to begin to integrate. Mentzer et al. (2001) argue that all traditional processes should be included in the process of SCM (see their Figure 3, p. 19). The identification of the key processes is what is crucial. As those key processes become successfully managed at a supply chain level, then other processes can be included. The key is agreeing to a set of processes from which to begin implementing SCM.

As with any initiative, SCM requires a supply chain leader (Mentzer et al. 2001; Ellram and Cooper 1990). One firm will play the key role in coordinating and overseeing the entire supply chain. Several factors may determine the supply chain leader, for example, size or economic power (Bowersox and Closs 1996). However, it may be the one firm that demonstrates the most commitment to managing the supply chain that takes the role of supply chain leader. Spekman et al. (2001, 10) state that “when one partner demonstrates commitment, there is often a similar response from the other, and on it goes in a virtuous cycle.” If that is true, then the firm who demonstrates the highest degree of commitment is in a position to begin the virtuous cycle and naturally take the lead role in coordinating and cooperating across firms in the supply chain.

Top management support is necessary and vital to sustain any long-term initiative and is the last antecedent to be discussed. Resources originate from top

management. Lack of support translates into lack of resources, which result in a failed initiative. This is true whether the initiative is SCM (Mentzer et al. 2001) or activity-based costing (Krumwiede 1998; Foster and Swenson 1997; McGowan and Klammer 1997), or any other long-term initiative.

Although not specifically mentioned by Mentzer et al. (2001), Spekman et al. (2001, 26) empirically find, “the importance of learning to developing truly affective enterprise-wide supply chain management.” In addition, they comment that the challenge is to ensure that learning occurs across all levels of the supply chain. Schendel (1996) highlights that the process of learning may be just as important as the content learned. With that, Spekman and his colleagues suggest that a process of learning should be an integrated aspect of ‘business as usual’ with a supply chain. Their results indicate the use of joint decision-making, taking a win-win approach to supply chain relationships, and having a shared culture are the most effective pre-conditions of supply chain learning.

Motivation for Supply Chain Management

Mentzer et al. (2001) identify lower costs, improved customer value and satisfaction and competitive advantage as consequences of successful SCM. Empirically, Spekman et al. (2001) did not find any of their supply chain learning measures significantly related to cost reductions but did find support for customer-focused performance measures. They state, “Perhaps, when one utilizes performance metrics that focus on cost (and/or time reduction), there might be little incentive to work closely to achieve other goals...Cost savings alone cannot result in a sustainable

competitive advantage. By pursuing goals that are end-user focused, firms/supply chains begin to address issues that can lead to superior gains (23).” It appears, while cost reduction is definitely an objective of SCM, increasing customer-focused performance is what drives the move toward SCM. Firms must look beyond just cost reduction and see SCM as a growth opportunity.

The literature appears to espouse that SCM is the new domain where firms will achieve a competitive advantage. To reach that goal requires firms achieving internal and external efficiencies. True SCM requires at least three firms collaborating with the common vision of improving the supply chain. SCM should be seen as a growth opportunity and not just a cost savings initiative. While SCM appears theoretically sound, understanding how firms proceed in its implementation is needed. Studies aimed at investigating the implementation process should be fruitful in further developing the theory of SCM. This study seeks just that aim, by qualitatively investigating how a direct supply chain attempted to implement SCM.

III. METHODOLOGY

Maxwell (1996, 65) presents four design components that researchers must address when designing a qualitative-based study:

1. The research relationship that you establish with those you study.
2. Sampling: what times, settings, or individuals you select to observe or interview and what other sources of information you decide to use.
3. Data collection: how you gather the information you will use.
4. Data analysis: what you do with this information in order to make sense of it.

This section addresses each of these design components as they relate to this study.

Research Relationship

In field research, the researcher is considered the research instrument. The research relationship is the means by which the research is done and affects not only the study's participants, but also the researcher and other parts of the research design. Relationships are formed to establish trust and rapport with the participants. There are four types of relationships between the researcher and the participants being observed (Atkinson and Shaffir 1998, Maxwell 1996):

1. Undercover—researcher joins the group under false pretenses.
2. Spy—researcher does not disclose his/her presence to the group.
3. Active Participant—researcher joins the group and the group understands that the researcher is a researcher who is observing the group's behavior.
4. Passive Participant—researcher joins the group but plays an entirely passive role (observer and interviewer only).

The first two relationships are considered covert methods and are used when the researcher is attempting to avoid affecting the process. While ethical considerations must be addressed regardless of the research relationship, ethical considerations are especially important when conducting research using one of the two covert methods.

Due to lack of informed consent, most researchers and ethicists agree that the covert methods are inappropriate (Atkinson and Shaffir 1998).

The difference between the two overt methods is the amount of interaction between the researcher and the research participants. The researcher as an active participant has a great deal of interaction with the participants. The advantage of this interaction is it allows the researcher to study the process more carefully, and ask more detailed questions of the participants. The disadvantage is that now the researcher is possibly influencing events and is unable to report on what behavior would have happened absent his/her involvement. Additionally, the researcher may lose objectivity, a condition of “overrapport.” The other overt method is the researcher is a complete observer in which he/she does not intervene in the social or decision making process (Atkinson and Shaffir 1998).

For this study, the research relationship fits more closely with the passive participant relationship than any of the other types. The research relationship began when the researcher and a second individual were engaged in assessing the level of internal integration (i.e., lean) within and across each site participating in this study. The assessment culminated in a workshop (discussed later) conducted by the researcher, among others. The researcher’s involvement included assessing, evaluating, and providing recommendations to each site on where/how they could improve their lean efforts. The researcher was also involved in facilitating discussions among the sites in how they can work together to improve their supply chain. From the conclusion of the workshop to the completion of the interviews, the

researcher became a complete observer and was only involved in observing the process and interviewing the participants.

Sampling

“Selecting those times, settings, and individuals that can provide you with the information that you need in order to answer your research questions is the most important consideration in qualitative sampling decisions (Maxwell 1998, 70).” The research question for this study deals with SCM and how firms progress toward it. True SCM involves at least three contiguous companies. In addition, there must be some attempt at managing a supply chain. The supply chain chosen for this study meets both of those requirements. The beginning point of this study is the Supply Chain Integration Workshop, which represents the first time the three contiguous companies began efforts at managing their supply chain.

In March of 2001 several individuals, representing a three-tier supply chain (i.e., Prime, first-tier supplier and second-tier supplier), met at the University of Tennessee to participate in a Supply Chain Integration Workshop (SCIW). The workshop’s objective was to facilitate SCM across all three tiers of the supply chain by identifying and resolving inefficiencies within and across the firms. The SCIW was the first time representatives from all three tiers gathered in one place. Prior to the SCIW, the researcher visited each site to gain an understanding of the internal

enhancement programs (lean/six sigma⁶) undertaken within each site and the interactions across each site.

The motivation for the SCIW arose from the operations managers of the first-tier supplier. That site had begun a concerted effort at implementing lean internally and realized the need to involve its suppliers and customers in order to maximize the benefit of its lean efforts. The purpose of this research study is to examine the supply chain beginning with the SCIW and ending one year later. Prior to the SCIW there was no effort at managing the supply chain by any of the sites involved. That fact gives this study a unique opportunity to investigate how organizations move toward SCM. While there exists some theoretical studies on SCM (e.g., Mentzer et al. 2001), there is very little empirical research examining supply chains⁷ (Spekman et al 2001).

The supply chain under study operates in the aerospace industry; it manufactures and delivers a major component (MC) on a weapon sold to the Department of Defense (DOD). As of March 2001, the MC for the supply chain was a newly designed component in the Engineering Manufacturing Development (EMD) phase. The EMD phase precedes the production phases and represents the phase when design changes are still taking place. The component was scheduled for Low-Rate Initial Production (LRIP) by summer 2001, which indicated it was close to final design. Once the component reaches full-rate production, the total program-life

⁶ All firms participating in the SCIW had formal lean/six sigma programs. While lean and six sigma are separate initiatives, these firms had integrated the principles of both initiatives into one internal enhancement program. Appendix D discusses lean principles in more detail.

⁷ There has been significant research examining the dyadic relationship between two firms; however, true supply chain research involves investigating, at least, three companies directly connected in a supply chain.

revenue is estimated to reach over \$200 million. The supply chain consists of three sites, the Prime, the first tier supplier (FTS), and the second tier supplier (STS), as shown in Figure 5.

The Manufacturing Operations Manager and Lean Trainer (PE) for the FTS was the initiator of the SCIW and was interested in involving the STS and Prime in removing inefficiencies and costs from the supply chain before LRIP production began. The FTS is a wholly owned subsidiary of a large aerospace firm with annual revenues exceeding one billion dollars. As with most large aerospace firms, the company is organized by programs⁸. The primary contacts at the FTS represented two groups within the organization. The first group is responsible for the internal training of lean/six sigma. The second group is the supplier development team responsible for improving the interactions between the FTS and its suppliers.

The Prime is an aerospace contractor with annual sales exceeding \$15 billion and over 50,000 employees worldwide. As with the FTS, the Prime is organized by programs. The researcher's primary contact at the Prime was the supplier development team. That team was responsible for conducting lean/six sigma training internally, as well as externally with its suppliers. The supplier development team also facilitated the execution of lean/six sigma principles within the different programs at the Prime. The MC Program at the Prime is a significant program.

The second tier supplier (STS) is a much smaller firm with just over 200 employees. The firm's primary focus is manufacturing products for the semi-

conductor industry. As of March 2001, MC was not a major source of revenue for the STS. The STS's stated motivation for participating in the SCIW was to increase their share of work awarded by the FTS (i.e., increase revenue). Unlike the other two sites in the supply chain, the STS is more like a job shop and has organized its manufacturing facility by cells. The researcher's primary contact with the STS was the Lead Industrial Engineer. This person was responsible for the continuous improvement of the manufacturing operations at the STS.

Data Collection

This research project attempts to further refine the theory of SCM through a qualitative field-study approach. The study uses site visits, survey data, and interviews to thoroughly investigate the dynamic nature of SCM. The objective is to determine the facilitators, as well as the impediments, firms encounter while attempting to move toward SCM. The first tier supplier of the supply chain is the focal firm for the research study. However, data from the other two tiers are used to give a broader picture of the supply chain.

Atkinson and Shaffir (1998, 45) comment, "the primary motivation for doing field research is that it provides the only reliable method to mine human experience using the people involved in the behavior under study." Since the evolution to SCM involves complex behaviors of individuals across firms in a supply chain and due to the lack of research addressing supply chains (Mentzer et al. 2001), a qualitative field study approach appears the appropriate method.

⁸ In other words, each major product is a program within the firm. A Program Manager leads each

Qualitative research is useful to develop an understanding about a phenomenon about which little is yet known (Strauss and Corbin 1998). Qualitative methods are useful for understanding the complex nature of a particular phenomenon of interest, even if there is previous speculative theory (McCracken 1988; Glaser and Strauss 1967). Research on SCM fits both of those requirements. While other methods are used in this study, interviewing is the primary data collection method.

Interviews are useful for examining actions and events, especially the interviewee's perspective of past actions and events, and observations that allow the researcher to draw inferences from those perspectives (Maxwell 1996). McCracken (1988) states that the in-depth, qualitative interview is a method that allows the researcher to gain insight into the "mental world" of the participant. A semi-structured interviewing approach was used to investigate the SCM phenomenon, "to ensure the appropriate balance between focus and completeness in understanding specific areas of interest on the one hand, and flexibility to identify and pursue new ideas that came up during the interview process on the other hand (Nix 2001, 85)."

A protocol (Appendix F) was created to guide the interviewing process. The framework relied on "grand-tour" questions and floating prompts (McCracken 1988). Grand tour questions are phrased in a general and nondirective manner. The goal was to allow the respondent to tell his/her own story in his/her own terms. The objective of floating prompts is to allow the interviewer to be as unobtrusive as possible, yet guide the interviewee to expand on a certain phrase or comment made. However,

program. The program office coordinates all activities with its product from procurement to final

planned prompts were designed into the questionnaire in case the interviewee had not fully discussed the phenomena. The planned prompts were placed at the end of each question category (McCracken 1988).

Several sources were used in developing the protocol. First, the literature review is a primary source of information on the phenomena of interest. The literature review specifies and defines the categories and relationships that may organize the data (McCracken 1988). Other sources used in developing the interview protocol include the initial site visits to each company, as well as, the data collected from the SCIW. Lastly, the responses to the Lean Enterprise Site Assessment (LESA⁹) were used to guide discussions regarding the implementation of internal integration within each firm and external integration between the firms.

During March 2002, on-site interviews with individuals from the FTS were conducted. The purpose of the interviews was to determine what had transpired since the SCIW with regard to the MC program. Eight interviews were conducted. The keys to selecting the individuals were knowledge, diversity and availability. Table 3 shows the identifiers and titles of the individuals interviewed. The individuals had knowledge of their respective supply chain and the programs under study. Also, each individual represented a different level of management and could offer different perspectives. Lastly, each individual interviewed consented to participate in the study. All interviews were taped with the exception of the AT, BA, and HJ. Notes were taken

delivery.

⁹ Appendix C contains the LESA instrument and Appendix D describes the LESA.

during their interviews. PE was present during the interviews with WC, SD, and FD¹⁰. Also, HG, JC and JH were interviewed together in a focus group setting. An independent source transcribed all taped interviews verbatim.

Data Analysis

While preliminary analysis began during the interview process for the purpose of refining interview questions based on respondents' answers to previous questions, the primary data analysis began once the researcher completed all of the interviews.

Data analysis consisted of the following steps:

1. Listening to interview tapes prior to transcription.
2. Reading verbatim transcripts.
3. Coding verbatim transcripts.

The first two steps involve creating notes of tentative ideas about categories and relationships (Maxwell 1996). These notes became useful in the subsequent step of coding the transcripts. The researcher listened to the interview tapes within the context of the theoretical constructs derived from the literature review and the field notes taken during the interviews. The objective was discovering broad categories that either supported or refuted the theoretical framework. By reading the verbatim transcripts the researcher was able to reaffirm or refine the broad categories annotated during the first step.

The researcher used QSR NUD-IST© (Nonnumerical Unstructured Data-Indexing, Searching, and Theorizing) Version 4 software to code the verbatim transcripts. The goal of coding is to “fracture the data and rearrange it into categories

¹⁰ PE is not in a supervisory role with regard to WC, SD and FD.

that facilitate the comparison of data within and between these categories and that aid in the development of theoretical concepts (Maxwell 1996, 78).” The beginning categories from which the transcripts were coded were derived from the literature review and the notes taken during the previous data analysis steps. The coding and recoding of the data continued until the researcher was able to integrate the categories within a theoretical framework.

Change in Study's Environment

One important qualification needs mentioning before continuing. The original study was aimed at examining two separate supply chains regarding two different aerospace programs (MC Program and 2TB Program)¹¹. The study's timeline was from March 2001 until March 2002. During the March 2002 site visits it was discovered that the 2TB Program had produced very little during the study's time span and future sales were suspect. As such, there was no supply chain to study. However, a related program (2TA) was running and during the interviews several serious supply chain issues were raised. The 2TA program is used to provide additional evidence on the issues raised during the investigation of the focal supply chain (the MC Program).

In addition, the MC Program, detailed in the next section, was under a stop order as of the beginning of 2002. No work on the program had been done since the stop order was issued. Before the stop order was issued there was activity between supply chain partners. The interviews were focused on investigating the supply chain interactions occurring prior to the stop order. Lastly, the individuals from the STS that

participated in the SCIW were no longer associated with the STS and were not available for follow-up interviews.

As is the case with field study research, the researcher had no control over the environment. The environment drastically changed over the prior year, with both programs halting production. The changes in the environment did not allow for the original study to move forward as planned. Once the researcher was informed of the change in the programs, the study's focus was altered to allow for the change. The MC Program did progress on supply chain issues and the researcher focused on the activities conducted between supply chain partners, as well as, attempted to identify facilitators and/or impediments encountered. The next section presents the results of the study.

¹¹ The actual names of the programs are changed to protect the confidentiality of the programs and companies involved. The 2TB Program involves a mature product in the declining stage of its product life cycle. The FTS's customer for the 2TB is the same customer as its MC program.

IV. RESULTS

Internal Improvement Initiatives

Before moving to supply chain interactions each site is examined to determine the level of internal integration existing within each site with respect to the supply chain. The success of SCM will be dependent upon, among other things, the level of internal integration existing at each tier in the supply chain. Since the MC component in the supply chain was in the EMD phase, the extent of internal integration using lean tools/techniques is limited as compared to products in full production. However, there was some effort made at integrating the functions internally.

First Tier Supplier

As with the Prime and STS, the FTS has a separate department tasked with training and facilitating the implementation of lean principles across programs. Prior to the SCIW in March 2001, training had occurred but little in way of implementing what was learned had happened. The lack of implementation is due in large part to the EMD phase. Many of the lean tools/techniques are geared toward manufacturing operations. Even in the EMD phase, the MC program was able to implement some of the tools they were taught.

The first activity completed by the MC program was centralizing its processes. As the Integrated Product Team (IPT) lead stated, “Because we were traveling throughout this whole company we centralized the location. We had the money, we got a plan, [and] we centralized like, say, 90% of the processes...And so instead of

traveling all over the company, there were only certain instances that we would have to travel.” Centralizing its processes occurred over four years ago.

The next improvement activity implemented was 5S¹² and it began approximately three years ago. This was the same time frame that 5S was a major initiative from upper management. When asked if the move to implement 5S in the MC program was due to the “big push” from upper management, a TTA (Tools and Testing Associate) commented, “Well, we were kind of doing it on our own and, you know, kind of in conjunction with everyone else...5S was the buzz around here, so, you know, we said I’m tired of all the crap around here, let’s just go ahead and do it. So, it was...we were kind of pushed by that, I would say.”

The last two improvement activities implemented before the SCIW were the visual shop¹³ and mistake-proofing¹⁴. As the TTA stated, “...we used the visual shop quite a bit. As a matter of fact, when I first got here there was none of that, and there was a few of us...myself and a few other TTAs when they came, and said, hey, we are getting a little bit too much work and too confused, let’s make a white board. So we did it with the status type boards...started hanging up schedules.” He continued, “The visual aspect of the shop probably started about two...not quite two years. And the mistake-proofing, we did that maybe a year and a half ago, and that was around the timeframe when our LRIP program was getting real hot and heavy, real aggressive, and we had more people here than just myself and another guy. So, it was

¹² 5S is a 5-step strategy for organizing and maintaining the work area. The steps are Sort, Store, Shine, Standardize and Sustain.

¹³ The concept around the visual shop is the use of visual signals to communicate information about the status of the production line.

almost like the more people that came here, the busier we got we decided we had better start a few things and make it easier for us.”

By the time the SCIW commenced, the FTS had internally implemented a few improvement activities to include centralizing its processes, instituting a visual shop, and implementing 5S and mistake-proofing devices. While not very exhausting, it was a start. The real benefit of the SCIW for the MC program at the FTS was in improving the FTS’s external interactions with its key suppliers and its customer. Their goal was for the MC program to be more externally integrated than other programs at the FTS. As PE (Mfg. Ops. Mgr.) with the FTS mentioned during the SCIW, their objective is to work with the suppliers within the program to facilitate the implementation of lean tools. They want to use the knowledge learned from the implementation of lean in other programs.

Second Tier Supplier

Unlike the FTS, the STS had made significant progress in implementing lean by March 2001. Table 4 summarizes the results of the LESA completed by the STS in March 2001¹⁵. It scored just over a .49 on a scale of 0 to 1 on the Lean Production Infusion Score. That score is quite good considering it represents the level of lean infusion throughout the entire manufacturing facility, not just one program, and the fact that the STS only began implementing lean in mid-1999. Compared to the FTS the STS was more mature in its lean implementation.

¹⁴ Mistake proofing is the use of fixtures or tools to eliminate or reduce the possibility of errors.

¹⁵ See Appendix D for details on the Lean Enterprise Site Assessment. There are no Lean Production scores to report for the FTS due to the EMD phase of the program. The only lean activity conducted in the MC Program by the FTS is detailed in the prior section.

The STS's motivation for implementing lean was to grow the business. In the late 1990's the STS was coming out of bankruptcy. The owners recognized lean as a way to reduce wastes and compete. It was also a way to become a Certified Lean Supplier in the semi-conductor industry, which did occur in 2001. In mid-1999 the STS hired a consultant to implement, what they called, world-class manufacturing techniques. In essence, the STS began implementing various lean tools and techniques. For example, by March 2001, the STS had 95% of the machines located in cells and almost 99% of the manufacturing cells produced based on a kanban signal¹⁶. In addition, 5S, method sheets, and flow were part of the standard operating procedures at the site.

The site's focus on continuous improvement resulted in quick success. Before the STS implemented lean they supplied a component for a piece of equipment used in the semi-conductor industry. After implementing lean and working with its customer, they began manufacturing the entire piece of equipment. The Lead Industrial Engineer credits that transformation on the relentless pursuit to continuously improve its operations.

Prime Contractor

Unlike the FTS and STS, the MC program at the Prime had done little in implementing lean/six sigma beyond some initial training¹⁷. During the site visit to the Prime, prior to the SCIW, the Supplier Development Team Lead stated there had

¹⁶ Kanban signals are the communication system of a lean manufacturing plant. As materials are consumed at a downstream station, signals are sent back to previous steps in the process to pull forward sufficient materials to replenish only those materials that have been consumed.

been very little improvement efforts internally. The FTS materials manager for the MC program commented, “I don’t know if [the Prime] is really doing anything with lean on the [MC program] that would have affected us at this point.” A reason for that might be the engineering phase of the program during 2001. During the site visit the Prime’s IPT Lead on the MC program commented that they were still tweaking the design and that was where the energy was focused. He did mention they were committed to working with the FTS in transitioning from EMD to LRIP.

Although the MC program at the Prime had not instituted any lean activities as of March 2001, they were indicating a willingness to work with the FTS in reducing costs between them. Outwardly the Prime appears committed to implementing lean across its entire organization. For example, lean/six sigma is one of the strategic initiatives consistently listed in its annual report. The supplier development team at the Prime had trained thousands of employees on lean/six sigma principles by March 2001. However, the facts are that they were not executing lean/six sigma principles in the MC program as of March 2001. The next section describes the Supply Chain Integration Workshop in which all three tiers sent representatives.

Supply Chain Integration Workshop (SCIW)

The SCIW held in March 2001 was the beginning point when all three tiers attempted to work together as a supply chain. A total of twelve representatives from the three tiers participated in the SCIW. The FTS sent six individuals, the Prime sent

¹⁷ As with the FTS, the Prime did not complete the LESA for this program due to the EMD phase and the fact that no lean activities were occurring during March 2001.

four and the STS sent two. Each company paid for the travel and time for their representatives. Table 5 details the itinerary of the SCIW.

The one-day SCIW began with everyone participating in a supply chain simulation (i.e., an adaptation of the MIT Beer Game). The idea was to actively engage the participants on how not communicating across a supply chain negatively affects all members of the supply chain (i.e., creates a whiplash effect). At the conclusion of the simulation the Lead Industrial Engineer at the STS commented that the results of the simulation were exactly what was happening to them (i.e., being whiplashed). Next, each site was debriefed on the results of their site assessment (i.e., the LESA results).

The afternoon session was devoted to supply chain integration issues. To facilitate the discussion five maps were developed from the information gathered during the initial site visits and the LESA. The first map, the Lean Capabilities Map (Figures 6a to 6c), details the results of the LESA completed prior to the SCIW. The purpose of that map was to visually demonstrate how effective each tier was in implementing lean/six sigma with respect to the other tiers¹⁸. The Lean Capabilities Map allowed each tier to see how their operations fit with the other tiers, especially when examining the Supplier Integration/Distribution Integration scores between tiers. This map, along with the Supply Chain Execution Map, facilitated dialogue across the tiers on improving the supply chain.

The second map is the Supply Chain Execution Map (Figure 7). This map visually detailed the flow of materials and information within each site and across the supply chain. The objective of the execution map was to show the amount of push versus pull in the system, highlighting areas for improvement and coordination. In other words, it is designed to provide a high-level process map of the supply chain segment. When used in concert with the supply chain metrics map, the participants were able to see their combined level of performance and their contribution (or lack thereof) to supply chain performance.

The third map is the Supply Chain Metrics Map (Figure 8). The goal of the Supply Chain Metrics map was to calculate common metrics across the supply chain. The Supply Chain Metrics Map calculates the current condition of the different tiers and the supply chain as a whole on a number of metrics. One of the objectives of the Supply Chain Metrics Map was to create awareness about overall supply chain performance and how each tier affected that performance.

Once the maps were presented, breakout sessions began. Each tier of the supply chain was represented in each breakout session. There were two outcomes expected from the breakout sessions, 1) identify internal actions items and 2) identify supply chain action items. The internal action items were those items each tier identified as key in improving its internal operations. The supply chain action items

¹⁸ The LESA scores for the FTS and the Prime represent the results of another program and not that of the MC program. The reason for using the results of another program was to show the current capabilities of a more mature program at each site. There are no Lean Production scores for the MC program as detailed in the previous section.

were those items the groups identified as needing resolved to improve the supply chain. Table 6 lists the actions items identified by the participants.

While the actual action items listed are not groundbreaking, they are unique in that all three tiers worked together and agreed on those items with the stated goal of improving the supply chain. More than one of the participants in the SCIW commented that the workshop was, “A unique experience because they often do not get to work within the supply chain.” Others mentioned that the unit-of-analysis (the supply chain of one program) makes it easier to talk with their customer. The SCIW also allowed each tier to display their capabilities. The Program Director of a different program with the FTS was so impressed with the STS capabilities, as demonstrated during the SCIW, that she asked the Director of Materials with her company, “...can you get these guys any work on [my program]; they would be a great supplier?”

The last two maps (Figures 9 and 10) were presented at the close of the workshop to display what the supply chain might look like in future if they worked together. The Supply Chain Metrics Map was calculated using the rate of improvement realized by the STS over the past year. That rate of improvement was applied to the current status of each tier to show the vast improvement possible if they worked together and was able to recognize the same rate of improvement over the next several months. The Supply Chain Execution Map provided a visual of an ideal supply chain. The objective of the future state maps was to have the participants leave the workshop with a vision of the possibilities. The participants left with an

understanding that it was their responsibility to move forward and work together in making the supply chain more efficient.

The next section details the activities performed between the tiers from the end of the SCIW in March 2001 until March 2002. The follow-up site visits occurred during March 2002.

Supply Chain Activity March 2001 to 2002

Upon arrival at the FTS in March 2002, the researcher learned the DOD had issued a stop order for the MC program around the beginning of 2002. Prior to the stop order, the MC program had begun the LRIP phase in June 2001, with the STS delivering the first order in September. According to FD (the IPT Lead), the FTS was just receiving the second lot from the STS when the stop order was issued. The expectations are the product will revert back to the EMD phase in late 2002. While the product was not in production during the March 2002 visit, there was work done and products delivered prior to the stop order. The interviews (all but one conducted with FTS's representatives) remained focused on examining supply chain interactions among the tiers.

STS—FTS Interactions

Several activities between the STS and the FTS transpired from the end of the SCIW until the stop order was issued around the beginning of 2002. According to AB (FTS Supplier Development Team Member), after the SCIW the STS toured the FTS's facility and they toured the STS's facility. The facility tours served two purposes. The first purpose was to show the STS how their part is processed downstream.

Before the SCIW, the STS was unaware how their part was used downstream. The second purpose of the tours was to enlighten the FTS on how a lean facility operates. Representatives from the FTS were able to see how the lean tools and techniques they were taught are implemented.

Another activity consisted of value stream mapping the supply chain (i.e., STS—FTS—Prime). The objective of the value stream mapping activity was to begin to create a lean supply chain. Significant progress was made toward creating a lean supply chain when the stop order was issued, as this exchange highlights:

Interviewer: Just try and take me through the process of evolution of your relationship with [the STS].

WC (Material Planning Lead): Okay. The relationship really started at the point of looking for a supplier to provide the parts that they're building for us now, and that was the engineering level and having engineers going down there and working with them to determine whether they could actually machine the components for us. The welding capabilities certainly not an issue, they have that...In the past [the STS] have ordered parts . . . you know, they go out and they make parts available. As an example, on the [component] itself, there is a an assembly that they manufacture . . . or they purchase all the materials that go into that assembly and make the component and then weld it into the [housing], so there is a coordination with them. You know, in the past we have ordered all of those [parts] for the [component] and brought them in here, inspected them, shipped them down to [the STS]. So a recent change that we made was where we had [the STS] go out and procure all the materials for the [component] and then they weld them up and then we get the completed [housing].

Interviewer: But it took out the step of them coming to you and then shipping out to [the STS]?

WC: Exactly. And then the next step we were working on, too . . . another one we were trying to eliminate was . . . we have to meet a certain cleaning requirement before they do some welding down there and they currently . . . well, they didn't have the capability to clean it at a level that we require and so certain components would come up here and we would clean them and we would have to ship them back to them before they could do the assembly of welding, and we were working to get [the STS] to the point to where they could actually clean down there, get it to the level that we required.

Interviewer: Is this recent?

WC: Yeah, that would have been within the last year. And then another thing, too, prior to that was girthwell x-rays. When they weld the two [housing] halves together there's an x-ray that gets done on that girthwell and we always brought them in here and had the x-ray done at [our facility], and then . . . you know, you shipped the parts back again so you got this going from [their facility] to [our facility] to [them] to [us] and back and . . . we decided that was crazy to do that, so [they] found a supplier down there, an x-ray house, that could do that girthwell x-ray.

Interviewer: So . . . but they still have to send it out, though? They just don't send it to you to be x-rayed?

WC: That's correct. It's a place right down the street from them.

The IPT Lead also commented on the working relationship with the STS, “Yes, we did have them up here a time or two where we were discussing issues on how we were going to process parts, and if at sometime they would . . . in this instance, they had parts that they could only do so much with and then they had to come up here to do something and then I would have to send them back, so we were trying to coordinate all of that, start working on that . . . you know, what's the best way to do that. So we did start that . . . that communication.”

The communication transformed into action with the tours, meetings, and value stream mapping activities. The activities between the FTS and STS highlighted by the above discussion are a direct result of moving beyond just communicating to implementing activities. The three changes WC mentions are all aimed at improving the supply chain. The direct procurement of parts by the STS allows the FTS to eliminate the ordering, inspecting and shipping of those parts.

All of the activities between the two sites came to the forefront with a meeting held on July 13, 2001. The minutes to the meetings are shown in Figure 11. The results of the value stream mapping are shown in Figures 12 and 13. Significant progress was made as a result of working together in creating a lean supply chain. For example, as shown in Figure 12, a new purchase order is issued each time the FTS is involved. By working with the STS and changing its internal operations, the FTS was able to issue only one purchase order (see Figure 13). In addition, by working with the FTS, the STS was able to go from supplying only a part of a component of the final product to supplying the full component. As CJ (Director of Materials for the FTS) commented, "...you guys are going to supply us a [full component]...period...and that is not going to be going back and forth. It's going to be totally your responsibility. So that was the driver for [the STS]. And we started to look at them based on the work that they were doing. We had many of our manufacturing folks going down there; we started looking at them for some other programs."

There were adjustments that had to occur between both sites to allow the STS to supply the entire component. CJ recalled one of those adjustments on the FTS part, "...[the STS] put their hands up for a while because they felt some of the cleaning [requirements], for instance, was a little too tough for them, they weren't quite ready for that. So that was one of the areas where we either did lose some requirement or we could have loosened the requirements and they eventually came around and said, okay, I think we can do that. But there were a number of technical interchanges

between our guys and theirs to see...where we actually worked through, you know, what can we do, what can't we do."

Unfortunately the stop order was issued for the program as significant progress was being made on the interactions between the FTS and the STS. When asked if the momentum and commitment would still be there when the stop order was lifted, each person answered in the affirmative. FD (the IPT Lead) did qualify his answer by stating, "The longer it goes, the less chance...it could be everybody's thrown to the wind because you're starting all over again." While there was a flurry of activity between the FTS and the STS, the story is much different when the interviews began examining the interactions between the FTS and the Prime.

FTS—Prime Interactions

When asked if the FTS attempted to get the Prime involved in completing some of the action items from the SCIW, CJ stated, "Oh, a number of times, and I guess in fairness to them we weren't ready for them. I think the benefit would have been...they could have seen what we were doing [with the STS]." [Interviewer] "What you're telling me is...nothing materialized?" "No."

While the Prime did not participate in any supply chain activities originating from the SCIW, they were involved with the FTS in two areas, visioning trips and lean/six sigma training. As FD noted, "In October we went and toured their plant [to] see how they were implementing all their changes and getting ideas there, and then, of course, even with our training on the green belt, my team was the [Prime's] people. We brought them in and trained together." The visioning trips and the lean/six sigma

training the Prime's Supplier Development Group (led by SJ) conducted were effective. The visioning trips allowed individuals from the FTS to see the effectiveness of implementing lean/six sigma. The goal of those trips was to get buy-in from all levels of a program that there is value in implementing lean/six sigma.

In summary, during the past year representatives from each tier of the supply chain got together to discuss supply chain issues. The STS and FTS executed on the issues raised during the SCIW, while the Prime did not. The next section probes deeper in trying to understand the facilitators and impediments to moving forward on a long-term improvement initiative like SCM externally and lean/six sigma internally. In other words, are there identifiable items that help distinguish why the FTS and STS worked together and the FTS and Prime did not?

In an attempt to answer that question, several items will be discussed. The discussion examines the alignment of management support, the commitment versus funding of an initiative, the training and visioning for an initiative, the link between lean and SCM, and the motivation for SCM.

Alignment of Management Support

When asked what does it take internally to institute a lean initiative, WC answered, "I think it comes from two different areas. I think it's from the plant manager, but I think it's also from the program manager and the two of them have to meet on common ground and say this is what we are going to do. We are going to do whatever it takes to make that happen, whether its resources, financially or whatever, and come to an agreement and say . . .you know, put a stake in the ground. This is

what it was, right, and in two years we are going to improve it and let's go make it happen. In general, I don't think it's much more complicated than that, other than making it happen. We've got the people here that have the education to go off and implement it.”

Then PE (Mfg. Ops. Manager) commented, “We have work statements that say this is what we are going to do, and usually [the Prime] or other people don't want to have to pay us to have that as part of the contract. They just want that contract to be as small as possible, okay. So what we have to deal with is externally do that, which means we have to invest [our] resources to do that, so that's where the program office and the plant manager get together and decide, yeah, I want this, and, yeah, I want you to have this, now let's spend the resources to go do this. And if they can get an agreement, it is a pretty simple...you know, an agreement to go it, now they just have to go spend the money to do it, okay. And on [the MC program] we were heading in that direction, we were starting to spend fairly up-front money to dialogue how we were going to go do it and then what tools we need and identify all the additional methods of support. Okay. But it can be that simple.”

Without question top management support is necessary to successfully implement any long-term initiative. The above quotes go beyond affirming the necessity of top management support; they suggest the need for the proper alignment of management support. For the FTS' lean initiative, the proper alignment of support came from the plant manager and the program manager. Both are needed, neither is sufficient.

The proper alignment of support is also necessary when dealing with supply chain issues. The following excerpts between the interviewer, CJ and CA show how misaligned support hindered progress on improving the MC Program's supply chain:

CA (Supplier Development Manager): I just want to make an observation...the people that are working with [the Prime], SJ and those guys; they are a different group.

CJ (Director of Materials): Right and that was part of the problem.

CA: In hindsight, it would have been great to have involved both [the program management side and the supplier development team].

Interviewer: Did the program guys at the Prime ever...

CJ: They did...I talked to SJ when we were trying to set up a meeting with them and I went to the program manager who sent me to someone else who sent me to...what we finally got to was the lead mechanical engineer.

Later in the interview CJ continued,

CJ: Yeah, we thought based on . . . [the SCIW] last March at your place, we felt pretty confident that the folks that were there from [the Prime] could make it happen. Just like [CA] said, you know, they were the six sigma guys . . .

Interviewer: Right.

CJ: And even though they were involved heavily with the program, it . . . once again it proved to us that you've got to have the buy-in from the program up front. So that was a lesson learned from us.

Interviewer: Right.

CJ: We had it on own end . . . our program manager was really into it because he was getting this from... [the Prime] and the [DOD] to get cost down...he was very supportive.

CA: But, you know, as aerospace change you got to have the program management involved in the bigger companies, because we . . .

CJ: We learn that consistently on everything that we do.

CA: Yeah.

CJ: Our strategic sourcing got off to a poor start because we didn't get the program managers involved. If you don't have the support of the program managers, it's not going to go.

Based on those interviewed, it appears the FTS had support from the Supplier Development Group at the Prime. As WC (Materials Planning Lead) reinforced, “And from [the Prime], SJ and those guys really wanted to see us go forward with [lean] and supported it, and, you know, I think we could have...if I personally called SJ up one day and said, SJ could you come out here next week, I’m really stuck on something...he probably would fly out on his own time and his own dime to come out and support us.” However, the FTS never had support from the program directors at the Prime. Without that support there was no chance of working together on supply chain issues.

The misalignment of management support was also discussed in interviews with an off-site facility of the FTS regarding the 2TA program¹⁹. The 2TA is sold to the same Prime as the MC program; however, it is sold to a different program office. When discussing the interactions between the off-site facility and the Prime the Director of Manufacturing Operations (HG) and the Program Manager (JC) had the following to say:

HG: I don't know about recently...but four or five years ago [the Prime] had a lean initiative where they had a training program...And [Bob] and I went over . . . Good course as far as looking at things, but what they wanted you do is...to go back

¹⁹ The 2TA program was not involved in the SCIW held in March 2001. A similar program (2TB) was the initial program under study. However, it was discovered during site visits in March 2002 that there was limited activity in the 2TB program and future sales was in doubt. As the site visits and interviews progressed with the off-site facility, several supply chain issues arose from the 2TA program. Those issues are presented in this study to compare/contrast with the MC program.

and implement this, even if . . . you don't have money . . . There's a hesitation, you know... Yeah, this particular initiative, the people that were running the programming [office] went over there and took a course from them, they weren't even associated with the program offices.

JC: No association . . .

Interviewer: Separate . . .

HG: They were completely separate. You went over there and if you would go back afterwards and then talk to the program people at [the Prime] what was reported back to me, that's . . . I've heard something going on, but that's a bunch of crap, don't worry about it. So they were . . . they had a complete segregation between this lean initiative that they were trying to start and their own program people so it was...

Interviewer: So when you guys followed . . . had to follow the program directive office.

JC: Oh, yeah, that's who you're dealing with on a day-to-day basis.

The previous two examples demonstrate what happens when an initiative does not have the proper alignment of support. The Prime's Supplier Development Group trained and verbally supported the off-site FTS facility's management on lean/six sigma; however, the program managers at the Prime did not support the initiative, at least outwardly, thus the initiative failed to proceed.

On the other hand, in discussing the support from the STS, CJ (Dir. of Materials) commented there was "no question" that they had the proper support from the STS's management. The support materialized in that the Lead Industrial Engineer and the Plant Manager at the STS participated in the SCIW and continued working with the FTS until the stop order was issued.

In line with Mentzer et al. (2001) and others, this study finds top management support is necessary to move toward SCM. More specifically, the interviews provide

support for the notion that initiatives need the proper level(s) of support from management. Internally at the FTS, both the plant manager and the program manager are needed to move forward on an initiative. Externally, the FTS needed the support of the Supplier Development Office at the Prime, as well as the program office to work on supply chain activities with the Prime. Fortunately they had the proper support from the STS.

Commitment versus Funding

Beyond just verbally supporting the lean and/or supply chain initiatives, commitment to the initiatives surfaced in each interview conducted. The theme that kept presenting itself was the notion of commitment versus funding. Each interviewee mentioned that the verbal commitment was there from management but when funding issues were discussed the interviewees' tone changed, as this exchange demonstrates with the management of the off-site FTS facility in discussing their lean initiatives:

JC: The management thinking has swung over now where you have a lot more acceptance in terms of doing these things and making the investment and trying to actually think differently and do things...because we all know that you've got to do it or you're just going to get left in the dust. I mean, the results are too significant and dramatic to ignore...so everybody's starting to get on board, so we're just now seeing...to me, we're starting to see this proliferation through the organization.

Interviewer: So is the funding there now to do these [lean/six sigma] initiatives?

JC: The commitment is there.

Interviewer: The commitment. Okay.

HG: There's always a difference between commitment and funding, I mean, you're not going to be successful until you are in the capital funding process and you're showing returns on your investment and are you going to break-even...

JC: You're not going to...there's not an earmarked budget within [the FTS] that says, a million dollars, lean implementation. There isn't that, but there is a commitment.

Regarding the MC program's lean initiative, WC noted, "I think the [Program Manager] on the MC Program definitely supports it and sees the benefit of lean and was supporting it the best he could...He was definitely willing to support it. As a matter of fact, he paid for our trip down to the [Prime]...I hear our plant manager saying the right things that they support it...I guess I am a little skeptical that they are going to be willing to pony up the money that [the lean initiative] is going to take to make it happen where...the people, really and the time."

Obviously, there is a difference between management's verbal commitment and having that commitment materialize. For the FTS, some funding for training and visioning trips was available from the Program Director. However, it is the plant manager that controls the funds for the larger initiatives and that is where WC feels skeptical the plant manager will release the requisite funds.

The commitment versus funding was also prevalent when discussing supply chain issues with CJ regarding the FTS's supplier development initiative²⁰. CJ mentions that upper management at the FTS has supported the initiative thus far, but added it also, "hasn't cost us a whole lot." He reiterated that they did set aside some money for the initiative, so he felt upper management thought it was value-added. When asked if he thought the FTS would fund a full supplier development group he responded:

CJ: I will be surprised if we're able to go in and do a full supplier development activity. That would surprise me if the company would do that. That's my own personal opinion.

Interviewer: Sure.

CJ: Because you look at a lot of the other primes out there, that's what they do. They go in and they do a quick . . . a quick hit. They'll go in and they'll do a kaizen.

CA: But they're still using quite a bit of outside consulting. It's not just all their own people.

CJ: Yeah, they don't go in and do a full development like we're doing on [our government funded initiative]. They generally don't do that. They go in and fix their product line, so to speak. [Our initiative] is supposed to help the enterprise, you know, the supplier's enterprise. You don't see . . . I don't see any primes going in and doing that.

Interviewer: In your business case...do you try to quantify the benefits of doing this?

CJ: Absolutely.

CA: And it's got implications for our development. I mean, you know, both sides. And the thing that's got to be critical though, we have to show a mechanism how this is going to work how the program management works, because of . . . in terms of funding. You know, maybe there is a way to get allocated funding from each program and say this is set aside for supply development.

CJ: I think that would be . . . that would probably be the best you could get. If you could go in and convince your program manager that if we can go in and work with supplier "A" on the line for your program, we think we can get you a return of such and such if you fund us this much money.

Interviewer: What's your feel on the program managers or directors on [supplier development]?

CJ: It depends . . . it depends what their motivation is. [The MC Program Manager] had a very strong motivation from [his program's final customer] so he was very supportive, plus it didn't cost him any . . .

²⁰ The supplier development initiative at the FTS was part of a DOD funded project on supplier development; however, the MC program was not part of the DOD funded supplier development project.

The discussion remained centered on the notion of funding. While there was some funding at the start of the supplier development initiative, CJ appears skeptical of future funding. He ends the dialogue that the MC Program manager was very supportive; however, it did not cost him anything. It's easy for management to commit to an initiative when their resources are not at stake.

As Spekman et al. (2001) define it, commitment is the willingness to devote time, energy, and/or resources. In examining each tier of the supply chain, different levels of commitment appear. On the positive side, all three tiers did spend resources to send representatives to attend and participate in the SCIW. The commitment appears to have dropped-off for the Prime once the SCIW was completed. Based on earlier comments from CJ, the FTS did attempt to get the Prime involved in the supply chain activities they were participating in with the STS; however, they were unable to get any involvement. The FTS and STS continued willing to spend resources for improvement initiatives.

With regard to supply chain activities, each site assigned individuals and set aside time to work on the value stream mapping and on travel between the two sites. When it came to internal improvement initiatives, the MC program director appeared willing to release funds, as FD stated, "I don't see any real barriers...because every piece...everything I ever wanted, even in constructing the whole area, I have never been turned down for money for everything I have put in for...I mean you might not get as much as you really wanted, but you'll continue to go and you'll get [some funds]."

Training/Visioning: Prelude to Execution

The one area where all three tiers appeared willing to spend significant resources was in training. In addition, the FTS spent additional funds sending representatives on visioning trips. The STS Industrial Engineering group's primary responsibility was training the workforce in lean principles. The Supplier Development Group conducts the training of lean at the Prime, while the lean group at the FTS is responsible for training its employees. The FTS's training group is similar in structure to the Prime's team. Remember, it was the supplier development team at the Prime that trained many of the MC Program's workforce at the FTS.

When PE was asked if the training had led to executing what was learned, he replied, "Beyond planning that, but there's some debate about the method of execution... And so there's some debate there. But in terms of the background, the training material, getting people up to speed, I think there's still a commitment on the part of [the FTS] to do this type of thing, but it's only interesting until you get to the execution, the actually putting it into place." A senior manager from the controller's office opined that eventually the training with no execution creates bad publicity and squashes other initiatives.

Transforming from training to execution is where the FTS finds itself. To help the progress toward the execution stage of lean and SCM, the FTS instituted visioning trips to the STS and the Prime. As PE observed, "The MC program director was willing to take the extra step to let his people get training, to let his people get visioning on it."

Regarding the visioning trips, WC continued, “I was really disappointed when we were down [at the Prime], because the way they explained it, being able to stand out on the floor, and the production manager stands out there and the lead stands out there, and they can close their eyes and just listen and know whether the program...or the production line is running correctly or not just by the drumbeat and the certain sound. So if it doesn’t sound just right, they know there is a problem somewhere. Or...they can look out there anywhere and see where the flag is...okay, it’s 10:15, the flag should be up there and there it is and everything is cool...That’s where we need to be. That’s where we should be on the MC program and hopefully all the programs could get there.”

PE feels the visioning trips are crucial in breaking the old mindset, “Now at [the Prime] we saw some things where they were breaking that paradigm. It used to be that way at [the Prime]. They were sent to break that paradigm where they had receiving docks right next to their stores. So seeing that...all of us, our eyes got big and started going we’d like to have that...We said, holly molly let’s get that here, and so by doing the [visioning trips] we are looking at making those changes.” And they are attempting to make those changes. The improvement initiative underway as of March 2002 at the FTS is introducing mixed model production²¹ in a division that includes the MC program. The mixed model activity is an internally funded activity aimed at improving its operations and is a visible sign of moving from training to executing what is learned.

Learning in this supply chain involved two components, classroom teaching and visioning trips. The focus of the training was on lean principles and related tools. The Prime was involved at the beginning in training many individuals at the FTS. The visioning trips to the Prime reinforced that training by demonstrating what is possible when the employees execute on their training. While the bulk of lean training concentrates on internal integration activities, the effectiveness of many of the lean techniques depend on how well the firm is integrated externally.

Lean/Supply Chain Management Link

According to the people interviewed the mixed model production initiative (see footnote 21) is recognized as an initiative that can link SCM and lean. This link goes back to the discussion on performance frontiers and the notion that the maximum performance capabilities of a supply chain (i.e., supply chain operating on or near its operating frontier) are a function of the individual firms comprising the supply chain. Lean is the internal betterment initiative aimed at positively shifting a firm's operating frontier, while SCM is seen as the external betterment initiative aimed at positively shifting the supply chain's operating frontier. In addition, the success of many of the internal lean activities is dependent on the success of the external SCM activities.

As CJ commented, "If there were things we could do smarter with [the STS] activity and the MC program, maybe they could apply some of that to the mixed model activity. And the tie-in from our standpoint from [supplier development] and

²¹ Mixed model production is the ability to make several products on the same line in a random or

working with the STS was BA, because BA is on the [supplier development team], he was the lead guy working with [the STS] and the supply management stuff, and he's also an integral part of the mixed model team." When asked if the mixed model initiative was going to happen CJ replied, "Oh yeah, no question about it, it's going to happen this year." He reinforced his comments by indicating the Vice-President of Operations told the plant manager that mixed model production was going to happen and that the FTS had already committed resources to the initiative. During the site visit, the MC program director also acknowledged his support for the mixed model initiative and was eager to see his program involved with it.

The link between SCM and lean was also discussed in the interview with the plant manager at the off-site facility of the FTS. He stated, "It starts with our customer. If we were going to make a change and have, like we started about, flow and pull across the supply chain, it definitely has to be a cooperative thing with [the Prime] and outside suppliers to think differently and to have, you know, kanbans that we're pulling...we just got to totally change all of that." In other words, the plant manager recognized that in order to succeed with its internal initiatives, involvement of suppliers is necessary.

Later in the interview he continued, "There [are] a lot of things that we need to do to bring us up current. I think we have a good foundation, but to bring us up to current ideas, and then reviews. I think we have gotten stagnant. We haven't sustained the [prior] initiatives. Right along with that I think that the biggest issues

sequence order.

that we have in the programs are the supply chain issues on it. Not that they are the only ones. We have the lean initiatives that we need to do here, but the real low hanging fruit out there is in the supply chain initiatives.”

PE, the manufacturing operations manager at the FTS also recognized the link between internal and external integration. When the MC Program Materials Lead was asked what he would like to see changed between them and the Prime he responded:

WC: No sources...

PE: That’s right.

WC: I mean...the source inspection really holds us up and it holds the [Prime] up. When you call for a source inspector, it may take a few days for them to get out of here and they may be here a couple of days and then you got the shipping time. You know, it could be two weeks before the point where you had a completed unit and the time you actually shipped.

PE: Right. If you clean that up, then you can work issues of how many and try to get it down to one or two and have shipping containers and stuff that work...that allow you to work the floor and have those kind of visual signals, okay. Right now, with all these roadblocks kind of in the way...

PE and WC appear to recognize that by working on supply chain issues like eliminating source inspections, they can begin realizing the benefits with their shop-floor lean initiatives. In addition the off-site FTS plant manager understands that to reap the full benefits with an internal initiative, like lean, the involvement of the key suppliers and customers are necessary. The mixed model production initiative, as well as instituting pull, requires close coordination across the supply chain. It is one thing to understand the need to include supply chain members, and quite another to execute on that understanding. The proper motivation must be present across the supply chain.

Motivation to Engage in SCM

The STS was motivated in working with the FTS through the possibility of getting increased business. In March 2001, the STS was only supplying a small component on the MC Program. As the two tiers worked together in increasing the efficiencies between them, the STS was increasing its share of work on the MC Program. As CJ stated, "...you guys are going to supply us a [full component]...period...and that is not going to be going back and forth. It's going to be totally your responsibility." In addition, the STS was considered on another program of the FTS. Unfortunately that program could not find work for the STS but there were discussions between the two to find work for the STS. The potential for additional business was the motivating factor in working with the FTS.

The plant manager at FTS's off-site facility echoed similar sentiments, "For [us], status and business. We become lean...we can go out and compete with lower costs. We can bring more business into here, which again...it's the opposite of downsizing...so I'm looking at it from [our] standpoint as being competitive and bring in more business down here."

It appears the motivating factor for the Prime to engage was cost reduction. The Supplier Development Group at the Prime works with suppliers with the goal of decreasing costs to the Prime.

A closer look at the 2TA program sheds some light on lack of proper motivation. During 2001 the FTS missed their delivery date for the first time in that program's history. One of the causes of the missed delivery relates to the fact that the

suppliers can no longer depend on the FTS as a steady stream of income. The component [Y₂²²] needed from a supplier has had manufacturing complications since the inception of the 2TA program three years ago; however, the FTS always met its delivery dates. This past year, that did not happen. A major factor was the reduction in volume as discussed in the interviews:

HJ: But right now we're in a serious hold. You know, we're losing a ton of money because of supply chain problems. Our Y₂ supplier is to being able to produce the compliant...

Interviewer: How significant is this to this supplier supplying this . . .

JC: I don't know. I really don't know. I need to find that out. They could not make a living off it, just doing [Y₂] because it's sporadic. I mean it's not anything they can count on.

HG: And the problem that we have . . . is actually what we've got is what I call a ten-percenter. This guy . . . we contracted with a guy that says he's with 'A' company, but what he's actually doing is going in utilizing the machines from here and tooling and . . .

JC: He subcontracts the work.

HG: He subcontracts the work out. So for him, maybe, it's a major part of his income, but for the subcontractor job, it's small, so it's a complex system to try and work around. And the material . . . or the equipment, the process is not robust enough for him to just start somewhere and go. He has to keep going back to these facilities and tweak it here and tweak it there.

Later in the interview HG elaborated:

HG: And the bottom line, too, and we're still struggling with this, you went from . . . and this is part of the supply chain management, it's a real challenge. We went from significant programs; year long large buys, to very small. So you're going to vendors now on a lot of your outside subcontractors who weren't totally focused on defense work. They had a mixture of defense and commercial. All of a sudden with the cuts in defense budget, they had to refocus on commercial. So now you walk into

²² To protect confidentiality of the program the component discussed is labeled Y₂ for this study. This component is a primary component in the 2TA Program.

somebody where you used to say, you know, I need 30,000 parts over this year and your major factor is income, and now you're very small and you're still trying to get the same kind of service out of them. And you just . . . they just tell you they're not interested in your kind of business anymore.

The lack of proper motivation exists throughout the 2TA Program history, beginning with the Y₂ supplier. JC, the program manager, specifically mentions his program's production is sporadic, thus it is nothing the suppliers can count on as a constant revenue source. The plant manager notes with the downward spiral of defense spending the suppliers are now more involved in commercial business, so the FTS is just not a significant customer in their eyes. When the plant manager was asked what he needed to have a successful, competitive supply chain he responded, "Velocity; it's all about velocity...and quality. To be able to respond to these demands, these smaller, spiky demands and be able to respond quickly is what we need to do to transition into the next level, give the suppliers a choice."

In summary, the FTS and STS earnestly worked on integrating externally, beginning with the SCIW and lasting until the stop order was issued on the MC Program. The Prime chose not to participate in those activities but was pressuring the Program Director at the FTS to reduce costs. The interviews conducted one year after the SCIW identified six pertinent areas that need addressing, 1) proper alignment of management support, 2) funding of verbal commitment, 3) proper motivation of initiative, 4) training on executing initiative, 5) visioning on successful initiatives, and 6) linkage between internal/external integration. The next section discusses each area within the theoretical model of SCM.

V. DISCUSSION

Mentzer et al. (2001) state that true SCM can only occur when three or more contiguous companies are working together to improve the supply chain. In March 2001 three contiguous companies within the MC Program began working together (i.e., SCIW) with the goal of improving their supply chain. Even though representatives from all three companies in the supply chain participated in the workshop, it did not necessarily mean all three companies would continue to work together on supply chain issues.

While the attempt to manage the supply chain started in March 2001, SCM never materialized over the next year. However, investigating the activities of the MC Program's supply chain over the past year helps identify the impediments companies must overcome, as well as the facilitators they should take advantage of, as they move toward managing their supply chain. This section discusses the implications of this study's findings within a theoretical model. In addition, the limitations of this study are presented and future research is detailed.

In addressing the research question for this study six constructs arose, 1) proper alignment of management support, 2) funding of verbal commitment, 3) proper motivation, 4) training, 5) visioning, and 6) internal/external integration linkage. The lack of one or more of the first three constructs within a company is considered an impediment in moving a firm toward SCM while training and visioning are seen as facilitators in moving a firm toward SCM. The sixth construct is the linkage between internal integration and external integration. Figure 14 incorporates those constructs

within the strategic model of SCM Antecedents and Consequences presented by Mentzer et al. (2001) in Figure 4 to show how a company progresses to SCM. Before discussing the model of SCM, how an individual company progresses to SCM, shown in Figure 14, is detailed.

SCO and its Antecedents

As defined in the literature review section, an SCO is, “the recognition by a company of the systemic, strategic implications of the activities and processes involved in managing the various flows in a supply chain (Mentzer et al. 2001).” SCO is the philosophical underpinning of SCM (Mentzer et al. 2001). It is a state of mind. This state of mind develops as the management of a company begins to understand the nature of SCM. That understanding develops as management willingly addresses the eight antecedents identified in Figure 4.

While this study does not provide explicit support of an SCO and the related antecedents, the participation of the different companies at the SCIW does provide some credence to the notion of SCO. The mere fact that representatives from three tiers in the MC Program supply chain participated in the SCIW could lead one to believe the management of each tier had an SCO. However, an SCO cannot be stated to exist by the mere presence at a workshop discussing SCM. An SCO must manifest itself into actionable items between tiers in a supply chain.

Two of the three companies (FTS and STS) that participated in the SCIW immediately began working together on supply chain activities. Those activities provide some support that the management of those companies understood the

systemic strategic nature of managing their supply chain (i.e., had an SCO). However, does the lack of activities between tiers aimed at managing the supply chain translate into the management of a company not having an SCO? Not necessarily. If SCO is the philosophical underpinning of SCM, then a company could have an SCO and yet not progress to SCM. There could be impediments blocking the transformation of an SCO to SCM. This study identified three such impediments. In addition, the study found two facilitators in moving a company from an SCO to SCM. The impediments and facilitators, discussed next, are grouped together in this study as SCM execution antecedents.

SCM Execution Antecedents

This study identified five SCM execution antecedents 1) alignment of management support, 2) funding of verbal commitment, 3) training, 4) visioning, and 5) proper motivation. The first two offer a deeper look at two of the common antecedents for any long-term initiative. The proper alignment of management support is necessary to sustain any initiative (e.g., lean and SCM). The lack of that alignment can impede a company in moving toward SCM.

For the MC Program, the support of both the plant manager and the program manager at the FTS were necessary to move forward on the lean initiatives. The program manager's support is necessary since that person is responsible for the budgetary process. His/Her support alone can provide short-term resources necessary to begin an initiative; however, the plant manager's support is necessary for the initiative to have the long-term support.

As the FTS attempted to work with the STS and the Prime on supply chain activities the necessity for the alignment of management support also became apparent. Those activities were successful, in part, due to the alignment of support at both the FTS and STS. As with its lean initiative, the FTS had the support of both the plant and program managers to work with the STS. Similarly, the STS had the support of the company's plant manager and industrial engineer manager. Achieving the correct alignment of management support across firms provides opportunities to work together for the benefit of the entire supply chain. Obtaining that alignment is not an easy task.

In working with suppliers and getting their support, CJ stated they found, "it probably took three management briefings with a supplier before you ever began an assessment. Usually you talked to a point of contact and generally tell them what the program was about. Then you would go in and talk to a couple of senior leadership folks and then you would get them to convince the leader of the company, we think we want to do this...And then you get them all together. We found that it usually takes about three briefings before you can really get in there and do that. And each briefing has more and more data involved with it, including what we are doing with other suppliers." The FTS understood the importance of having the appropriate levels of management support.

The alignment of management support was not present at the Prime. The manager of the Supplier Development Group supported the idea of working with the FTS; however, there was a lack of programmatic support. That lack of programmatic

support impeded the Prime from engaging in any supply chain activities identified during the SCIW.

The support of management must materialize into funding for the initiatives. Several interviewees mentioned the notion of commitment versus funding, the second SCM execution antecedent. The fact is there is no commitment without funding. While almost every person interviewed agreed they had a verbal commitment from upper management, many expressed doubt as to whether the initiatives (lean/SCM) would be funded in the future, although the IPT Lead on the MC Program did comment that they “had the money” for their lean initiative. In addition, the FTS and STS did commit some resources toward working together on supply chain issues, while no such funding materialized with the Prime. The result was the FTS and STS worked together without the Prime’s involvement.

Presenting a sound business case was the one method CJ stated was needed to help ensure future funding. He, along with the plant manager at the off-site facility, both mentioned the need to present a case that shows management an adequate return on investment. As with most funding requests management must be shown the rewards of its investments.

The third impediment identified in this study is lack of proper motivation. The motivation for the Prime to become involved in SCM was receiving a decrease in the cost of the components supplied by the FTS. The FTS’s motivation to engage in SCM was the potential for growth opportunities with the Prime. Looking upstream, the FTS engaged the STS with the idea of the FTS receiving a cost reduction in the

components the STS delivered. In the same vein, the STS was willing to participate with the potential for increases in business from the FTS and the Prime.

It appears there are two motivating factors at work, cost reduction and growth. Firms looking upstream at their suppliers expect price concessions, while firms looking downstream must see the potential for growth. Each tier is expecting cost reductions from its suppliers. In addition, each tier wants to transform those cost reductions into increased business from its customers. This observation refutes Spekman et al. (2001, 23) that state, “When one utilizes performance metrics that focus on cost (and/or time reduction), there might be little incentive to work closely to achieve other goals.” The results of the study identify both cost and growth as motivating factors for engaging in SCM.

There were two facilitators identified in this study and listed as SCM execution antecedents, training and visioning. Both of them can be seen as preludes to executing on an initiative. All three tiers recognized the necessity of training individuals so that everyone agrees on the objectives. The IPT Lead says as much when talking about the MC Program’s lean initiative, “Basically it’s been an evolution from day one of the program. And the more concepts we’ve learned and techniques from...basically from doing it ourselves to actually getting the education and applying those things...we’ve actually starting to come around...I think people are always leery of it until they understand and get more understanding.”

Training was the one area where the Prime was involved with the FTS. It was the Prime’s Supplier Development Group that trained the FTS on increasing its

operations. This common training across tiers in the supply chain can facilitate tiers working together because everyone agrees conceptually.

In addition to training, the visioning trips held by the FTS allowed their people to see how efficient sites can operate. Visioning trips were held at the STS's and the Prime's locations. As PE implied, the purpose of the visioning trips was to show the individuals how the traditional batch production paradigm was being broken. The training and the visioning allowed the individuals to see what needs to be done for their program to succeed. The appropriate training and vision allows individuals to understand how to improve and what can be achieved. The combination of training and visioning can lead to everyone working together internally and externally on a common goal.

According to Figure 14, the progression towards SCM begins when the management of a company is willing to address the antecedents identified by Mentzer et al. (2001) and develops an SCO. That SCO materializes to external integration activities when the SCM execution antecedents are present. The other part of the model states that SCM depends on the internal efficiencies of the company (i.e., level of internal integration).

Internal Integration/External Integration Reinforcing Loops

Throughout the interviews there was a constant melding of lean and SCM (i.e., internal integration activity and external integration activity). The interviewees saw both as extensions of the other. This internal/external integration linkage reinforces the theory of production frontiers discussed in the literature review section. The

activities undertaken by the FTS and STS following the SCIW demonstrate this linkage. For example, conducting a process flow chart between the two sites highlighted the necessity of increasing the efficiencies internally to take advantage of trying to integrate externally. Also, the plant manager at the off-site FTS stated the success of their lean initiatives depended on the cooperation of their suppliers. The shop-floor individuals at the FTS understood that if source inspections were eliminated by the Prime, the FTS could increase the efficiencies of its operations and thus increase its performance to the Prime. Lastly, the training conducted across the tiers was mostly concerned with lean principles. However, the lean principles the tiers apply internally allow them to better integrate externally.

These examples seem to suggest the mutual dependency between external integration issues (i.e., SCM) and internal integration issues (i.e., lean). In other words, using the theory of production frontiers as a foundation, the maximum performance capabilities of an individual firm are a function of the maximum performance capabilities of its direct supply chain partners. Additionally, the maximum performance capabilities of a supply chain are a function of the maximum performance capabilities of the individual firms comprising the supply chain. As opposed to Stevens (1989) four integration stages of SCM (shown in Table 1) being step functions, maybe Stage 3 (internal integration) and Stage 4 (external integration) consist of reinforcing loops. Accordingly, to succeed in SCM requires firms to be successful with their internal initiatives (e.g., lean). Similarly, for a firm to succeed

with its internal initiatives requires success in integrating with its direct supply chain members (e.g. SCM).

Going back to Figures 2 and 3 for illustrative purposes, if the FTS is operating off its operating frontier and the STS and the Prime are operating on or near their operating frontiers, then the maximum performance capabilities of the supply chain are defined by the FTS. The operating inefficiencies at the FTS are preventing the supply chain from operating on or near its operating frontier. As the FTS successfully implements internal integration tools and techniques (e.g., lean), the benefits go to the firm and the supply chain as a whole. In other words, the firm moves closer to its operating frontier, while simultaneously, the supply chain moves closer to operating on its operating frontier.

That logic also applies when examining the effect of external integration activities on internal integration. For example, assume the Prime institutes electronic kanban signals upstream to the FTS. In addition, the Prime requires more frequent JIT deliveries from the FTS. These new requirements are instituted to improve the external integration between the Prime and FTS. The FTS, with its traditional batch-operating mode, must institute new internal integration tools and techniques to successfully implement the JIT deliveries and kanban signals (e.g., reducing setup times, converting to mixed model production). Again, the supply chain and the FTS shift up and move closer to operating on or near their respective operating frontiers.

Figure 15 displays the Model of SCM based on the study's findings and Mentzer et al. (2001). According to the model, SCM occurs when at least three

contiguous companies have progressed to external integration. To successfully manage a supply chain those companies should be externally integrated and operating on or near their operating frontier such that the supply chain is operating on or near its operating frontier²³. Technically, SCM only occurs when three or more contiguous companies are externally integrated. The path to external integration for each company is conceptually the same, as shown in Figure 14.

To create a competitive advantage, the supply chain's operating frontier must be higher than its competitors supply chains' operating frontiers. Maintaining that competitive advantage requires the companies to continually integrate both internally and externally in order to push the supply chain operating frontier closer to its asset frontier. Once its operating frontier shifts to its asset frontier, the supply chain will require additional assets to continue the upward mobility. What keeps feeding the continual increase in performance is the reinforcing nature between internal and external integration.

Future Research

The goal of the current study was to further refine the theory of SCM. Figures 14 and 15 are the end products of this study. They extend the model proposed by

²³ System theorists may argue this point. The essence of systems theory is that the whole is more than the sum of its parts (Bertalanffy 1968, Kramer and Smit 1977). Sub-optimization of a sub-system for the benefit of the whole system (i.e., making trade-offs) is a common theme in systems theory. In other words, one tier of a supply chain may sub-optimize their operations (i.e., operate off its operating frontier) in order to optimize the supply chain (i.e., supply chain operating on or near the supply chain operating frontier), provided they were compensated. Bertalanffy (1968, 55) states that an element has two characteristics, summative and constitutive. The constitutive characteristics are "those which are independent of the specific relations within the complex; for understanding such characteristics we therefore must know, not only the parts, but also the relations." He continues, "If, however, if we know the total of parts contained in the system and the relations between them, the behavior of the system

Mentzer et al. (2001) by adding the SCM execution antecedents and the internal/external integration reinforcing loops. The next logical step is studying an actual supply chain to provide additional support for, or modifications to, the model presented. While this study began with that goal, changes in the environment prevented the study of an actual supply chain, as discussed in the limitation section.

Two different phenomena might be present upon a closer examination of SCM. The first phenomenon is the progression to SCM. Incorporating Stevens (1989), Spekman et al. (1998) and Mentzer et al. (2001) with the results of this study suggest a firm proceeds to SCM by first developing an SCO. Once an SCO is developed, the firm must have the SCM execution antecedents present before moving to external integration. Operationally, the firm must progress from internal integration (Stage 3) to external integration (Stage 4). As such, the firm develops more collaborative relationships with its trading partners. SCM is said to occur once three contiguous firms accomplish these tasks. This first phenomenon is a process type model. Each step is necessary but not sufficient.

The second phenomenon is the success of SCM. The success of SCM is dependent upon the level of internal integration and the level of the SCM execution antecedents present within each supply chain firm. This phenomenon is the more familiar variance type model. Each component is necessary and sufficient to affect the success of SCM.

may be derived from the behavior of the parts. Examining SCM within the systems theory framework would be a valid future research endeavor.

Both phenomena are valid research areas as both provide relevant information to academicians and practitioners interested in SCM. The first phenomenon provides the steps necessary in order for firms to move toward SCM. If SCM is the next competitive advantage, then understanding how to get to SCM is vital. Research in the second phenomenon allows one to understand the key leverage points in successfully implementing SCM, as well as, defining how to measure its success.

Large-sample testing of the model is also needed. Structural Equation Modeling appears an appropriate method for testing the proposed theoretical model. Empirical testing of the effect SCM has on firm and supply chain performance is also warranted. Lastly, analytically investigating the role between SCM and the theory of performance frontiers would be beneficial. The objective of the analytical investigation would be to incorporate the microeconomic foundation of the theory of performance frontiers within the parameters of SCM. Identifying and understanding the assumptions that make the analytical model tractable would be of the utmost importance. Beamon (1998) provides a focused literature review on various models and methods used in investigating supply chains.

The research question for this study sought to investigate the facilitators and impediments for firms moving from co-operation to collaboration within a supply chain. That question involved examining the relationships between the supply chain firms and how they communicated among themselves. Due to the change in the supply chain environment, the study's aim shifted to examining the operational side of firms. The study investigated how supply chain firms worked together to improve

their operations as they moved toward SCM. In other words, the relationship dynamics of SCM were not investigated and remain an important area for future research. Again, using the supply chain as the unit of analysis would be important contribution to this stream of research.

If SCM is the next competitive advantage, future research must begin to unlock the complexity of SCM, with its multiple actors and processes. Empirical studies are necessary to move SCM from theory generation to theory testing. This study used qualitative techniques to help refine the theory of SCM and develop a model ready for empirical testing (i.e., Figure 14). As with every study, this study was not without limitations as the next section discusses.

Limitations

Qualitatively investigating an actual supply chain and how the firms managed that supply chain was the original intent of this study. According to Mentzer et al.'s (2001) definition of SCM a study requires examining at least three contiguous companies, and at the start of the study three contiguous companies were involved in the study. Individuals from the STS, FTS and the Prime participated in the SCIW. Shortly after the workshop, any potential for managing the supply chain was lost as the Prime backed away. The STS and FTS did work together on supply chain issues until a stop order was issued for the MC Program. One year later, the original supply chain no longer existed and some of the participants at the SCIW were no longer associated with the companies.

These conditions severely limited studying the SCM phenomenon. What did present itself was the opportunity to understand why the FTS and the STS worked together on supply chain activities and why the Prime did not participate, using Mentzer et al.'s (2001) model of SCM as the foundation to the study. However, this new angle was studied using the FTS as the focal firm and very limited information beyond the SCIW was obtainable from the STS and the Prime. As a matter of fact, only one person outside the FTS was interviewed²⁴. While the study did provide some refinement to the theory of SCM, the results would have been more powerful and informative had all three firms participated in the interviewing process.

The above limitations underscore the lack of control a field researcher has over the environment. On the other hand, the uncontrolled environment is what gives field researchers the opportunity to understand how theory plays out in a real setting. The key for the field researcher is being able to adapt the study to changes in the environment.

Trustworthiness in Qualitative Research

Lincoln and Guba (1985) present a set of criteria for assessing the rigor and trustworthiness of a qualitative study. They argue the traditional validity and reliability criteria of quantitative studies are inappropriate for qualitative research. They identify credibility, transferability, dependability and confirmability as the appropriate criteria for evaluating the trustworthiness of a qualitative study.

²⁴ The researcher made numerous attempts to interview individuals at the STS and the Prime with no success.

Credibility refers to the extent the study's results appear as adequate representations of the construction of the reality studied. Lincoln and Guba identify several techniques (prolonged engagement, persistent observation, peer debriefing, negative case analysis, referential adequacy, and member checking) available to enhance credibility. This study used prolonged engagement and member checks to enhance the credibility of the study.

Prolonged engagement is the “investment of sufficient time to achieve certain purposes (Lincoln and Guba 1985, 301).” The researcher spent a year investigating the dynamics of the supply chain under study. This prolonged time allowed the researcher the ability to examine how and why the supply chain changed. This time period also allowed the researcher to understand the operations of the individual sites involved.

The second technique used by the researcher was member checks. Member checks consist of receiving feedback about the researchers' data and conclusions from the individuals interviewed (Lincoln and Guba 1985). Maxwell (1996, 94) states that member checks is the “single most important way of ruling out the possibility of misinterpretation of the meaning of what they say and the perspective they have on what is going on.” The researcher solicited three interviewees to read the Results and Discussion sections, after which they were asked to answer the following questions:

- 1) Have I correctly interpreted the interviews conducted at your facility? If no, what exactly have I misinterpreted?
- 2) Are there incomplete depictions of what you had intended to convey in the interview? If yes, please comment.

The three individuals selected were the three individuals that were intimately involved with the supply chain from the start of the research project and were the most qualified to reply. Each individual agreed with the researcher's interpretations and none of the individuals selected had any clarifications to add to the researcher's findings.

Transferability refers to the extent the findings of a study have applicability in other contexts or with other subjects (Lincoln and Guba 1985). The authors state that transferability is an empirical issue, and it is the researcher's responsibility to provide the "thick" description that makes transferability judgments possible on the part of potential appliers. The most appropriate method for ensuring transferability is conducting the fieldwork in various settings and contexts (i.e., purposeful sampling).

While this study did not use purposeful sampling, effort was made to provide "thick" descriptions of the supply chain under study so as to provide "a full and revealing picture of what is going on (Maxwell 1996, 95)." Maxwell states that verbatim transcripts of interview data are necessary to accomplish that objective. Each audio taped interview for this study was transcribed verbatim.

Dependability relates to the consistency or stability of the results (Lincoln and Guba 1985). One method used to support the dependability of the results is the overlap method (Guba 1981). This method is a type of triangulation where different methods are used in tandem. Originally, the researcher planned to use the LESA and the interviews as a form of triangulation with regard to the operational activities conducted within and between the companies. The change in the study's focus prevented this type of triangulation.

Another method examining the dependability of the process is having an audit trail for others to follow to ensure the procedures used “fall within generally accepted practice” of qualitative research (Guba 1981, 87). The Methodology section details the procedures the researcher followed throughout this study and allows others to audit the research process.

The last criteria Lincoln and Guba (1985) discuss is confirmability—the extent the study’s findings are a product of the phenomenon and not the researcher’s bias. The authors suggest the use of a confirmability audit and keeping a reflexive journal as the two major techniques for establishing confirmability. Time constraints prevent the application of those techniques in many studies.

Confirmability was addressed in this study via the three-stage protocol used during the data analysis phase of the study. While listening to the interview tapes, the researcher took notes of important themes and categories. The researcher then read the verbatim transcripts for support or refutation of the themes and categories developed while listening to the tapes. Any additional themes or categories were also noted. The third process of coding the verbatim transcripts provided further support or refinement of the original themes and categories. This incremental approach towards analyzing the data mitigated the introduction of the researcher’s bias via the constant reflection of the original themes and categories discovered.

VII. CONCLUSIONS

While the supply chain under study was not conducting true SCM, investigating what was happening in the supply chain has provided some clarification to the theory of SCM as presented by Mentzer et al. (2001). In moving toward SCM, this study identified six issues that the individual firms in a supply chain must address; 1) proper alignment of management support, 2) funding of verbal commitment, 3) proper motivation, 4) training, 5) visioning, and 6) internal/external integration linkage.

Further research is needed to replicate and refine the above findings. Additional longitudinal, qualitative research at a true supply chain level is still desirable. However, this research has highlighted the difficulties in that type of research (i.e., lack of continuity of contacts and activity over time). The level of knowledge attainable with qualitative supply chain research far outweighs the level of difficulty of the research.

The importance of SCM should not be underestimated. As a senior engineering specialist at the Prime commented, “we are doing ok with understanding lean internally and moving it to the first-tier suppliers; however, the problems [affecting us] are at the sub tiers.” SCM affects every discipline from marketing to accounting. For example, it was important enough to the managerial accounting discipline that the Institute of Management Accountants (IMA) issued two Statements on Management Accounting (SMA) in 1999 dealing with SCM issues (SMA 4II and 4JJ). As the authors of SMA 4II commented, “Supply chain management is not just

the wave of the future. It is a tsunami that will engulf everything in its path...For financial professionals and others working in the field, the issue is not so much whether to become expert in the art and science of supply chain management but rather, how fast (47).”

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APPENDICES

Appendix A—Tables

Table 1: Integration Stages of Supply Chain Management	
Stage	Definitions
Stage 1: Independent Operation of each Function	• Business functions such as sales, manufacturing, planning, material control, and purchasing are operated on an almost separate basis. • This stage is characterized by organizational boundaries, whereby purchasing might control the incoming material flow or raw material stocks, manufacturing and production control then cover raw material through the processes which convert it into finished goods, and further along the chain, sales and distribution divide the responsibility for outbound supply chain and inventories.
Stage 2: Functional Integration	• Limited integration between functions such as shipping and inventory or purchasing and raw material management is accomplished. • This stage is characterized by emphasis on cost reduction rather than performance improvement; discrete business functions, each of which is buffered by inventory; elements of internal trade-off between, for example, purchase discount and the level of inventory investment; high plant-utilization and batch sizing; and reactive customer service.
Stage 3: Internal Integration	• All internal functions from raw material management through production, shipping, and sales are connected and integrated real-time. • This stage is characterized by full systems-visibility from distribution through to purchasing medium-term planning; a focus on tactical rather than strategic issues; an emphasis on efficiency rather than effectiveness; and reaction to customer demand rather than managing the customer.
Stage 4: External Integration	• Full supply chain integration extending the scope of integration outside the company encompassing suppliers and customers is accomplished. • This stage is characterized by the supply of high quality products shipped direct to the line on time; completely shared information on products, processes, and specification changes; technology exchange and design support; a focus on strategic rather than tactical issues; and above all long-term commitment, which usually means the elimination of multiple sourcing.
Source: Graham C. Stevens (1989), "Integrating the Supply Chain," <i>International Journal of Physical Distribution and Materials Management</i> , Vol. 19, No. 8, p 3-8. As compiled by Narasimhan and Kim (2001), "Information System Utilization Strategy for Supply Chain Integration," <i>Journal of Business Logistics</i> , Vol. 22, No. 2, p 61.	

Table 2: Definitions of Supply Chain Management		
Authors	Definition	Category²⁵
Tan et al., 1998	SCM encompasses materials/supply management from the supply of basic raw materials to final product (and possibly recycling and re-use). SCM focuses on how firms utilize their suppliers' processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimization and efficiency.	MP
Berry et al., 1994	SCM aims at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to a particular OEM so as to release management resources for developing meaningful, long-term relationship.	MP
Saunders 1995	External chain is the total chain of exchange from original source of raw material, through the various firms involved in extracting and processing raw materials, manufacturing, assembling, distributing and retailing to ultimate end customers.	SMP
Ellram 1991	A network of firms interacting to deliver product or services to the end customer, linking flows from raw material supply to final delivery.	IMP
Christopher 1992	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 consumer.	SMP
Lee and Billington 1992	Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers.	SMP
Kopczak 1997	The set of entities, including suppliers, logistics service providers, manufacturers, distributors and resellers, through which materials, products and information flow.	SMP
Lee and Ng 1997	A network of entities that starts with the suppliers' supplier and ends with the customers' customer involved in the production and delivery of goods and services.	IMP
(Source: Croom et al. 2000)		

²⁵ Management philosophy (MP); Implementation of management philosophy (IMP); Set of management processes (SMP)

Table 2: Continued.		
Authors	Definition	Category²⁶
Monczka et al., 1998	SCM requires traditionally separate materials functions to report to an executive responsible for coordinating the entire materials process, and also requires joint relationships with suppliers across multiple tiers. SCM is a concept, “whose primary objective is to integrate and manage the sourcing, flow and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers.”	IMP
LaLonde and Masters 1994	Supply chain strategy includes: “...two or more firms in a supply chain entering into a long-term agreement; ...the development of trust and commitment to the relationship; ...the integration of logistics activities involving the sharing of demand and sales data; ...the potential for a shift in the locus of control of the logistics process.”	MP
Stevens 1989	The objective of managing the supply chain is to synchronize the requirements of the customer with the flow of materials from suppliers in order to effect a balance between what are often seen as conflicting goals of high customer service, low inventory management, and low unit cost.	IMP
Houlihan 1988	Differences between supply chain management and classical materials and manufacturing control: “1) The supply chain is viewed as a single process. Responsibility for the various segments in the chain is not fragmented and relegated to functional areas such as manufacturing, purchasing, distribution, and sales. 2) SCM calls for and in the end depends on strategic decision making. “Supply” is a shared objective of practically every function in the chain and is of particular strategic significance because of its impact on overall costs and market share. 3) SCM calls for a different perspective on inventories, which are used as a balancing mechanism of last, not first, resort. 4) A new approach to systems is required—integration rather than interfacing.”	SMP
Jones and Riley 1985	SCM deals with the total flow of materials from suppliers through end users.	SMP
Cooper et al., 1997	SCM is “...an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user.”	MP
Above cites from Mentzer et al. 2001.		
Metz 1998	SMC is a process-oriented, integrated approach to procuring, producing, and delivering products and services to customers.	SMP
Spekman, et al., 1998	SCM is “...a process for designing, developing, optimizing, and managing the internal and external components of the supply system, including material supply, transforming materials and distributing finished products or services to customers, that is consistent with overall objectives and strategy.”	SMP
Christopher 1998 (in Skjoett-Larsen 1999)	SCM is “the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole.”	IMP

²⁶ Management philosophy (MP); Implementation of management philosophy (IMP); Set of management processes (SMP)

Table 3: Individuals Interviewed	
Identifier	Title
PE	Manufacturing Operations Manager, Lean Trainer, FTS
CJ	Director of Material, FTS; Lead on Supplier Development Initiative
CA	Supplier Development Manager, FTS
HJ	Senior Manager of Business Operations, FTS
FD	MC Program IPT Lead, FTS
SD	MC Program Operator (TTA), FTS
WC	MC Program Materials Manager Lead, FTS
AT	MC Program Manager, FTS
BA	Supplier Development Team Member, FTS
HG	Director Manufacturing Operations, Off-site FTS
JC	Off-site Program Manager, Off-site FTS
JH	Product Development Lead, FTS
SJ	Lean/Six Sigma Trainer, Supplier Development Lead, Prime

Table 4: STS Production Lean Infusion Score	
Lean Production Elements	LIS
1. 5S	0.037
2. Total Productive Maintenance	-
3. Set-up Reduction	0.035
4. Standard Work	0.030
5. Method Sheets	-
6. Quality Assurance	0.017
7. Mistake-Proofing	0.014
8. Production to a Takt Time	0.004
9. Formulation of Flow Cells	0.056
10. Visual Controls	0.031
11. One Piece Flow	0.019
12. Mixed Model Production	0.050
13. Point-of-Use Storage	0.023
14. Pull Production Scheduling	0.069
15. Design for Manufacturing	0.042
16. Complexity Reduction	0.008
17. Lean "Kaizen" Events	0.031
18. Ergonomic Design	-
19. Cross-Trained Workforce	0.029
Total-Lean Production	0.494

Table 5: Itinerary for the Supply Chain Integration Workshop	
Event	Purpose
Supply Chain Simulation	To get participants thinking about how each firm's actions affect the entire supply chain. This is a variant of the MIT Beer Game.
Presentation of the LESA results	To inform each firm where they stand with regard to the extent of internal and external integration.
Break-out Sessions between dyads	To allow participants to develop action items for improving the internal integration and external integration between firms.
Reporting actions items agreed to from the break-out sessions	To provide visibility of where the supply chain is today, and what action items are necessary to improve the efficiency of the supply chain.

Table 6: Action Items from SCIW		
Internal Action Items		
STS	FTS	Prime
Process flow chart	Streamline purchase order process	Check delivery rates
Review product quality records	Verify the degree of product development with Prime	How do we reduce lead-time?
Supply Chain Action Items		
STS	FTS	Prime
Site visits with FTS and Prime	Process map/flow with STS and Prime	Reusable containers at kanban signal?
Possibility of managing sub-tier suppliers?	Certify STS	Identify communication issues.

Appendix B—Figures

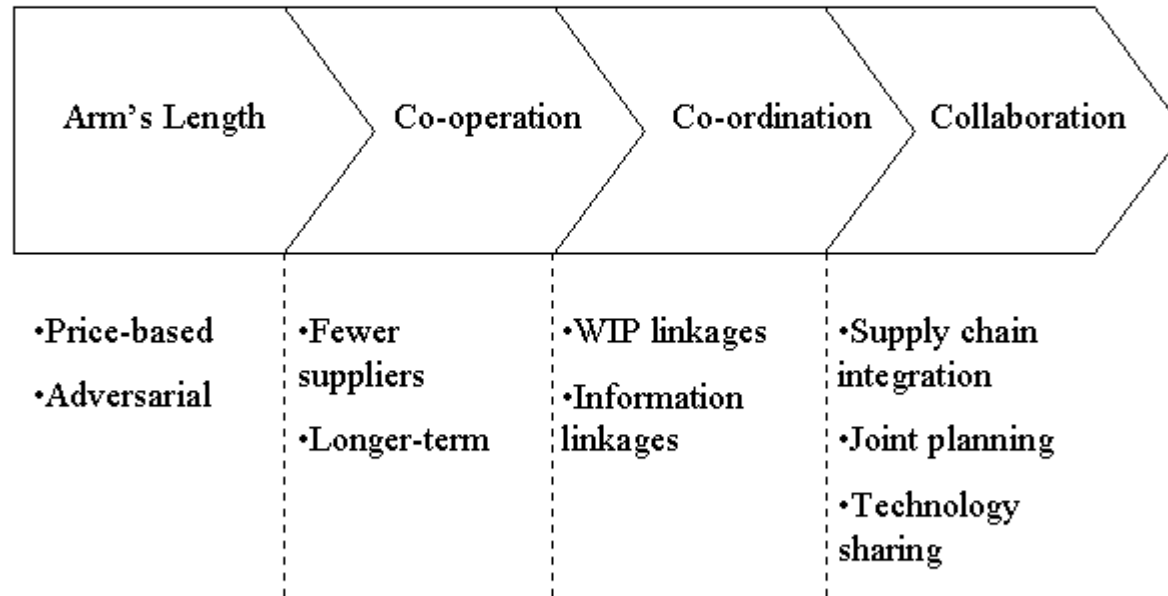


Figure 1: Transition from Open-Market Negotiations to Collaboration
(Source: Spekman et al. 1998)

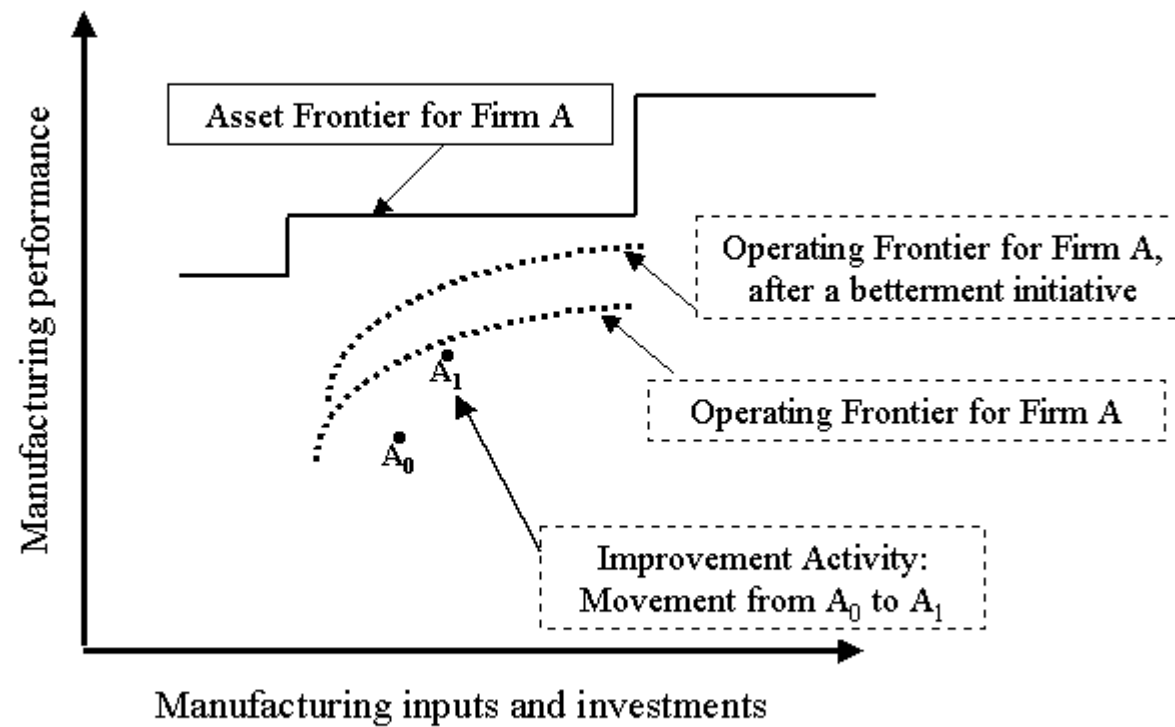


Figure 2: Asset and Operating Frontiers for a Firm

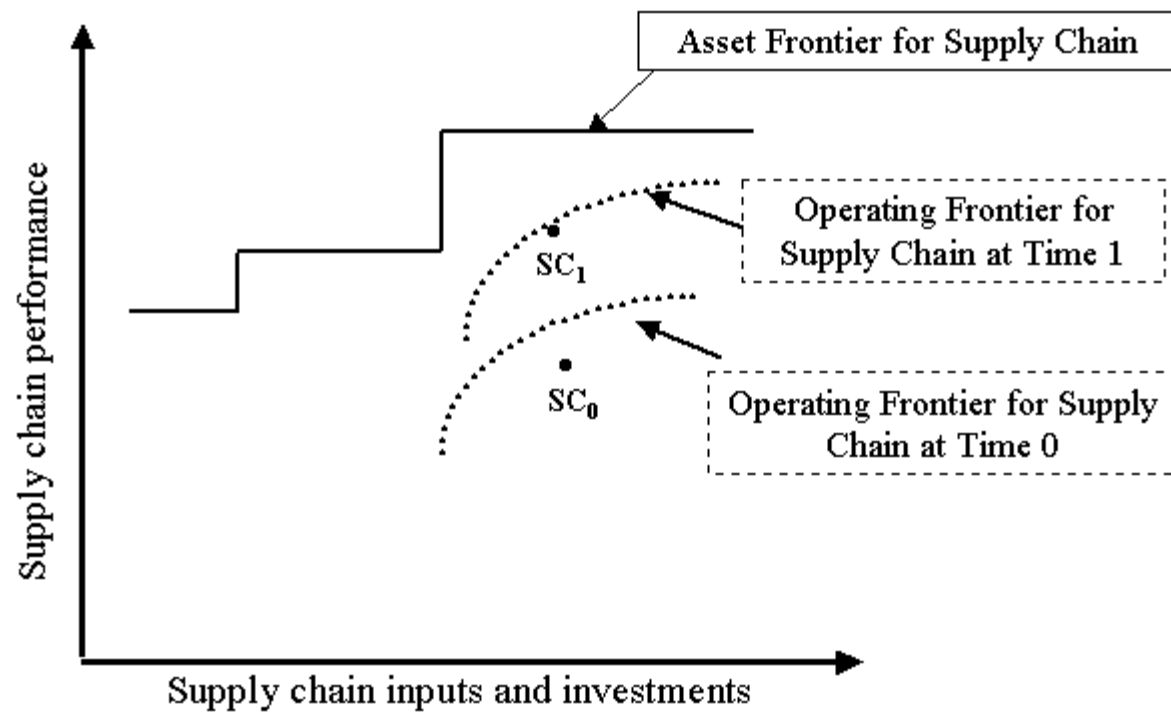


Figure 3: Asset and Operating Frontiers for a Supply Chain

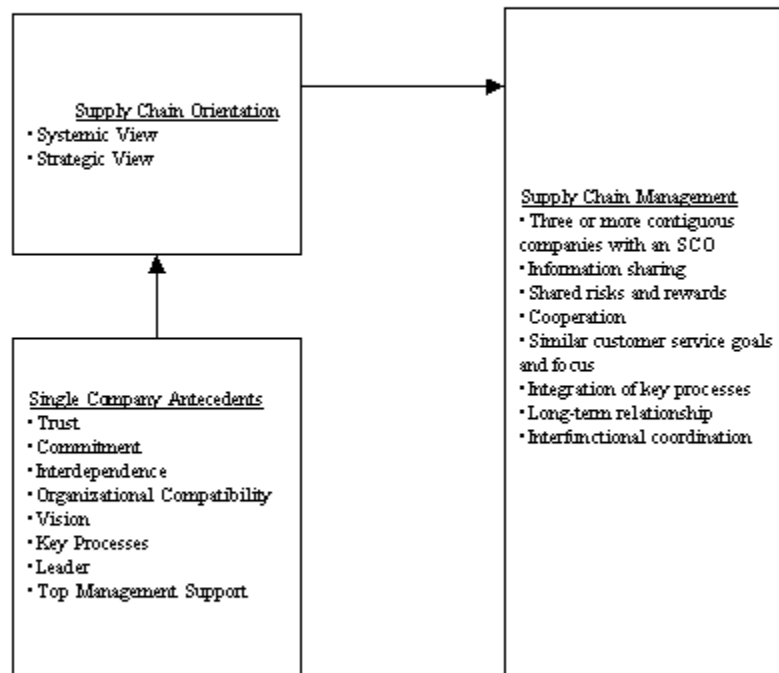


Figure 4: Supply Chain Management Antecedents
(Source: Mentzer et al. 2001)

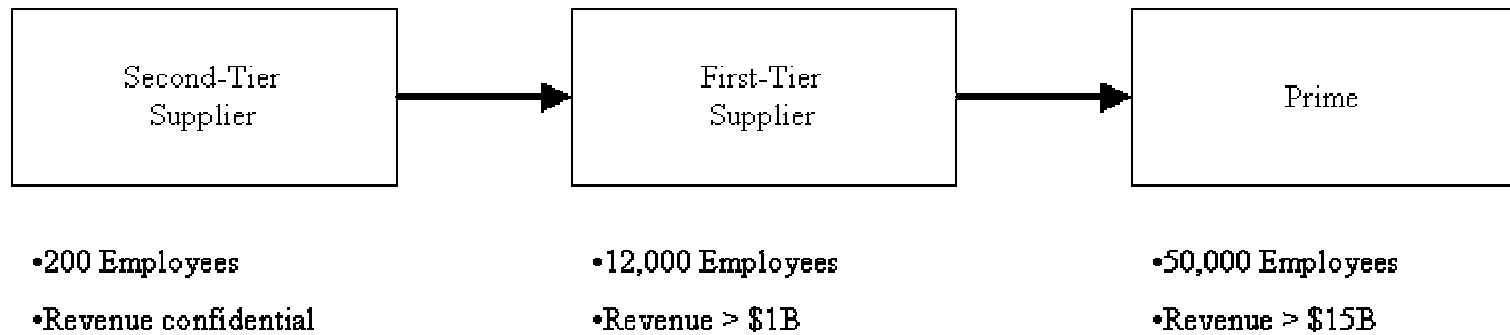


Figure 5: Major Component Program Supply Chain

Distribution Integration		Lean Production		Supplier Integration	
Product Development Integration	0	5s	67	Product Development Integration	17
Blanket Orders	0	Total Productive Maintenance	80	Blanket Orders	0
Kanban Replenishment	0	Set-up Reduction	70	Kanban Replenishment	100
Rate-Based Planning	0	Standard Work	53	Rate-Based Planning	0
Supplier Broadcast	0	Method Sheets	75	Supplier Broadcast	50
Demand Data Exchange	0	Quality Assurance	43	Demand Data Exchange	100
Point-of-Use Material Delivery	0	Mistake-Proofing	50	Point-of-Use Material Delivery	100
Quality Certification	0	Production to Takt Time	100	Quality Certification	85
		Flow Cells	90		
		Visual Controls	91		
		One-Piece-Flow	5		
		Mixed Model Production	15		
		Point-of-Use Material Storage	100		
		Pull Production Scheduling	98		
		Design for Manufacturing	0		
		Complexity Reduction	80		
		Lean" Kaizen" Events	75		

Figure 6: Lean Capabilities Map a) Prime

Distribution Integration		Lean Production Tow		Supplier Integration	
Product Development Integration	95	5s	68	Product Development Integration	15
Blanket Orders	0	Total Productive Maintenance	100	Blanket Orders	9
Kanban Replenishment	0	Set-up Reduction	35	Kanban Replenishment	0
Rate-Based Planning	20	Standard Work	53	Rate-Based Planning	0
Supplier Broadcast	0	Method Sheets	50	Supplier Broadcast	16
Demand Data Exchange	100	Quality Assurance	40	Demand Data Exchange	0
Point-of-Use Material Delivery	10	Mistake-Proofing	25	Point-of-Use Material Delivery	10
Quality Certification	0	Production to Takt Time	0	Quality Certification	2
		Flow Cells	100		
		Visual Controls	73		
		One-Piece-Flow	25		
		Mixed Model Production	15		
		Point-of-Use Material Storage	75		
		Pull Production Scheduling	0		
		Design for Manufacturing	100		
		Complexity Reduction	5		
		Lean "Kaizen" Events	50		

Figure 6: Continued. b) FTS

Distribution Integration		Lean Production		Supplier Integration	
Product Development Integration	0	5s	72	Product Development Integration	0
Blanket Orders	20	Total Productive Maintenance	0	Blanket Orders	78
Kanban Replenishment	90	Set-up Reduction	65	Kanban Replenishment	58
Rate-Based Planning	0	Standard Work	40	Rate-Based Planning	75
Supplier Broadcast	78	Method Sheets	0	Supplier Broadcast	75
Demand Data Exchange	80	Quality Assurance	42	Demand Data Exchange	100
Point-of-Use Material Delivery	100	Mistake-Proofing	40	Point-of-Use Material Delivery	15
Quality Certification	100	Production to Takt Time	5	Quality Certification	80
		Flow Cells	70		
		Visual Controls	82		
		One-Piece-Flow	30		
		Mixed Model Production	75		
		Point-of-Use Material Storage	45		
		Pull Production Scheduling	70		
		Design for Manufacturing	95		
		Complexity Reduction	20		
		Lean "Kaizen" Events	80		

Figure 6: Continued. c) STS

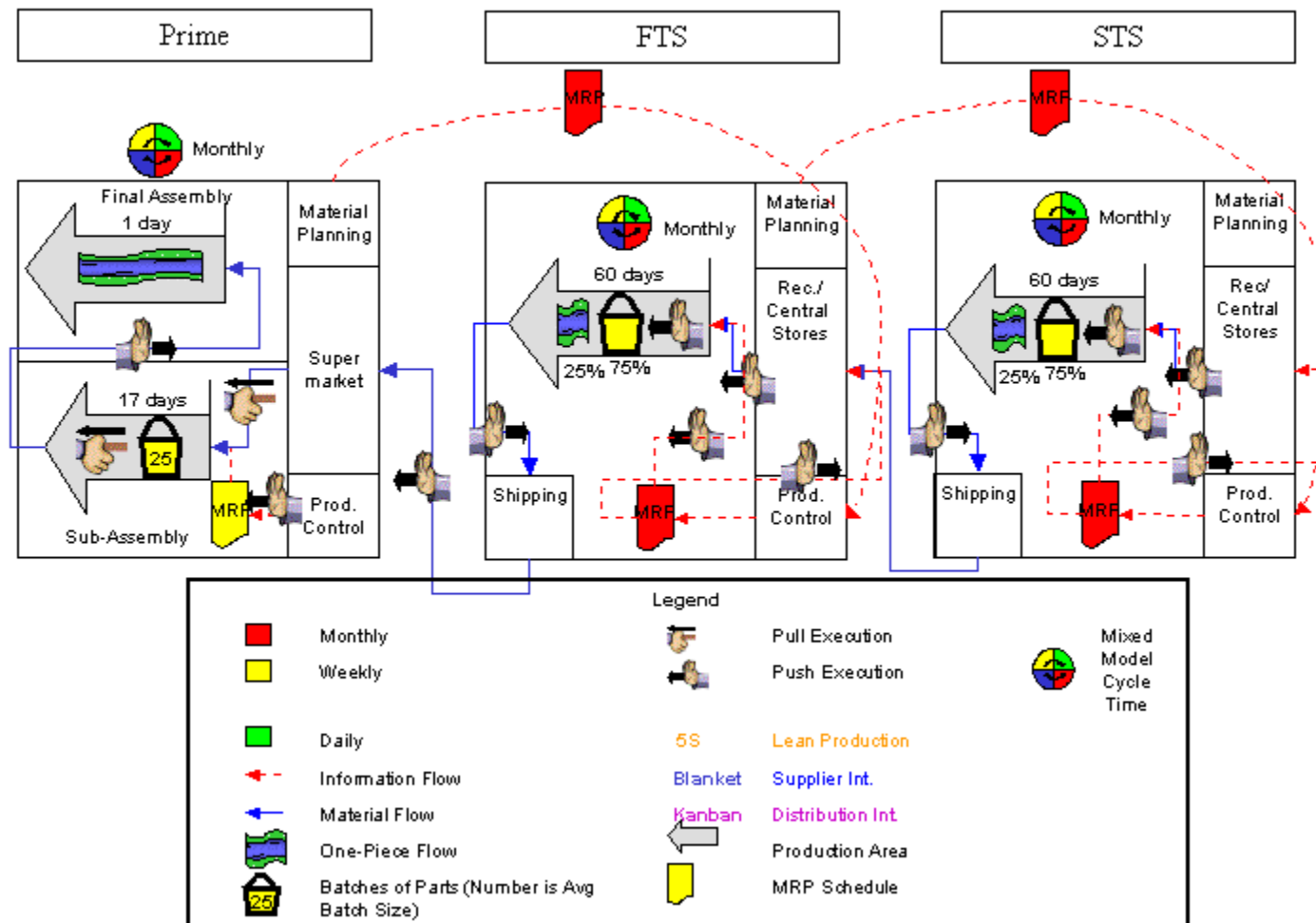


Figure 7: Supply Chain Execution Map (As Is)

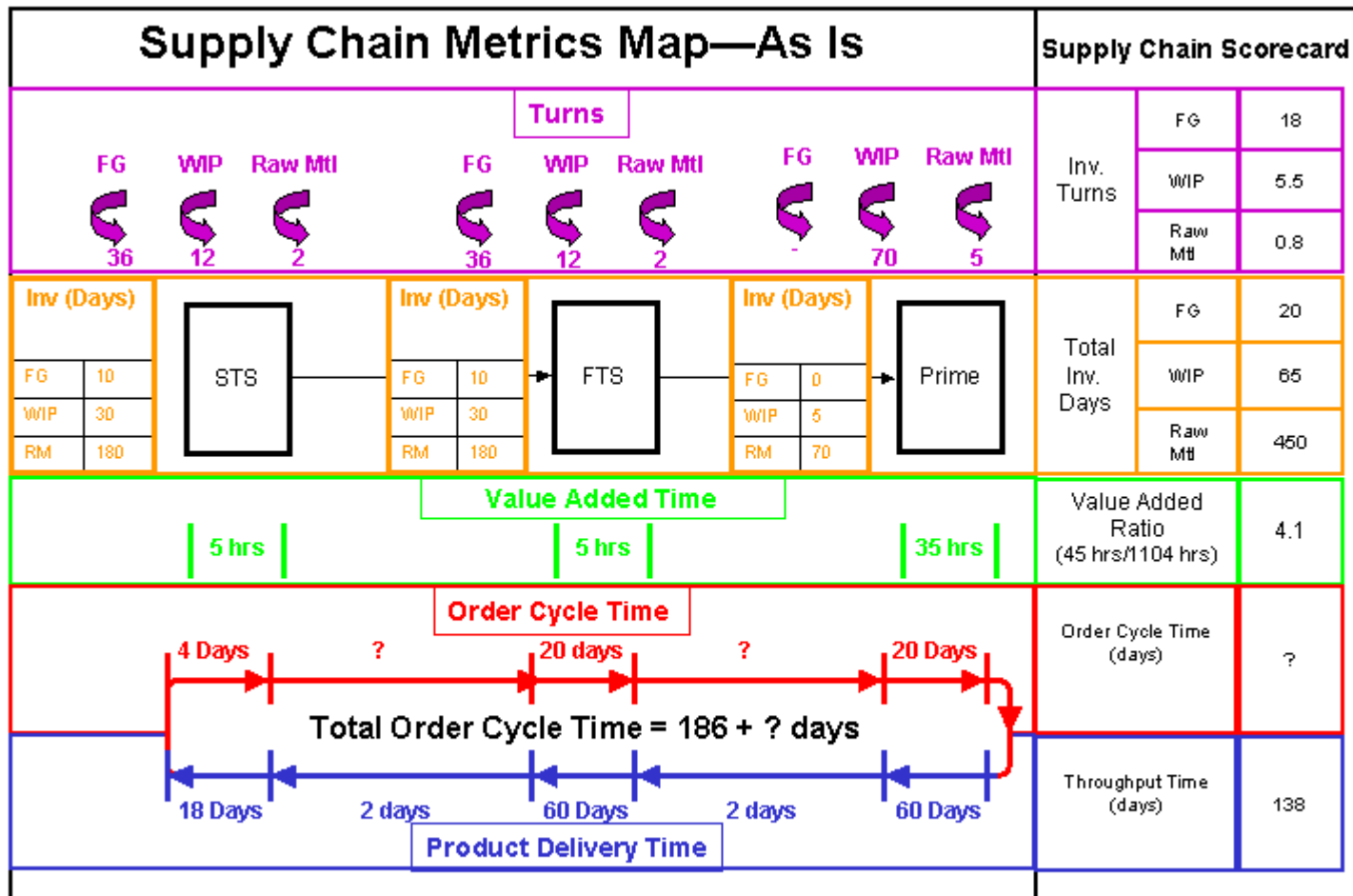


Figure 8: Supply Chain Metrics Map (As Is)

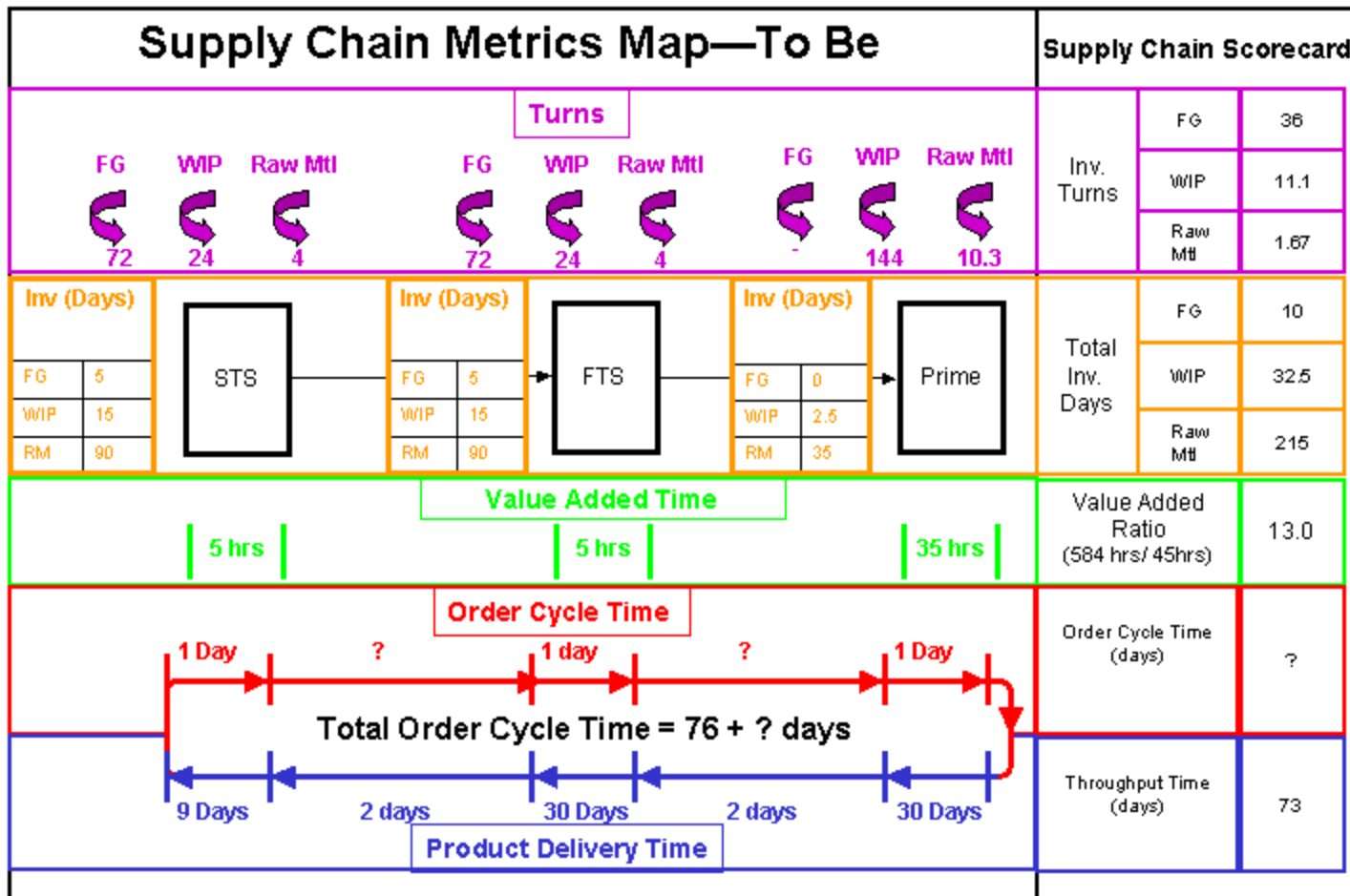


Figure 9: Supply Chain Metrics Map (To Be)

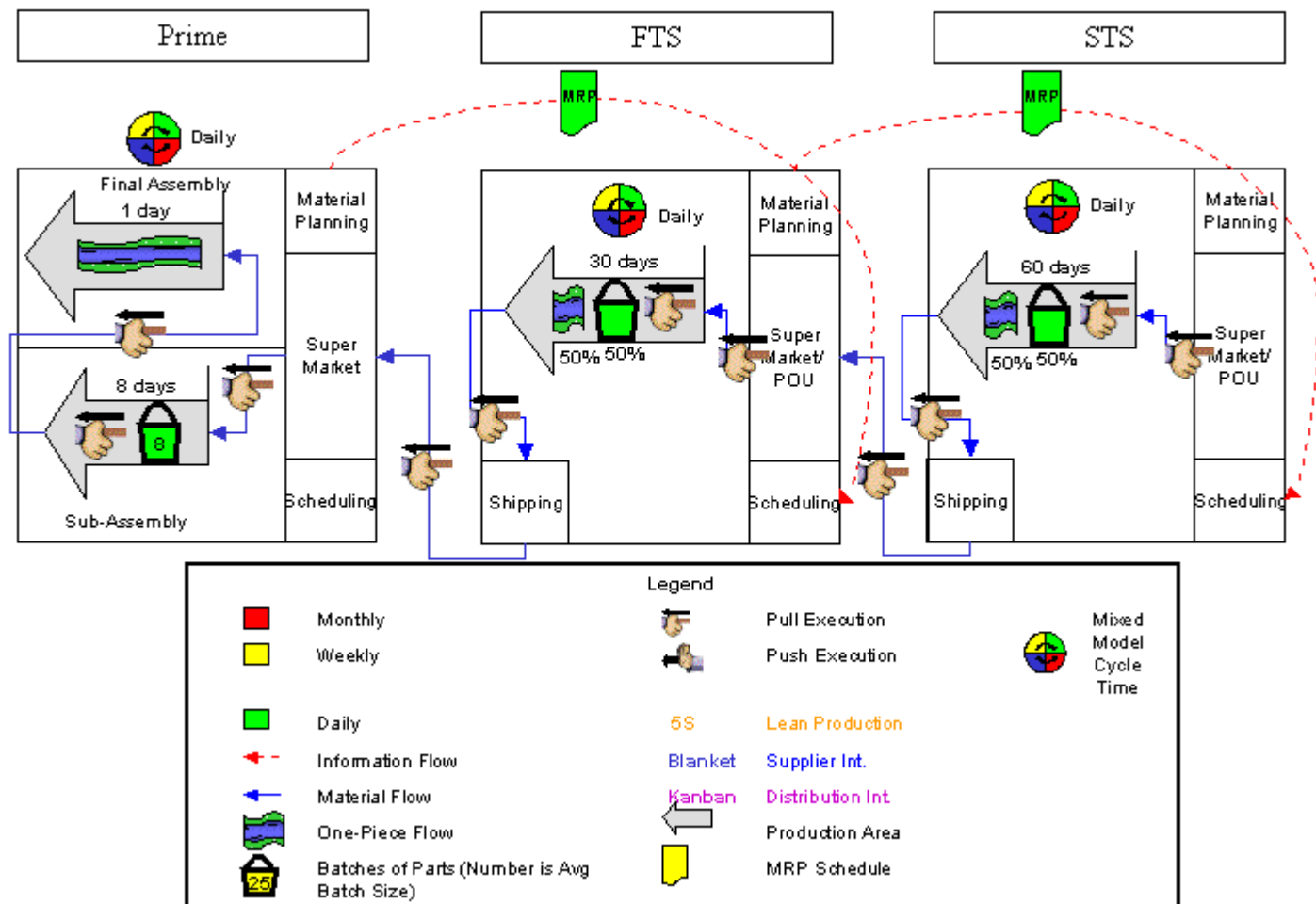


Figure 10: Supply Chain Execution Map (To Be)

Agenda:	Setup of Lean supply chain
Attendants:	FTS:
	STS:
Location:	FTS
Date:	7/13/01
DW opened the meeting with the following points: - Recap of progress to date reaffirming original goals and objectives of Lean exclusive. - JR observed the need for improved alignment in the PC Standard project. All agreed to continue with the Lean initiative to reap the mutual benefits until this realignment can be brought about. - AB requested that the FTS be able to send people to tour the STS to view Lean practices first hand. One possible scenario is to include this item during the next Lean joint meeting. - All discussed 'next step' at length. The FTS requires the STS to be under contract for old method by 7/26/01 (Plan A). The FTS will also send all specs ASAP to the STS to assess the feasibility of taking all operations excepting [Procedure Z₁]. The assessment to be completed by 8/1/01. - The FTS to contact DW to plan meeting at the FTS to Further discuss and determine the required desirable changes to the process before the next meeting. - Forgings delivery due for 9/12/02 machining to start immediately. - Work on components for [assembly kit] may need to begin earlier. [Component X₁] delivery due for October. - Delivery date of [Component X₂] is to be determined and may be of concern. - The FTS to assess timeline to get autoclave operation up to speed. Co-ordination would be needed between the FTS and the STS re-training and qualification of this operation. - The STS to investigate an alternative for [Special Weld Inspection] nearer, shorter lead-time etc. - DW commented that the STS packing slips are difficult to read which added to the previous paperwork difficulties encountered. - Both the FTS and STS to investigate possibility of the STS using the FTS as an Outside Vendor for [Procedure Z₁]. The benefits of this approach would be: - A defined lead-time, which will restrict and reduce WIP and overall lead-time. - Reduced paperwork, which will also lead to reduced requirement of administrative support. The benefits of the Len Initiative will be: - Reduction in paperwork/Administrative support. - Reduced lead-time: - Material Handling - Transportation - Reduced/Stable WIP quantity (due to reduced lead-time). - Reduced risks to parts: - Material handling - Transportation - Elimination of traceability problems. Observations—All participants concluded that this meeting had been very positive, with good progress being made to further the Lean initiative and raising the confidence and will to bring a successful conclusion to the project.	

Figure 11: Minutes to STS—FTS Meeting

Current State Value Stream Map

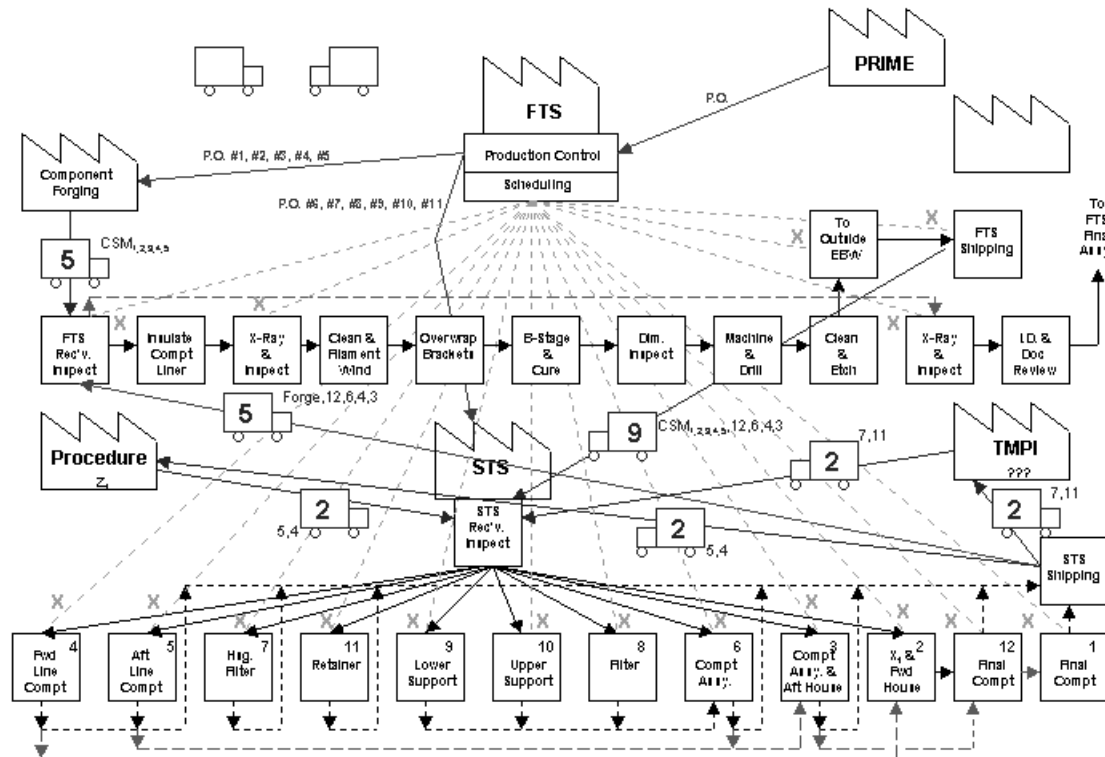


Figure 12: MC Program Value Steam Map (Current)

Future State Value Stream Map

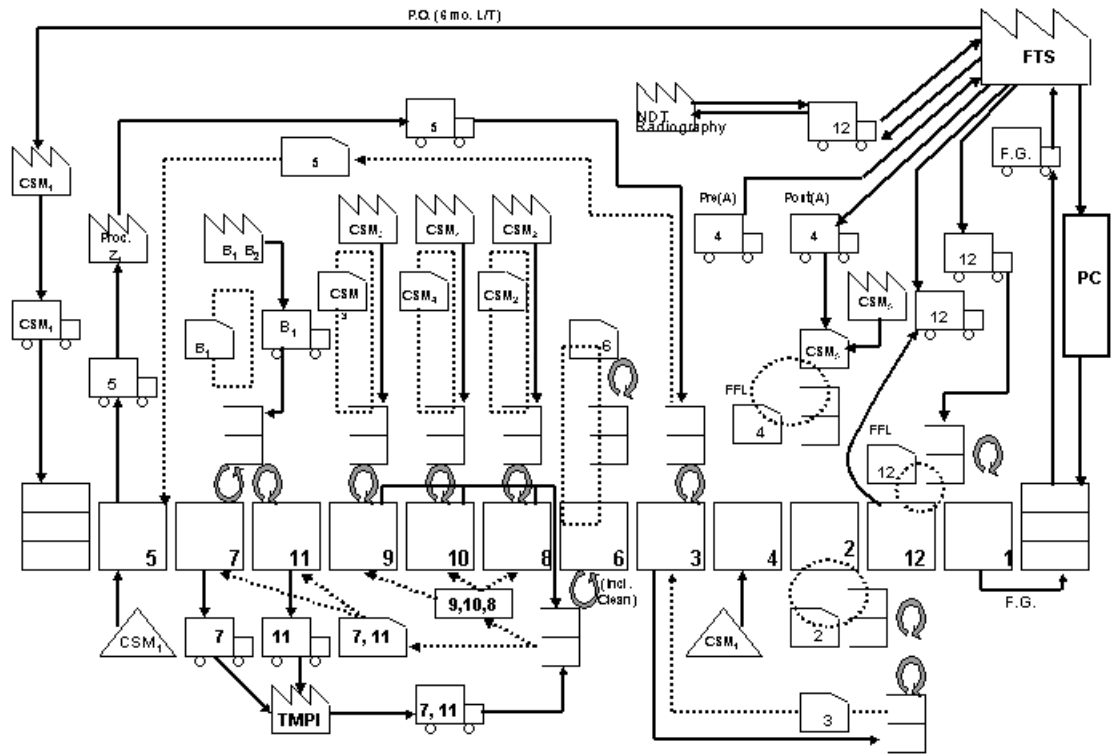


Figure 13: MC Program Value Stream Map (Future)

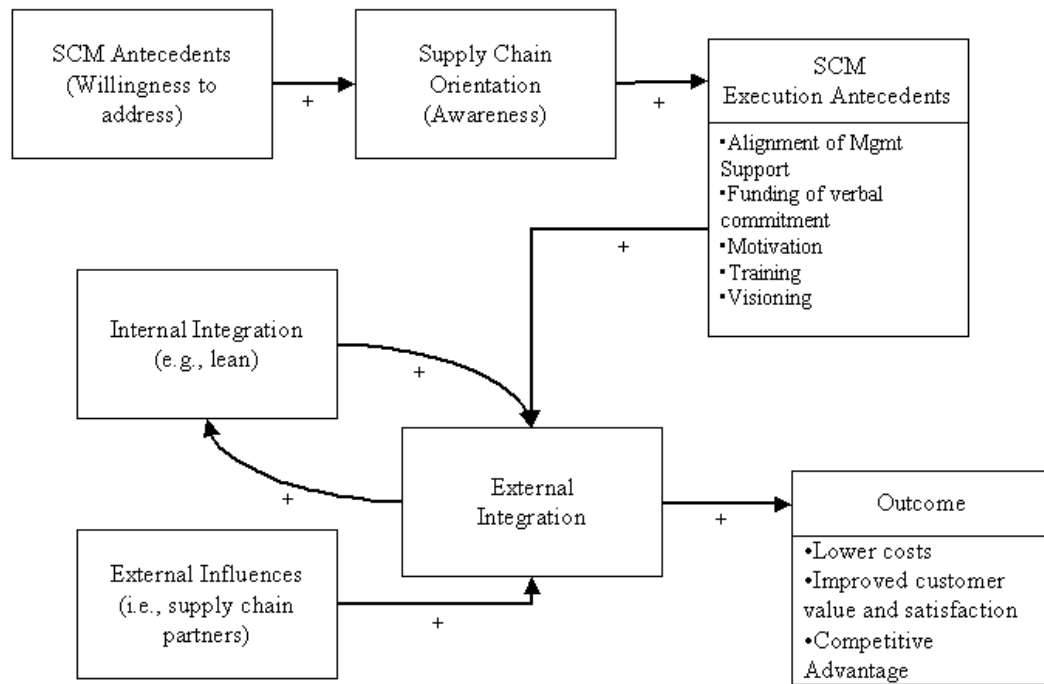


Figure 14: A Single Company's Progression to SCM

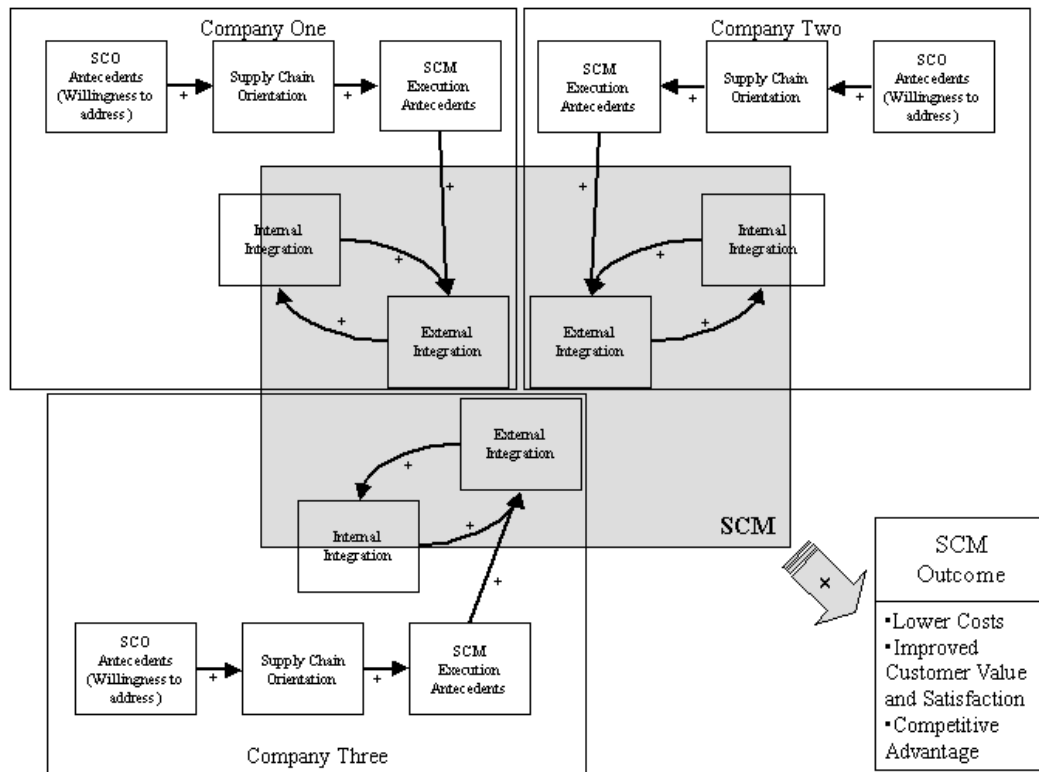


Figure 15: A Model of Supply Chain Management

*Appendix C—The Lean Enterprise Site Assessment*²⁷

²⁷ The materials presented in this appendix are a significant part of the Lean Enterprise Site Assessment and are copyrighted by Greene et al. 2001.

Lean Production

Lean Production Elements	Current Fiscal Year
1) 5S (Sort, Storage, Shine, Standardize, Sustain): <i>Organization and daily maintenance of the work area.</i>	
a) What percentage of the workstations on this site have held a 5S event (focused improvement session)?	%
b) What percentage of the work areas on this site have daily 5S responsibilities posted in a visible manner?	%
c) How often are workstations audited for 5S?	☐ Weekly ☐ Every 2 weeks ☐ Monthly ☐ Every 6 months ☐ Yearly ☐ Other _____
2) Total Productive Maintenance (Autonomous Maintenance): <i>A maintenance strategy, which incorporates the operators in daily maintenance activity. This strategy frees the maintenance personnel to work on more technical maintenance issues.</i>	
a) What percentage of the machines on this site is on a TPM schedule?	%
b) What percentage of the operators has been trained by maintenance to perform daily preventive maintenance?	%
c) What percentage of these machines on a TPM schedule have daily operator responsibilities visibly posted?	%
d) Check all of the maintenance strategies employed at this site.	☐ Reliability Centered Maintenance ☐ Proactive Maintenance ☐ Preventive Maintenance ☐ Predictive Maintenance
e) On what percentage of machines do you track OEE (Overall Equipment Effectiveness)?	%
3) Set-Up Reduction: <i>A concentrated effort to decrease the amount of time needed to prepare material and equipment for changing over from product to product.</i>	
a) What percentage of machines has had one or more set-up reduction events (focused improvement sessions)?	%
b) What is the average percent overall decrease in setup time at these machines?	%
c) Have set-up reduction activities been focused on bottleneck operations?	☐ Yes ☐ No
d) Are set-up performances tracked and posted?	☐ Yes ☐ No
4) Standard Work: <i>The establishment of an optimal flow of work activities within a cell or on an assembly line.</i>	
a) What percentage of the workstations at this site has held standard work flow events (focused improvement session)?	%
b) Standard work flow events (focused improvement sessions) are conducted by: (check all that apply)	☐ A team of operators ☐ Industrial Engineers ☐ Supervisors ☐ Design Engineers ☐ Other _____
c) Standard work flow patterns are reviewed:	☐ Weekly ☐ Every 2 weeks ☐ Monthly

Lean Production Elements	Current Fiscal Year
	☐ Every 6 months ☐ Yearly ☐ Other_____
5) Method Sheets: <i>Guidelines or instructions that graphically depict standard operating procedures.</i>	
a) What percentage of operations has posted visual operator instructions for that station?	%
b) How often are method sheets updated/reviewed?	☐ Monthly ☐ Every 6 months ☐ Yearly ☐ Other_____
Lean Production Elements	Current Fiscal Year
6) Quality Assurance: <i>A collection of tools used to detect and eliminate defects in the production process.</i>	
a) At what percentage of workstations are inspections of material and/or equipment performed prior to beginning work at the next workstation (Source inspection)?	%
b) At what percentage of workstations are inspections of work performed before passing on to next station (Self check inspection)?	%
c) At what percentage of workstations are inspections of the previous operator's work performed. (Successive check inspection)?	%
d) Check all quality tools that are used to track defects and analyze problems:	☐ Pareto charts ☐ Check sheets ☐ Histograms ☐ Scatter diagrams ☐ Process control charts ☐ Cause and effect diagrams
7) Mistake-Proofing: <i>The use of fixturing and tooling to eliminate or reduce the possibility of errors being made in the assembly of the product.</i>	
a) What percentage of operations has been reviewed for mistake-proofing opportunities?	%
b) Approximately what number of mistake-proofing devices was implemented last month?	
c) Approximately what number of mistake-proofing devices was implemented last year?	
8) Production to Takt Time: <i>Pace of demand that is used to determine the required pace of production.</i> Takt time = Total available production time / Demand rate (i.e. (8hrs x 60min/day)/ 60 units per day = 7 min. takt time).	
a) What is the frequency with which takt times are updated?	☐ Daily ☐ Twice a week ☐ Weekly ☐ Every 2 weeks ☐ Monthly ☐ Yearly ☐ Other_____
b) Is the current takt time posted where all production personnel can view it?	☐ Yes ☐ No
c) What percentage of workstations are currently producing to a posted takt time?	%
9) Formulation of Flow Cells (for Fabrication and Assembly Operations) or Flow Lines: <i>Flow Cells: The grouping of product families into close proximity to eliminate unnecessary material movement.</i>	
a) What percentage of operations for the site has been moved into a flow cell?	%
b) What percentage of operators is cross-trained within cell operations?	%

Lean Production Elements	Current Fiscal Year
c) What percentage of operators is cross-trained across cell operations?	%
d) What is the total distance traveled for your primary product(s) within the facility?	Feet
e) What percentage of the products at this site is assembled on moving lines?	%
10) Visual Controls: <i>The use of visual signals to communicate information about the status of the production line. Visual controls include any graphical marking or other visual signal that serves as a quick and complete communication to the operator.</i>	
Check all of the following visual control applications that are used on-site. Visual Work Controls ☐ Outlines for tools ☐ Labeling of racks, ☐ Shadow boxes for incoming and outgoing parts ☐ Floor markings (aisle ways, cell areas) Visual production controls ☐ Andon Lights ☐ In-Process Kanbans ☐ Schedule boards Visual Material Control ☐ Standard Work-in-Process ☐ Color coded inventory boxes ☐ Defect bins Equipment, Fixture, and Tool Controls ☐ Visually displayed tool locations ☐ Standardized Set-up tool kit ☐ Machine operation status display ☐ Method Sheets ☐ Cell and Line Metric Controls	☐
Lean Production Elements	Current Fiscal Year
11) One-Piece-Flow (for Fabrication and Assembly Operations): <i>The ability to produce one part at a station at a time. This is contrasted with batch production, in which more than one part is processed at a station before moving to the next station.</i>	
a) What percentage of workstations builds in one-piece-flow?	%
b) What percentage of workstations process in batches of: 2 to 5?	%
c) What percentage of workstations process in batches of: 5 to 10?	%
d) What percentage of workstations process in batches of: 10 to 25?	%
e) What percentage of workstations process in batches of > 25?	%
	100%
12) Mixed Model Production: <i>The ability to make several products on the same line in a random or sequenced order.</i>	
a) For 80% of products produced at this site, all major variations are produced how often?	☐ More than daily ☐ Daily ☐ Twice a week ☐ Weekly ☐ Every 2 weeks ☐ Monthly ☐ Yearly ☐ Other _____
13) Point-of-Use Storage: <i>The preparation of work areas for the direct presentation of supplied materials.</i>	
a) What percentage of workstations has the necessary production materials at the point-of-use?	%
b) What percentage of all part numbers is presented at the point-of-use?	%
c) What percentage of Raw Material (\$) and Work-in-Process Inventory (\$) is presented at the point-of-use?	%

Lean Production Elements	Current Fiscal Year	
14) Pull Production Scheduling: <i>As materials are consumed at an upstream station, signals are sent back to previous steps in the production process to pull forward sufficient materials to replenish only those materials that have been consumed.</i>		
Discrete Production		
a) What percentage of <u>fabrication/ batch processing</u> stations produce parts based on a signal (kanban) from an upstream operation?		
b) What percentage of <u>assembly stations</u> assemble parts based on a signal (kanban) from an upstream operation or finished goods replenishment signal?		
Continuous Production		
c) What percentage of <u>processes</u> produce based on a signal (kanban) from an upstream operation or finished goods replenishment signal?		
15) Design for Manufacturing: <i>The incorporation of manufacturing capabilities in the design phase of a product in order to make necessary engineering changes due to process capabilities before the new product reaches the production stage.</i>		
a) What percentage of product design teams includes one or more representatives from production?		
16) Complexity Reduction: <i>The decreasing of parts or operations needed for a product by increasing component usage and simplifying the design.</i>		
a) On average what percentage of parts in the Bills of Materials are standard parts?	Before Lean Implementation	Current
	%	%
17) Lean “Kaizen” Events: <i>A focused improvement exercise during which a cross-functional team of operators, engineers and others spends 1-3 days dramatically improving a production cell, line, or process.</i>		
a) What percentage of the workstations has been through one or more Lean Events (1-3 day focused improvement activity)?		
b) At a given workstation, the frequency of all lean events (5S, Standard Work Flow, TPM, etc.):	☐ Daily ☐ Twice a week ☐ Weekly ☐ Every 2 weeks ☐ Monthly ☐ Yearly ☐ Other _____	
18) Ergonomic Design: <i>The design of processes to natural human movements, postures, and environment.</i>		
a) What percentage of operations has been evaluated for ergonomic design?		
19) Cross-Trained Workforce		
a) What percentage of the workforce at this site has been trained to perform multiple operations?		
b) What percentage of the workforce is represented by a union?		
c) The total number of job classifications represented at this site is:		

Supplier Integration Survey

Supplier Integration Elements	Current Fiscal Year
1) Product Development Integration	
a) What percentage of <i>supplied parts</i> is designed by the supplier?	%
b) What percentage of <i>suppliers</i> participates in the design of components?	%
2) Blanket Orders	
a) What percentage of <i>suppliers</i> currently deliver based on blanket purchase orders?	%
b) What percentage of <i>all supplied components or raw materials</i> are supplied based on blanket purchase orders?	%
3) Kanban Replenishment	
a) What percentage of <i>supplied parts</i> is on kanban replenishment?	%
b) What percentage of the <i>dollar volume of parts</i> is on supplier kanban replenishment?	%
c) What percentage of <i>suppliers</i> is on kanban replenishment?	%
4) Rate-Based Planning	
a) For what percentage of your <i>suppliers</i> has your company developed upper and lower capacity flex limits over time (i.e. response profiles)?	%
5) Supplier Broadcast	
a) What percentage of your <i>suppliers</i> receives demand forecast information (i.e. MRP)?	%
b) How often is the demand forecast information broadcast to suppliers?	☐ Daily ☐ Weekly ☐ Bi-weekly ☐ Monthly ☐ Every 6 months ☐ Yearly ☐ Other _____
c) What percentage of your <i>suppliers</i> has established upper/lower production bounds on their supplier broadcast information?	%
6) Data Exchange	
a) What percentage of your <i>suppliers</i> receives information on production demand electronically?	%
b) What percentage of your <i>suppliers</i> uses the following media to exchange data?	☐ Internet _____ % ☐ Intranet _____ % ☐ Direct Connection _____ % ☐ Fax _____ % ☐ EDI _____ % ☐ Other _____ , %
7) Point-of-Use (POU) Material Delivery	
a) What percentage of your <i>suppliers</i> delivers directly to the Point-of-Use (supermarket or consignment area)?	%
b) What percentage of <i>supplied parts</i> is stored at the Point-of-Use (supermarket or consignment area)?	%
c) What percentage of the <i>total plant</i> is designated for consolidated storage of raw materials (i.e. not at POU)?	%
8) Quality Certification	
a) What percentage of your <i>suppliers</i> is certified to deliver without any inspection at receiving?	%

Distribution Integration Survey

Distribution Integration Elements	Current Fiscal Year
1) Product Development Integration	
a) For what percentage of supplied products is your organization involved in the product design?	%
2) Blanket Orders	
a) For what percentage of supplied products does your organization deliver based on blanket purchase orders?	%
3) Kanban Replenishment	
a) What percentage of supplied products is on kanban replenishment?	%
b) With what frequency are supplied products delivered? (<i>Include Units: Ex. 3 times a day</i>)	
4) Rate-Based Planning	
a) What percentage of your customers has developed upper and lower capacity flex limits over time (i.e. response profiles)?	%
5) Supplier Broadcast	
a) From what percentage of your customers do you receive demand forecast information (i.e. MRP)?	%
b) How often do you receive demand forecast information broadcast from your customers?	☐ Daily ☐ Weekly ☐ Bi-weekly ☐ Monthly ☐ Every 6 months ☐ Yearly ☐ Other_____
6) Data Exchange	
a) What percentage of your customers uses the following media to exchange data?	☐ Internet_____% ☐ Intranet_____% ☐ Direct connection_____% ☐ Fax_____% ☐ EDI_____% ☐ Other_____%
b) With what frequency does your facility receive customer orders?	☐ Daily ☐ Weekly ☐ Bi-weekly ☐ Monthly ☐ Other_____
7) Point-of-Use (POU) Material Delivery	

Distribution Integration Elements	Current Fiscal Year
a) For what percentage of your customers do you deliver directly to the Point-of-Use (supermarket or consignment area)?	%
8) Quality Certification	
a) For what percentage of your customers are you certified to deliver without any inspection at receiving?	%

Appendix D—The Development of the Lean Enterprise Site Assessment

The goal of developing the Lean Enterprise Site Assessment (LESA)²⁸ was to have a detailed instrument rigorous enough to measure the various dimensions of lean and related antecedents. The development of the LESA took the participation of several individuals over three years to bring the LESA to its current form. The current version of the LESA has gone through several iterations. The Lean Production, Supplier Integration and Distribution Integration modules were first developed in 1999 from a framework created by Dr. Thomas Greenwood based on his involvement with over 60 lean implementations worldwide. The Performance Measurement module and the Organization Dynamics modules were developed from a review of the literature and discussions with various faculty members involved with the Lean Enterprise Forum. In addition, Ernest Smith and Robert Brown were consulted to give specific feedback on the instrument from a lean practitioner focus. The first version of the LESA was finalized in the fall of 1999.

Once a complete set of the site assessment was developed, members of the Lean Enterprise Advisory Council²⁹ were asked to complete the assessment for one of their sites and to provide feedback on the assessment to include; understanding of each question, length of time to complete, difficulty in answering the questions, and suggestions and modifications to the instrument. A total of three sites from two Advisory Council members participated. Also, one independent company (i.e., not a

²⁸ The full version of the LESA is comprised of three operational modules (supplier integration, lean production, and distribution integration), two organizational dynamics modules (management level, and front-line level), and one performance measurement module.

²⁹ The Lean Enterprise Advisory Council is comprised of representatives from several top U.S. companies that have experience with lean implementations. The Council's purpose is to act as the board of directors for the Lean Enterprise Forum.

member of the Advisory Council) completed the entire assessment and provided similar feedback. In addition, the LESA was presented at two Lean Enterprise Advisory Council meetings to obtain general feedback from all members of the Advisory Council. Armed with the feedback from all sources, several meetings were held between Dr. James Schmidhammer³⁰, Bradley Greene, and DeWayne Searcy to revise the instrument based on the feedback received. The above activities occurred from the fall of 1999 until September 2000, bringing the LESA to its current form.

Literature Supporting the LESA

There are numerous studies that investigate various activities and practices (i.e., internal firm enhancements) aimed at improving internal integration within a firm (e.g., Fullerton and McWatters 2001; McLachlin 1997; Chenhall 1997; Inman and Mehra 1993; Young, et al. 1988). Many of the significant internal firm enhancements studied in the literature appear to be related to one or more of the dimensions of lean manufacturing. Gilmour (1999, 262) defines lean manufacturing as the “...effective utilization of the manufacturing asset base while maintaining high levels of flexibility and quality.” In other words, lean manufacturing moves a firm on or near its operating frontier while moving the operating frontier closer to the firm’s asset frontier. Spear and Bowen (1999) spent four years investigating 40 plants worldwide to understand how the Toyota production system (i.e., lean) works. They found that rigid standardization is the very thing that generates high levels flexibility and creativity found in lean organizations (what they called the Toyota paradox).

³⁰ Dr. Schmidhammer is an instructor in the Department of Statistics at UT, and he also teaches in the

Implementing lean can provide firms with the standardization, flexibility, and quality necessary for successfully implementing SCM (i.e., moving to external integration). In other words, implementing lean manufacturing should move firms closer to their operating frontier, thus increasing their efficiency and utilization. The implementation of lean manufacturing in firms across a supply chain should facilitate the implementation of SCM. As such, the extent of lean manufacturing at a firm will be used as a proxy for measuring the extent of internal integration in a firm.

Table D1 lists the various lean manufacturing elements found in the literature. Lean is a multi-dimensional construct and to properly measure it requires a measurement approach that attempts to objectively capture all the dimensions of lean. However, many studies in the area of lean attempt to measure lean using general measures such as Likert scales (e.g., McLachlin 1997; Koufteros et al. 1998; Flynn et al. 1999; and Fullerton and McWatters 2001). In addition, many of the studies only examine one or two elements of a lean implementation (e.g., JIT, cellular manufacturing, preventive maintenance). As part of this research, due to the importance of the proxy, is the development of an instrument to effectively and fully measure the infusion of lean production in a firm.

Table D2 defines the lean production elements measured with the LESA and identifies which of the three lean objectives are associated with the respective elements. Examining the raw scores of each firm for all of the elements listed in Table D2 will give a clear understanding of where the firms are with respect to internal

integration. Comparing each firm's Lean Infusion Score (discussed later) to each other will allow for a measure of relative internal integration. Where each firm stands relative to one another could influence the success of SCM across the firms.

Table D3 defines the external integration activities measured with the Supplier Integration and Distribution Integration modules of the LESA. As with examining the internal integration of each firm, the extent of external integration will be measured two ways, 1) the raw scores of each element for each firm, and 2) the Lean Infusion Scores for external integration across firms.

Lean Infusion Score (LIS)³¹

Lean infusion is measured within each module of LESA by computing a Lean Infusion Score (LIS). In addition, an overall LIS will be calculated. The overall LIS is the average of the three operations LISs (Lean Production, Supplier Integration, and Distribution Integration). The Lean Production LIS measures the level of internal integration. The Supplier Integration and Distribution Integration LISs measure the extent of external integration. Each LIS is computed using the Analytical Hierarchy Process (AHP) developed by Saaty (1980). The AHP has been used in numerous applications to include performance evaluation (Chan and Lynn 1991), facility relocation (Min and Melachrinoudis 1999), and other related applications (e.g., Min 1994; Tyagi and Das 1997)³². The AHP uses paired comparisons of objects with

this phase of the process is greatly appreciated.

³¹ See Appendix E for the detailed calculations of the LISs.

³² Golden, Wasil and Harker (1989) provide a summary of studies applying the AHP in various settings. A search in the ScienceDirect database identified 85 articles related to the Analytic Hierarchy Process published since 2000.

respect to a common goal or criteria (e.g., benefit from lean implementation). The end result of the AHP is a set of weights derived from the pairwise comparison.

The LISs were created with the help of the Lean Enterprise System Design Institute³³ faculty. The faculty was asked to complete two sets of pairwise comparisons, one for lean production elements and one for the supplier integration and distribution integration elements³⁴. Eight faculty members agreed to participate and each completed the two sets of pairwise comparisons. Since the comparisons are assumed to be reciprocal³⁵, there were $n(n-1)/2$ (where n is the number of alternatives under consideration) comparisons to complete the matrix of judgments (Golden et al. 1989). For example, there are 19 lean production elements, so there were 171 pairwise comparisons completed. Likewise, there were 28 pairwise comparisons for the eight supplier integration and distribution integration elements.

Each individual performed a two-step process in answering each pairwise comparison. First, the individual selected which of the two elements listed is the *more important lean implementation element* (e.g., standard work is more important than set-up reduction). Next, the individual indicated the magnitude of that importance based on the scale in Figure D1 (e.g., standard work is 3 times more important than set-up reduction). This two-step process was performed for all pairwise comparisons.

³³ The Lean Enterprise System Design Institute is a one-week course held by the Lean Enterprise Forum at the University of Tennessee to teach lean enterprise concepts and implementation issues.

³⁴ The faculty also completed a third set of pairwise comparisons. This third set involved distribution integration elements specific to retail channels.

³⁵ Reciprocity, for example, means that if standard work is 3 times more important than set-up reduction; then set-up reduction must be 1/3 more important than standard work.

Once the pairwise comparisons were completed a matrix was developed for each of the eight individuals. By taking the geometric mean a single matrix was derived for each AHP application. The matrices were normalized and a weighing system was calculated using the principal eigenvector approach (Appendix E provides the detail calculations). The principal eigenvector approach is accomplished by raising the single matrix calculated above to increasing powers of k that are successively squared each time. The row sums are calculated and normalized (Saaty 1980; Jung and Jung 2001). Tables D4 and D5 are the priority weighing systems calculated from using the AHP for each respective module. A consistency ratio was calculated to determine the consistency of the results (Saaty 1980; Saaty and Vargas 2001) with favorable results. Tables D6 and D7 detail the raw data collected and how the LISs are calculated. The question number corresponds to the specific question in the respective LESA module. Expert opinion was sought in determining which questions to include and the weight of each question within an element in calculating the LISs.

Table D1: The Lean Toolbox	
Lean Elements (Production Focus)	Representative Cites—Practitioner and Academic Literature (not intended as all inclusive)
5S	Suzaki (1987); Ohno (1988); Deluzio (1993a, 1993b); Henderson & Larco (1999); Inman & Mehra (1993)
TPM	Suzaki (1987); Ohno (1988); Inman & Mehra (1992); McLachlin (1997); Fullerton & McWatters (2001)
Set-up Reduction	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999); Inman & Mehra (1993); Kalagnanam & Lindsay (1998); McLachlin (1997); Detty & Yingling (2000); Fullerton & McWatters (2001); Claycomb et al., (1999)
Standard Work	Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999); Detty & Yingling (2000)
Method Sheets	Suzaki (1987); Ohno (1988); Henderson & Larco (1999)
Mistake-Proofing	Suzaki (1987); Ohno (1988); Henderson & Larco (1999); Young, et al., (1988)
Takt-Time	Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999); Inman & Mehra (1992); Flynn et al., (1999)
Plant layout/Flow Cells	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999); Banker, et al., (1999); Inman & Mehra (1992); Kalagnanam & Lindsay (1998); McLachlin (1997); Detty & Yingling (2000)
Visual Controls	Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999)
One-Piece Flow	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Henderson & Larco (1999); Kalagnanam & Lindsay (1998); McLachlin (1997)
POU Delivery/Storage	Suzaki (1987); Ohno (1988); Henderson & Larco (1999); Inman & Mehra (1992); McLachlin (1997); Detty & Yingling (2000); Fullerton & McWatters (2001)
Pull (Kanban)	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Deluzio (1993a); Henderson & Larco (1999); Banker, et al., (1999); Young, et al., (1988); Detty & Yingling (2000); Flynn et al., (1999); Fullerton & McWatters (2001); Claycomb et al., (1999)
DFMA	Suzaki (1987); Ohno (1988)
Complexity Reduction	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Henderson & Larco (1999)
Kaizen Events	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Henderson & Larco (1999); Detty & Yingling (2000); Flynn et al., (1999)
Ergonomic Design	Suzaki (1987)
Cross-Training	Schonberger (1982, 1986, 1996); Suzaki (1987); Ohno (1988); Banker, et al., (1999); McLachlin (1997); Flynn et al., (1999); Fullerton & McWatters (2001)
Quality	Schonberger (1982, 1986, 1996); Kalagnanam & Lindsay (1998); McLachlin (1997); Detty & Yingling (2000); Flynn et al., (1999); Fullerton & McWatters (2001); Claycomb et al., (1999)

Table D2: Lean Production Element Definitions and Consequences				
Lean Production Element	Definition	Standardization	Flexibility	Quality
5S	Organization and daily maintenance of the work area.	X		
Total Productive Maintenance	Operators are incorporated in the daily maintenance activity.			X
Set-up Reduction	A concentrated effort to decrease the amount of time needed to prepare material and equipment for changing over from product to product.		X	
Standard Work	The establishment of an optimal flow of work activities within a cell or on an assembly line.	X		
Method Sheets	Guidelines or instructions that graphically depict standard operating procedures.	X		
Quality Assurance	A collection of tools used to detect and eliminate defects.			X
Mistake-proofing	The use of fixtures and tools to eliminate or reduce the possibility of errors.			X
Production to Takt Time	Pace of demand that is used to determine the required pace of production.	X		
Flow Cells	The grouping of product families into close proximity to eliminate unnecessary material movement.		X	
Visual Controls	The use of visual signals to communicate information about the status of the production line.	X		X
One-piece Flow	The ability to produce one part at a station at a time.		X	X
Mixed-model Production	The ability to make several products on the same line in a random or sequence order.		X	
Point-of-use Storage	The preparation of work areas for the direct presentation of supplied materials.		X	
Design for Manufacturing	The incorporation of manufacturing capabilities in the design phase of a product in order to make necessary engineering changes due to process capabilities before the new product reaches the production stage.	X	X	X
Complexity Reduction	The decreasing of parts or operations needed for a product by increasing component usage and simplifying the design.	X	X	
Kanban/Pull Production	The communication system of the manufacturing environment. As materials are consumed at a downstream station, signals are sent back to previous steps in the production process to pull forward sufficient materials to replenish only those materials that have been consumed.	X	X	X
Kaizen Events	A focused improvement exercise during which a cross-functional team spends 1-3 days improving a production cell, line, or process.	X	X	X
Ergonomic Design	The design of processes to natural human movements, postures, and environment.			X
Cross-Training	The training of the workforce to perform multiple tasks.	X	X	X

Table D3: Supplier and Distribution Element Definitions and Consequences				
Integration Element	Definition	Standardization	Flexibility	Quality
Production Development Integration	The integration of supplier design capabilities and sharing of information so as to enhance, improve and shorten the overall product design process.			X
Blanket Orders	A long-term purchasing agreement that eliminates repetitive purchase orders and therefore shortens the order-entry process and significantly reduces paperwork.		X	
Kanban Replenishment	An inventory strategy in which the supplier builds their schedule solely to replenish the consumed inventory of an downstream factory, DC, or retailer.	X	X	X
Rate-based Planning	The establishment of minimum and maximum bounds of capacity flexibility around future demands.		X	
Supplier Broadcast	The sharing of MRP information with integrated suppliers.		X	
Data Exchange	The electronic exchange of demand information between suppliers and manufacturers.		X	
Point-of-use Material Delivery	The delivery of materials by the supplier to the location (e.g., cell, assembly line, etc.) that the materials will be added.		X	
Quality Certification	A supplier audit process, which over time eliminates the need for inspection of incoming materials.	X		X

Table D4: Priority Weights for Supplier and Distribution Integration Elements	
Integration Elements	Weight
1. Kanban Replenishment	0.1919
2. Rate-based Planning	0.1786
3. Product Development Integration	0.1335
4. Supplier Broadcast	0.1316
5. Point-of-use Material Delivery	0.1237
6. Supply Quality Certification	0.0930
7. Blanket Orders	0.0881
8. Electronic Data Interchange	0.0597
Sum of weights	1.0000

Table D5: Priority Weights for Lean Production Elements			
Lean Production Elements	Weights	Lean Production Elements	Weights
1. Pull Production Scheduling	0.0983	11. Cross-training	0.0421
2. Production to Takt Time	0.0805	12. Complexity Reduction	0.0410
3. Flow Cells	0.0801	13. Total Productive Maintenance	0.0404
4. Standard Work	0.0750	14. Quality Assurance	0.0394
5. Mixed Model Production	0.0663	15. Kaizen Events	0.0381
6. One-Piece Flow	0.0627	16. Visual Control	0.0376
7. Set-up Reduction	0.0541	17. Mistake-proofing	0.0340
8. 5S	0.0516	18. Method Sheets	0.0323
9. Point-of-use Material Storage	0.0516	19. Ergonomic Design	0.0305
10. Design for Manufacturing	0.0444	Sum of weights	1.0000

Table D6: Worksheet to Calculate the Supplier Integration and Distribution Integration LISs						
Integration Element	Element Weight	Question Number	Site's Response	Question Weight	Adjusted Question Score	Element Score
Col. a	Col. b	Col. c	Col. d	Col. e	Col. f	Col. g
					Col. (d * e)	(Sum Col. f) * Col. b
Product Development Integration	0.1335	1(a)		0.50		
		1(b)		0.50		
Blanket Orders	0.0881	2(a)		0.50		
		2(b)		0.50		
Kanban Replenishment	0.1919	3(b)		0.50		
		3(c)		0.50		
Rate-based Planning	0.1786	4(a)		1.00		
Supplier Broadcast	0.1316	5(a)		0.50		
		5(b)		0.50		
Date Exchange	0.0597	6(a)		1.00		
Point-of-use Material Delivery	0.1237	7(a)		0.50		
		7(b)		0.50		
Quality Certification	0.0930	8(a)		1.00		
Integration LIS						

Table D7: Worksheet to Calculate the Lean Production LIS						
Lean Production Element	Element Weight	Question Number	Site's Response	Question Weight	Adjusted Question Score	Element Score
Col. a	Col. b	Col. c	Col. d	Col. e	Col. f	Col. g
					Col. (d * e)	(Sum Col. f) * Col. b
5S	0.0516	1(a)		0.34		
		1(b)		0.33		
		1(c)		0.33		
Total Productive Maintenance	0.0404	2(a)		0.40		
		2(b)		0.40		
		2(c)		0.20		
Set-up Reduction	0.0541	3(a)		0.70		
		3(d)		0.30		
Standard Work	0.0750	4(a)		0.50		
		4(c)		0.50		
Method Sheets	0.0323	5(a)		0.50		
		5(b)		0.50		
Quality Assurance	0.0394	6(a)		0.40		
		6(b)		0.40		
		6(c)		0.20		
Mistake-proofing	0.0340	7(a)		0.50		
		7(c)		0.50		
Production to Takt Time	0.0805	8(a)		0.50		
		8(c)		0.50		
Formation of Flow Cells	0.0801	9(a)		1.00		
Visual Controls	0.0376	10(a)		1.00		
One-piece Flow	0.0627	11(a)		1.00		
Mixed-model Production	0.0663	12(a)		1.00		
Point-of-use Storage	0.0516	13(a)		1.00		
Pull Production	0.0983	14(a)		0.50		
		14(b)		0.50		
Design for Manufacturing	0.0444	15(a)		1.00		
Complexity Reduction	0.0410	16(a)		1.00		
Kaizen Events	0.0381	17(a)		0.50		

Table D7: Worksheet to Calculate the Lean Production LIS						
Lean Production Element	Element Weight	Question Number	Site's Response	Question Weight	Adjusted Question Score	Element Score
		17(b)		0.50		
Ergonomic Design	0.0305	18(a)		1.00		
Cross-training	0.0421	19(a)		0.34		
		9(b)		0.33		
		9(c)		0.33		
Lean Production LIS						

<u>Intensity of Importance</u>	<u>Definition</u>	<u>Explanation</u>
1	Equal importance	Two criteria contribute equally to the evaluation of performance
2	Weak importance of one item over another	Experience and judgment slightly favor one criterion over another
3	Strong importance	Experience and judgment strongly favor one criterion over another
4	Very strong importance	A criterion is strongly favored and its dominance is demonstrated in practice
5	Absolute Importance	The evidence favoring one criterion over another is of the highest possible order of affirmation

Figure D1: The Response Scale for Magnitude of Importance

Appendix E—Detailed Calculations of the Lean Infusion Scores

Supplier and Distribution Integration Elements AHP Calculations ³⁶											
Matrix	PDI	BO	KP	RBP	SB	EDI	SQC	POUMD			
PDI	1.00	1.53	0.77	0.81	1.12	1.93	1.57	0.92			
BO	0.65	1.00	0.45	0.36	0.64	1.79	1.40	0.56			
KP	1.29	2.03	1.00	0.98	2.16	2.67	1.67	1.95			
RBP	1.24	2.78	1.02	1.00	1.57	2.63	1.70	1.17			
SB	0.89	1.57	0.46	0.64	1.00	3.20	1.43	1.24			
EDI	0.52	0.56	0.37	0.38	0.34	1.00	0.62	0.52			
SQC	0.64	0.71	0.60	0.59	0.70	1.63	1.00	0.85			
POUMD	1.09	1.77	0.51	0.85	0.81	1.92	1.17	1.00			
Matrix 2	PDI	BO	KP	RBP	SB	EDI	SQC	POUMD	Row Sums	Normalize	
PDI	8.00	12.48	5.70	6.08	8.66	18.72	11.82	8.90	80.3605	0.1334	
BO	5.32	7.90	3.85	4.08	5.58	12.38	7.85	5.94	52.9113	0.0878	
KP	11.61	18.31	7.90	8.78	12.26	27.43	16.89	12.88	116.0639	0.1926	
RBP	10.72	16.76	7.56	8.00	11.53	25.40	16.17	11.80	107.9397	0.1791	
SB	8.11	12.22	5.65	6.13	8.10	18.56	11.73	8.72	79.2082	0.1315	
EDI	3.62	5.63	2.58	2.77	3.88	8.10	5.20	3.96	35.7392	0.0593	
SQC	5.63	8.77	3.97	4.33	6.03	12.78	7.99	6.26	55.7758	0.0926	
POUMD	7.50	11.80	5.31	5.66	7.88	17.21	11.17	7.99	74.5253	0.1237	
									602.5240	1.0000	
Matrix 3	PDI	BO	KP	RBP	SB	EDI	SQC	POUMD	Row Sums	Normalize	Difference
PDI	533.11	824.71	376.08	404.68	563.27	1,231.78	780.09	585.30	5,299.0221	0.1335	(0.0001)
BO	351.93	544.64	248.22	267.13	371.94	813.23	514.99	386.38	3,498.4592	0.0881	(0.0003)
KP	766.58	1,185.75	540.94	581.93	810.06	1,771.01	1,121.80	841.62	7,619.6903	0.1919	0.0007
RBP	713.45	1,103.65	503.34	541.63	753.86	1,648.19	1,043.78	783.34	7,091.2469	0.1786	0.0006
SB	525.45	813.07	370.71	398.86	555.47	1,214.25	768.96	577.00	5,223.7593	0.1316	(0.0001)

³⁶ The first matrix presented is the overall matrix calculated from taking the geometric mean across the eight respondents completing the AHP for the supplier and distribution integration elements. The matrix that follows is derived by taking the previous matrix and squaring it. This procedure is done until there are no differences between the normalized scores of each element. Once completed, the importance weight is derived.

Supplier and Distribution Integration Elements AHP Calculations ³⁶											
EDI	238.32	368.66	168.11	180.89	251.79	550.80	348.80	261.66	2,369.0344	0.0597	(0.0003)
SQC	371.42	574.55	262.02	281.91	392.42	858.37	543.63	407.76	3,692.0838	0.0930	(0.0004)
POUMD	494.19	764.45	348.65	375.16	522.25	1,141.97	723.10	542.71	4,912.4886	0.1237	(0.0000)
									39,705.7847	1.0000	
Matrix 4	PDI	BO	KP	RBP	SB	EDI	SQC	POUMD	Row Sums	Normalize	Difference
PDI	2,319,979.06	3,589,112.34	1,636,691.74	1,761,053.61	2,451,579.38	5,360,803.45	3,394,964.34	2,547,261.97	23,061,445.8932	0.1335	0.0000
BO	1,531,624.39	2,369,492.14	1,080,525.68	1,162,628.01	1,618,505.48	3,539,142.90	2,241,317.74	1,681,674.04	15,224,910.3775	0.0881	0.0000
KP	3,336,112.72	5,161,116.96	2,353,550.64	2,532,382.06	3,525,353.02	7,708,795.63	4,881,933.61	3,662,943.87	33,162,188.5185	0.1919	(0.0000)
RBP	3,104,746.06	4,803,182.32	2,190,326.78	2,356,755.88	3,280,862.15	7,174,173.89	4,543,360.85	3,408,910.77	30,862,318.7081	0.1786	(0.0000)
SB	2,287,009.57	3,538,107.12	1,613,432.52	1,736,027.06	2,416,739.76	5,284,620.51	3,346,718.13	2,511,062.56	22,733,717.2251	0.1316	0.0000
EDI	1,037,151.74	1,604,520.55	731,686.64	787,282.88	1,095,983.94	2,396,559.00	1,517,726.29	1,138,759.06	10,309,670.0893	0.0597	0.0000
SQC	1,616,386.66	2,500,623.12	1,140,323.52	1,226,969.49	1,708,075.83	3,735,004.10	2,365,355.47	1,774,740.26	16,067,478.4559	0.0930	0.0000
POUMD	2,150,765.94	3,327,331.99	1,517,315.79	1,632,607.03	2,272,767.69	4,969,800.66	3,147,344.63	2,361,471.46	21,379,405.1715	0.1237	(0.0000)
									172,801,134.4391	1.0000	
Weights											
0.1919	Kanban Replenishment			KR							
0.1786	Rate-based Planning			RBP							
0.1335	Product Development Integration			PDI							
0.1316	Supplier Broadcast			SB							
0.1237	Point-of-Use Material Delivery			POUMD							
0.0930	Quality Certification			QC							
0.0881	Blanket Orders			BO							
0.0597	Electronic Data Interchange			EDI							
1.0000											

Lean Production Elements AHP_Calculations ³⁷								
Matrix 1	PTT	CT	5S	TPM	KE	ED	SUR	SW
PTT	1.00	3.02	1.95	2.21	2.00	2.16	1.92	1.00
CT	0.33	1.00	0.71	0.74	0.83	1.74	0.70	0.62
5S	0.51	1.40	1.00	1.85	1.00	1.84	0.87	0.75
TPM	0.45	1.35	0.54	1.00	1.00	1.43	0.67	0.60
KE	0.50	1.20	1.00	1.00	1.00	1.47	0.51	0.44
ED	0.46	0.58	0.54	0.70	0.76	1.00	0.53	0.40
SUR	0.52	1.43	1.15	1.49	1.94	1.87	1.00	0.64
SW	1.00	1.77	1.84	1.67	2.26	2.52	1.57	1.00
PPS	1.37	2.17	2.16	2.48	3.03	2.25	2.25	1.10
DFM	0.81	1.10	0.84	1.06	1.07	1.51	0.89	0.74
CR	0.60	1.12	0.81	0.73	0.88	1.49	0.67	0.53
MS	0.48	1.00	0.85	0.70	0.62	1.04	0.56	0.51
QC	0.54	0.82	0.54	0.91	1.20	1.00	0.63	0.51
POUMS	0.51	0.91	0.96	1.10	2.45	1.51	0.84	0.66
MP	0.45	0.82	0.58	1.00	0.78	1.35	0.49	0.47
VC	0.59	0.70	0.54	0.94	0.60	0.96	1.32	0.59
OPF	0.73	1.45	1.24	1.64	2.57	2.10	1.77	0.53
MMP	0.61	1.57	1.60	1.51	2.38	2.52	1.15	1.17
FC	1.04	1.17	1.89	2.12	2.70	2.38	1.10	1.43

³⁷ The first matrix presented is the overall matrix calculated from taking the geometric mean across the eight respondents completing the AHP for the supplier and distribution integration elements. The matrix that follows is derived by taking the previous matrix and squaring it. This procedure is done until there are no differences between the normalized scores of each element. Once completed, the importance weight is derived.

Lean Production Elements AHP_Calculations

Matrix 1	PPS	DFM	CR	MS	QC	POUMS	MP	VC
PTT	0.73	1.24	1.67	2.07	1.84	1.95	2.25	1.70
CT	0.46	0.91	0.89	1.00	1.22	1.10	1.26	1.43
5S	0.46	1.19	1.24	1.17	1.84	1.04	1.74	1.84
TPM	0.40	0.94	1.37	1.43	1.10	0.90	1.00	1.06
KE	0.37	0.93	1.13	1.62	0.83	0.41	1.28	1.57
ED	0.44	0.66	0.67	0.96	1.00	0.66	0.67	1.04
SUR	0.45	1.12	1.49	1.77	1.57	1.19	2.03	0.76
SW	0.91	1.35	1.89	1.95	1.95	1.51	2.12	1.87
PPS	1.00	1.55	2.90	3.02	1.81	2.17	2.90	2.63
DFM	0.65	1.00	0.91	1.26	0.77	0.74	1.14	0.82
CR	0.34	1.10	1.00	1.29	1.14	0.77	1.12	1.24
MS	0.33	0.79	0.72	1.00	0.70	0.67	1.22	0.74
QC	0.55	1.29	1.22	1.43	1.00	0.74	0.91	0.87
POUMS	0.46	1.35	1.29	1.49	1.35	1.00	1.37	1.70
MP	0.34	0.88	0.89	0.82	1.10	0.73	1.00	0.91
VC	0.38	1.22	0.81	1.35	1.15	0.59	1.10	1.00
OPF	0.73	1.64	1.49	1.99	1.35	1.17	1.77	1.74
MMP	0.62	1.51	1.51	2.21	1.49	1.12	1.87	2.03
FC	0.52	1.17	1.57	2.85	2.34	1.43	2.52	2.48

Lean Production Elements AHP_Calculations

Matrix 1	OPF	MMP	FC
PTT	1.37	1.64	0.96
CT	0.69	0.70	0.85
5S	0.85	0.62	0.53
TPM	0.52	0.66	0.47
KE	0.39	0.42	0.37
ED	0.48	0.40	0.42
SUR	0.56	0.87	0.91
SW	1.87	0.85	0.70
PPS	1.37	1.60	1.92
DFM	0.61	0.66	0.85
CR	0.67	0.73	0.64
MS	0.50	0.45	0.35
QC	0.74	0.67	0.43
POUMS	0.85	0.98	0.70
MP	0.56	0.53	0.40
VC	0.58	0.49	0.40
OPF	1.00	0.77	0.60
MMP	1.29	1.00	0.60
FC	1.67	1.67	1.00

Lean Production Elements AHP Calculations								
Matrix 2	PTT	CT	5S	TPM	KE	ED	SUR	SW
PTT	18.99	38.80	31.41	38.53	44.35	52.25	29.45	21.60
CT	10.39	19.23	16.33	20.04	23.38	26.62	15.66	11.41
5S	12.73	24.57	19.44	24.62	27.66	32.92	19.37	13.85
TPM	9.96	19.37	15.77	18.85	21.77	25.97	14.87	10.91
KE	9.55	18.61	14.74	18.28	19.17	24.50	14.35	10.37
ED	7.59	14.55	11.90	14.60	16.61	19.01	11.56	8.14
SUR	13.21	26.03	21.25	25.90	29.37	35.16	18.99	14.65
SW	18.30	36.23	29.27	36.23	41.09	47.86	28.24	19.57
PPS	23.86	47.33	38.99	47.39	53.70	62.94	35.96	26.53
DFM	10.89	21.40	17.75	21.35	24.23	28.15	16.38	11.94
CR	10.15	19.53	16.06	19.58	22.15	26.19	15.33	11.13
MS	7.89	15.61	12.62	15.57	17.32	20.81	11.97	8.68
QC	9.86	19.16	15.62	18.64	21.48	25.06	14.71	10.52
POUMS	12.83	24.81	20.44	24.76	28.03	33.17	19.10	13.88
MP	8.41	16.24	13.08	16.14	18.47	21.64	12.62	9.11
VC	9.33	18.30	14.70	18.04	20.49	23.82	14.16	10.06
OPF	15.43	30.61	24.58	30.21	33.79	40.28	23.19	16.61
MMP	16.39	31.98	26.07	31.88	35.55	42.82	24.84	17.68
FC	19.64	38.80	31.65	38.78	43.62	51.39	29.95	21.51

Lean Production Elements AHP_Calculations								
Matrix 2	PPS	DFM	CR	MS	QC	POUMS	MP	VC
PTT	16.03	35.93	38.82	47.90	41.41	31.31	45.99	43.93
CT	8.51	18.90	20.05	25.41	21.66	16.04	23.68	22.93
5S	10.62	23.71	25.14	31.00	26.64	19.92	28.79	27.68
TPM	8.22	18.24	19.41	24.29	20.51	15.59	22.81	21.90
KE	7.77	17.34	18.20	22.73	19.74	14.71	21.75	20.72
ED	6.18	13.67	14.73	18.46	15.37	11.67	17.23	16.31
SUR	10.85	24.24	26.27	32.69	27.83	20.67	30.82	29.79
SW	15.20	33.77	36.35	44.91	38.18	28.80	42.63	40.68
PPS	19.12	43.50	47.21	59.43	50.43	37.52	56.61	53.51
DFM	8.85	18.99	21.19	26.46	22.43	17.23	25.29	23.81
CR	8.34	18.41	19.42	24.56	20.92	15.74	23.21	22.10
MS	6.56	14.37	15.43	18.92	16.61	12.61	18.37	17.42
QC	8.03	17.61	18.99	23.81	19.38	14.98	22.31	21.03
POUMS	10.42	23.48	24.95	31.77	25.99	19.09	29.41	28.43
MP	6.98	15.36	16.42	20.42	17.28	13.06	18.93	18.32
VC	7.65	16.76	18.14	22.49	18.92	14.58	21.49	19.04
OPF	12.63	28.22	30.50	38.12	31.72	23.81	36.01	33.76
MMP	13.59	30.05	32.01	39.94	33.85	25.15	37.80	36.33
FC	16.18	36.44	38.73	48.58	40.91	30.20	45.56	43.77

Lean Production Elements AHP_Calculations					
Matrix 2	OPF	MMP	FC	Row Sums	Normalize
PTT	25.31	24.28	20.44	646.73	0.0806
CT	13.53	12.73	10.64	337.14	0.0420
5S	16.28	15.45	13.02	413.41	0.0515
TPM	12.79	12.22	10.40	323.85	0.0404
KE	11.89	11.30	9.71	305.44	0.0381
ED	9.59	9.21	7.72	244.12	0.0304
SUR	17.00	16.37	13.65	434.73	0.0542
SW	23.34	22.22	18.85	601.72	0.0750
PPS	30.85	29.96	24.70	789.51	0.0984
DFM	14.11	13.52	11.38	355.32	0.0443
CR	13.08	12.39	10.38	328.66	0.0410
MS	10.27	9.70	8.24	258.99	0.0323
QC	12.29	11.84	10.10	315.42	0.0393
POUMS	16.06	15.23	12.74	414.59	0.0517
MP	10.75	10.24	8.60	272.08	0.0339
VC	11.70	11.36	9.67	300.70	0.0375
OPF	18.90	18.61	16.08	503.08	0.0627
MMP	20.81	19.30	16.47	532.51	0.0664
FC	25.64	23.57	18.99	643.92	0.0803
				8,021.90	1.00

Lean Production Elements AHP_Calculations								
Matrix 3	PTT	CT	5S	TPM	KE	ED	SUR	SW
PTT	7,494.27	14,634.48	11,908.02	14,573.34	16,474.66	19,470.58	11,303.43	8,170.07
CT	3,917.44	7,652.61	6,225.93	7,619.49	8,612.54	10,180.68	5,908.80	4,271.22
5S	4,803.28	9,381.90	7,634.96	9,342.62	10,562.88	12,482.72	7,244.53	5,237.52
TPM	3,763.90	7,351.44	5,982.01	7,321.12	8,276.75	9,781.14	5,677.51	4,103.94
KE	3,550.19	6,933.95	5,643.18	6,905.57	7,810.14	9,226.44	5,354.88	3,871.18
ED	2,837.52	5,542.37	4,509.78	5,519.21	6,239.44	7,374.80	4,279.72	3,094.21
SUR	5,038.98	9,840.76	8,007.23	9,799.74	11,079.05	13,092.50	7,601.57	5,493.63
SW	6,976.77	13,625.22	11,087.22	13,568.37	15,339.59	18,129.50	10,522.24	7,607.48
PPS	9,148.24	17,865.41	14,535.97	17,790.54	20,112.34	23,770.48	13,798.92	9,973.69
DFM	4,129.05	8,063.95	6,561.09	8,030.40	9,078.24	10,730.04	6,228.08	4,501.92
CR	3,820.37	7,462.02	6,071.70	7,430.77	8,400.84	9,928.36	5,762.37	4,165.53
MS	3,009.00	5,876.48	4,781.91	5,852.02	6,616.54	7,818.92	4,538.43	3,280.70
QC	3,666.18	7,160.47	5,826.54	7,131.34	8,061.95	9,528.24	5,530.05	3,997.93
POUMS	4,803.95	9,382.71	7,634.36	9,343.69	10,563.59	12,483.98	7,246.34	5,238.31
MP	3,162.24	6,176.51	5,026.03	6,150.77	6,953.53	8,218.03	4,769.70	3,448.11
VC	3,497.12	6,829.94	5,558.00	6,802.03	7,689.94	9,088.90	5,274.56	3,813.51
OPF	5,831.54	11,388.36	9,267.42	11,341.74	12,823.39	15,153.82	8,796.02	6,358.91
MMP	6,174.95	12,060.03	9,813.52	12,009.89	13,579.16	16,046.34	9,313.60	6,733.21
FC	7,458.06	14,565.42	11,851.59	14,504.44	16,398.45	19,379.93	11,248.60	8,131.85

Lean Production Elements AHP_Calculations								
Matrix 3	PPS	DFM	CR	MS	QC	POUMS	MP	VC
PTT	6,158.74	13,667.65	14,659.37	18,308.89	15,502.07	11,661.88	17,285.94	16,440.92
CT	3,219.53	7,145.11	7,664.38	9,571.37	8,104.95	6,097.51	9,038.17	8,595.68
5S	3,947.27	8,759.99	9,397.21	11,736.59	9,937.72	7,476.21	11,082.32	10,540.55
TPM	3,093.32	6,865.11	7,363.92	9,196.78	7,787.54	5,858.26	8,683.69	8,259.22
KE	2,917.80	6,475.31	6,946.60	8,675.64	7,345.41	5,526.16	8,191.07	7,790.86
ED	2,332.09	5,175.76	5,551.68	6,933.29	5,871.54	4,416.83	6,546.72	6,227.25
SUR	4,141.31	9,190.19	9,857.33	12,310.68	10,424.18	7,842.60	11,623.75	11,054.60
SW	5,733.60	12,724.44	13,648.47	17,045.97	14,434.47	10,858.76	16,094.58	15,308.29
PPS	7,518.97	16,685.77	17,896.26	22,349.71	18,925.57	14,237.86	21,101.72	20,070.86
DFM	3,393.66	7,532.34	8,078.24	10,088.83	8,543.05	6,426.01	9,525.08	9,060.62
CR	3,139.78	6,968.30	7,474.72	9,334.88	7,904.51	5,946.36	8,814.08	8,383.45
MS	2,472.85	5,488.25	5,886.80	7,352.37	6,225.03	4,682.80	6,941.48	6,602.52
QC	3,013.19	6,687.59	7,173.07	8,958.18	7,586.87	5,706.88	8,458.53	8,045.99
POUMS	3,948.31	8,761.70	9,398.61	11,736.79	9,940.21	7,478.74	11,082.94	10,540.31
MP	2,598.78	5,767.59	6,186.73	7,726.68	6,542.88	4,922.01	7,295.94	6,939.29
VC	2,874.16	6,379.24	6,842.09	8,545.40	7,236.56	5,443.01	8,068.08	7,676.28
OPF	4,792.77	10,636.25	11,408.39	14,247.89	12,065.95	9,077.02	13,452.63	12,796.22
MMP	5,074.76	11,262.04	12,080.89	15,087.48	12,776.06	9,611.96	14,245.78	13,548.71
FC	6,129.33	13,601.56	14,590.43	18,221.10	15,430.27	11,609.32	17,205.11	16,362.98

Lean Production Elements AHP_Calculations						
Matrix 3	OPF	MMP	FC	Row Sums	Normalize	Difference
PTT	9,572.21	9,125.17	7,688.34	244,100.03	0.0805	0.0001
CT	5,003.85	4,770.69	4,019.80	127,619.75	0.0421	(0.0001)
5S	6,136.36	5,850.33	4,928.83	156,483.80	0.0516	(0.0001)
TPM	4,808.41	4,583.90	3,861.80	122,619.75	0.0404	(0.0001)
KE	4,536.12	4,324.60	3,643.09	115,668.19	0.0381	(0.0001)
ED	3,625.19	3,455.96	2,911.67	92,445.04	0.0305	(0.0001)
SUR	6,436.82	6,136.28	5,170.25	164,141.47	0.0541	0.0001
SW	8,912.86	8,497.09	7,158.80	227,273.72	0.0750	0.0001
PPS	11,685.82	11,139.79	9,386.37	297,994.28	0.0983	0.0001
DFM	5,274.49	5,027.94	4,236.16	134,509.20	0.0444	(0.0001)
CR	4,880.39	4,652.80	3,920.11	124,461.34	0.0410	(0.0001)
MS	3,843.73	3,664.40	3,087.22	98,021.45	0.0323	(0.0000)
QC	4,684.26	4,465.34	3,761.78	119,444.36	0.0394	(0.0001)
POUMS	6,137.59	5,851.56	4,930.30	156,503.99	0.0516	0.0001
MP	4,039.81	3,851.38	3,244.80	103,020.80	0.0340	(0.0001)
VC	4,468.19	4,259.13	3,587.96	113,934.08	0.0376	(0.0001)
OPF	7,451.10	7,102.63	5,983.41	189,975.46	0.0626	0.0001
MMP	7,888.81	7,521.53	6,336.95	201,165.67	0.0663	0.0000
FC	9,526.90	9,084.02	7,654.74	242,954.12	0.0801	0.0001
				3,032,336.51	1.00	

Lean Production Elements AHP Calculations								
Matrix 4	PTT	CT	5S	TPM	KE	ED	SUR	SW
PTT	1,071,633,488.41	2,092,971,290.62	1,703,068,726.66	2,084,264,001.42	2,356,391,271.37	2,784,809,754.80	1,616,373,748.95	1,168,468,405.25
CT	560,261,364.37	1,094,227,617.68	890,382,414.83	1,089,675,352.16	1,231,946,374.05	1,455,928,112.70	845,057,354.92	610,887,689.02
5S	686,976,012.75	1,341,709,732.06	1,091,760,745.41	1,336,127,882.03	1,510,576,440.16	1,785,216,249.50	1,036,184,481.07	749,052,526.47
TPM	538,309,953.16	1,051,355,052.30	855,496,644.09	1,046,981,151.14	1,183,677,908.57	1,398,883,885.18	811,947,448.72	586,952,705.68
KE	507,791,327.99	991,750,153.09	806,995,629.63	987,624,225.15	1,116,571,190.04	1,319,576,395.38	765,915,380.35	553,676,358.94
ED	405,840,482.08	792,633,387.19	644,972,600.67	789,335,833.39	892,393,703.16	1,054,640,934.20	612,140,164.80	442,513,032.34
SUR	720,605,833.49	1,407,390,995.97	1,145,206,148.95	1,401,535,894.15	1,584,524,298.61	1,872,608,663.61	1,086,909,253.07	785,721,199.09
SW	997,760,589.43	1,948,692,622.29	1,585,667,937.78	1,940,585,571.41	2,193,953,793.94	2,592,839,310.59	1,504,949,256.01	1,087,920,211.23
PPS	1,308,238,549.88	2,555,076,671.54	2,079,087,844.08	2,544,446,908.15	2,876,656,930.39	3,399,665,574.84	1,973,251,558.20	1,426,453,568.39
DFM	590,506,004.87	1,153,297,401.01	938,448,006.63	1,148,499,394.14	1,298,450,649.02	1,534,523,611.08	890,676,164.28	643,865,294.59
CR	546,394,344.58	1,067,144,405.85	868,344,576.02	1,062,704,816.45	1,201,454,498.10	1,419,892,461.33	824,141,354.06	595,767,619.00
MS	430,322,405.58	840,448,206.10	683,879,930.40	836,951,730.34	946,226,466.08	1,118,261,095.35	649,066,911.95	469,207,189.09
QC	524,369,767.45	1,024,128,943.72	833,342,525.59	1,019,868,312.02	1,153,025,141.47	1,362,658,102.15	790,921,089.64	571,752,858.99
POUMS	687,076,645.05	1,341,906,269.54	1,091,920,665.19	1,336,323,602.13	1,510,797,711.56	1,785,477,751.98	1,036,336,270.24	749,162,250.96
MP	452,269,290.71	883,311,930.99	718,758,511.82	879,637,131.20	994,484,989.55	1,175,293,563.90	682,169,991.63	493,137,239.50
VC	500,176,328.87	976,877,552.48	794,893,663.66	972,813,499.08	1,099,826,721.88	1,299,787,612.31	754,429,471.25	545,373,253.78
OPF	834,017,462.90	1,628,891,431.43	1,325,442,961.86	1,622,114,836.86	1,833,902,644.45	2,167,326,798.22	1,257,971,075.91	909,380,932.52
MMP	883,143,284.08	1,724,837,423.44	1,403,515,039.42	1,717,661,666.51	1,941,924,334.22	2,294,988,045.59	1,332,068,878.18	962,945,859.89
FC	1,066,608,259.68	2,083,156,690.28	1,695,082,503.03	2,074,490,233.02	2,345,341,420.88	2,771,750,909.31	1,608,794,058.06	1,162,989,092.26

Lean Production Elements AHP_Calculations								
Matrix 4	PPS	DFM	CR	MS	QC	POUMS	MP	VC
PTT	880,721,986.74	1,954,578,820.60	2,096,553,342.66	2,618,358,209.44	2,217,205,981.43	1,667,968,288.47	2,472,255,870.60	2,351,474,948.90
CT	460,450,804.54	1,021,874,558.24	1,096,100,348.80	1,368,905,471.24	1,159,178,831.23	872,031,533.32	1,292,521,622.85	1,229,376,072.92
5S	564,591,238.18	1,252,992,537.38	1,344,006,023.80	1,678,511,647.91	1,421,351,004.14	1,069,259,429.67	1,584,852,016.41	1,507,424,802.48
TPM	442,410,037.29	981,836,837.24	1,053,154,412.44	1,315,270,851.93	1,113,761,437.54	837,864,759.87	1,241,879,769.70	1,181,208,307.41
KE	417,328,305.02	926,173,160.69	993,447,504.37	1,240,703,671.22	1,050,618,508.80	790,363,355.36	1,171,473,378.35	1,114,241,587.48
ED	333,540,002.11	740,222,493.68	793,989,953.74	991,603,728.68	839,682,561.72	631,679,642.72	936,273,018.94	890,531,835.40
SUR	592,229,907.53	1,314,330,798.35	1,409,799,699.57	1,760,680,511.87	1,490,930,978.20	1,121,603,324.26	1,662,435,919.77	1,581,218,373.85
SW	820,009,544.49	1,819,840,213.78	1,952,027,747.74	2,437,862,071.82	2,064,363,220.44	1,552,987,145.31	2,301,831,279.94	2,189,376,375.99
PPS	1,075,175,859.18	2,386,128,646.09	2,559,449,603.62	3,196,463,326.73	2,706,741,041.23	2,036,237,616.96	3,018,103,176.68	2,870,655,136.83
DFM	485,307,363.42	1,077,038,510.86	1,155,271,233.80	1,442,803,222.32	1,221,754,888.24	919,106,487.27	1,362,295,930.64	1,295,741,597.28
CR	449,054,194.50	996,582,159.06	1,068,970,788.80	1,335,023,718.01	1,130,488,016.64	850,447,895.44	1,260,530,441.93	1,198,947,809.97
MS	353,660,470.78	784,875,678.54	841,886,606.90	1,051,421,237.29	890,335,572.36	669,785,085.96	992,752,755.05	944,252,278.89
QC	430,953,296.18	956,410,990.04	1,025,881,709.14	1,281,210,326.83	1,084,919,246.20	816,167,242.96	1,209,719,795.03	1,150,619,497.33
POUMS	564,673,944.15	1,253,176,082.26	1,344,202,898.87	1,678,757,517.91	1,421,559,211.79	1,069,416,064.64	1,585,084,168.69	1,507,645,607.02
MP	371,697,518.30	824,905,144.46	884,823,690.25	1,105,044,801.52	935,743,604.85	703,944,816.72	1,043,384,169.21	992,410,117.71
VC	411,069,918.42	912,283,980.73	978,549,449.56	1,222,097,685.29	1,034,863,105.69	778,510,813.41	1,153,905,590.32	1,097,532,075.23
OPF	685,437,256.06	1,521,185,077.17	1,631,679,230.18	2,037,782,973.75	1,725,579,257.84	1,298,125,436.00	1,924,076,280.28	1,830,076,424.35
MMP	725,811,311.69	1,610,786,873.64	1,727,789,428.23	2,157,813,748.50	1,827,220,411.26	1,374,588,439.93	2,037,409,435.62	1,937,872,732.91
FC	876,592,002.77	1,945,413,176.96	2,086,721,945.65	2,606,079,899.32	2,206,808,811.17	1,660,146,672.34	2,460,662,689.31	2,340,448,138.94

Lean Production Elements AHP_Calculations							
Matrix 4	OPF	MMP	FC	Row Sums	Normalize	Difference	Weights
PTT	1,369,022,772.31	1,305,140,815.42	1,099,597,872.18	34,910,859,596.23	0.0805	(0.0000)	0.0983 Pull Production Scheduling
CT	715,739,639.85	682,341,476.67	574,881,444.21	18,251,768,083.62	0.0421	0.0000	0.0805 Production to Takt Time
5S	877,618,908.59	836,667,062.98	704,902,726.02	22,379,781,467.00	0.0516	0.0000	0.0801 Flow Cells
TPM	687,696,490.15	655,606,887.26	552,357,207.08	17,536,651,746.74	0.0404	0.0000	0.0750 Standard Work
KE	648,708,636.79	618,438,304.51	521,042,198.05	16,542,439,271.21	0.0381	0.0000	0.0663 Mixed-Model Production
ED	518,465,382.26	494,272,517.46	416,430,932.27	13,221,162,206.80	0.0305	0.0000	0.0627 One-Piece Flow
SUR	920,581,344.22	877,624,764.74	739,410,118.36	23,475,348,027.64	0.0541	(0.0000)	0.0541 Set-up Reduction
SW	1,274,649,393.27	1,215,171,131.70	1,023,797,257.82	32,504,284,674.97	0.0750	(0.0000)	0.0516 Point-of-Use Material Storage
PPS	1,671,288,167.34	1,593,301,766.56	1,342,377,169.59	42,618,799,116.28	0.0983	(0.0000)	0.0516 5S
DFM	754,377,480.00	719,176,376.28	605,915,317.17	19,237,054,932.91	0.0444	0.0000	0.0444 Design for Manufacturing
CR	698,024,382.84	665,452,855.92	560,652,562.53	17,800,018,901.02	0.0410	0.0000	0.0421 Cross-Trained Workforce
MS	549,741,288.97	524,089,013.75	441,551,712.80	14,018,715,636.19	0.0323	0.0000	0.0410 Complexity Reduction
QC	669,887,762.41	638,629,157.24	538,053,250.97	17,082,519,015.36	0.0394	0.0000	0.0404 Total Productive Maintenance
POUMS	877,747,466.51	836,789,623.02	705,005,987.34	22,383,059,738.85	0.0516	(0.0000)	0.0394 Quality Assurance
MP	577,778,661.15	550,818,094.25	464,071,305.82	14,733,684,573.55	0.0340	0.0000	0.0381 Kaizen Events
VC	638,980,396.82	609,164,003.50	513,228,479.99	16,294,363,602.27	0.0376	0.0000	0.0376 Visual Controls
OPF	1,065,465,872.26	1,015,748,623.81	855,781,236.24	27,169,985,812.09	0.0627	(0.0000)	0.0340 Mistake-Proofing
MMP	1,128,224,610.59	1,075,578,891.02	906,189,005.91	28,770,369,420.65	0.0663	(0.0000)	0.0323 Method Sheets
FC	1,362,602,996.15	1,299,020,610.25	1,094,441,523.15	34,747,151,632.51	0.0801	(0.0000)	0.0305 Ergonomic Design
				<u>433,678,017,455.90</u>	<u>1.00</u>		<u>1.0000</u>

Appendix F—Interview Protocol

I. Interviewees—Potential

1. FTS—Focal firm (1st Tier Supplier, MC Program)
 - 1.1. PE
 - 1.2. CJ
 - 1.3. CA
 - 1.4. JH
 - 1.5. FD
 - 1.6. SD
 - 1.7. WC
 - 1.8. Individual(s) completing the Supplier/Distribution Integration instruments if not included above
2. Off-site FTS (1st Tier Supplier, 2TA Program)
 - 2.1. HJ
 - 2.2. Materials Manager
 - 2.3. Operator
 - 2.4. Individual(s) completing the Supplier/Distribution Integration instruments if not included above
3. STS(2nd Tier Supplier, Program B)
 - 3.1. Plant Manager
 - 3.2. Lead Industrial Engineer
 - 3.3. Individual(s) completing the Supplier/Distribution Integration instruments if not included above
4. Prime (Prime, MC & 2TA Programs)
 - 4.1. SJ
 - 4.2. Supplier Development Team member
 - 4.3. Supplier Development Team member
 - 4.4. Operator (MC Program)
 - 4.5. Individual(s) completing the Supplier/Distribution Integration instruments if not included above

II. Introduction

1. Purpose of Interview
 - 1.1. To understand the dynamics of Program A's and Program B's supply chain.
 - 1.2. To understand how Lean principles affect the supply chain.
2. What they will get
 - 2.1. Summary report of findings
3. Ensure confidentiality, if wanted
4. Permission to audiotape

III. General Orientation Interview³⁸

1. The Person and His/Her Job (Individual Level)
 - 1.1. What do you do here? Please tell me about your past experience in the organization and your current job. (Probe for job title, description of work, department, or unit in which person works, previous positions in organization, time spent in them.)
 - 1.2. What is it like to work here? (Probe for feelings about work ad atmosphere.)
2. Work Roles, Technology, and Outputs (Individual and Group Levels)

³⁸ Harrison, M. I. 1994. *Diagnosing Organizations Methods, Models, and Processes* 2nd Ed. Sage Publications: Thousand Oaks, CA.

- 2.1. What tasks does your unit (group/department/division/organization) perform? What are the main techniques and means used to do these things?
- 2.2. What are the main outputs of this unit—products, services, ideas? What units in the organization or outside receive these outputs?
- 2.3. How does your job fit into the work done here? With whom do you have to work inside and outside the organization to get things done? How do you communicate with them—informal discussions, meetings, telephone, written reports, computer links, etc.?
- 2.4. Are there difficulties and barriers to getting work done here or to doing it the way you'd like?
3. Group Structures and Processes—Controls, Coordinating Mechanisms (Group and Organizational Level)
 - 3.1. How is work coordinated within the unit? (Probe for the kinds of controls used, e.g. budgets, direct supervision, QC, evaluations, etc.)
 - 3.2. Are goals and objectives spelled out for your unit? If so, how? (Probe for the specification of targets versus general direction and for the ways in which they are specified.)
4. Environment—Relations within the Organization (Group and Organization Levels)
 - 4.1. What other units do you have to work with to get work done? How are contacts with other units coordinated?
 - 4.2. What kinds of things does your unit need to get from other units—funds, approval for actions, materials, people, information, etc.? How do you get these things?
 - 4.3. Are relations to other units pretty smooth and trouble free or do uncertainties and problems arise? If so, please describe them.
5. Environment—External Relations (Group and Organization Levels)
 - 5.1. What kinds of contacts does your unit have with external groups or organizations? In what markets or fields (areas) does your unit work (compete)? What kinds of things do people in your unit need to know about what is going on outside the organization? (Probe for important technical conditions.) How do they find out?
 - 5.2. What are the main kinds of resources—people, materials, services, funds, and information—that you get from these groups and supply to them? On which groups do you depend the most?
 - 5.3. Do you run into problems and challenges in obtaining or supplying these resources and in dealing with external groups and conditions? If so, please describe them and explain how you handle them.
 - 5.4. What are the main needs and expectations of your customers/clients/constituencies? How well do your unit and organization as a whole satisfy these expectations?
6. Structure and Processes (Group and Organization Levels)
 - 6.1. How is work in this unit organized and how does the unit fit into the whole organization? (Probe for formal structure.)
 - 6.2. Are there opportunities for obtaining additional skills or training while working here?
 - 6.3. How do people find out about what's going on in the unit and in the organization as a whole? (Probe for informal and official communication channels and their uses.)
 - 6.4. How are decisions made in your unit? What about the organization/division as a whole—how are decisions made that affect your unit?
 - 6.5. What do you have to do to get ahead around here? Do you get rewarded for doing your job well? (Probe for kinds of rewards—pay, promotion, praise, feelings of doing well—and the kinds of behavior rewarded in the unit and the organization.)
 - 6.6. When people in the unit disagree about things, how are these differences resolved? (For example, the boss decides alone; we discuss all the sides of the question until we have the best solution; we compromise, etc.)
 - 6.7. Does it pay to take risks or stick your neck out in your unit? (Probe for support for initiative, risk taking, attitudes toward criticisms.)
7. Problems and Challenges (Group and Organization Levels)
 - 7.1. What do you see as the main challenges that will be facing your unit and organization in the next 2 or 3 years? Do you have any suggestions for how to handle them?

- 7.2. What do you feel are the main strengths of your unit? What are the strengths of the organization as a whole? What are the main problems in the unit? What are the main problems in the organization (or division) as a whole?
- 7.3. What things seem to be most in need of change in your unit? What about in the organization as a whole? (Probe for mentioning these problems.)

IV Focus on Programs—Supply Chain Issues

1. General supply chain management questions
 - 1.1. Define supply chain management.
 - 1.2. Define a successful supply chain management
 - 1.3. Is Program A/B an example of a supply chain being successfully managed as you define it?
 - 1.4. What makes it successful? Why is it not successful?
 - 1.5. What is needed to transform Program A/B's supply chain into a best-in-class managed supply chain?
2. Cover each question in Distribution Integration and Supplier Integration instruments.
 - 2.1. What cause the change in the particular element?
 - 2.2. What is needed to increase the use of the particular element near 100 percent?
 - 2.3. Is there anything else not covered in the instrument that is crucial in integrating the supply chain?
3. Impediments to successful supply chain
 - 3.1. People
 - 3.2. Processes
 - 3.3. Technology
4. Solutions to impediments
 - 4.1. People
 - 4.2. Processes
 - 4.3. Technology

VITA

DeWayne L Searcy, CPA CMA CIA began his career working as a public accountant for a local accounting firm in Birmingham, AL. After a few years as a public accountant he worked as a controller in the employment services industry and plastics manufacturing industry also in the Birmingham area. It was as the controller of a plastics manufacturer that DeWayne's interest in pursuing a PhD began. DeWayne received both a Bachelor's of Science with a major in accounting and a Master's of Accountancy from the University of Alabama at Birmingham.