Using an Extended Enterprise Model to Increase Responsiveness

By

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Submitted to the Sloan School of Management and Department of Materials Science and Engineering on May 12, 2006 in partial fulfillment of the Requirements for the Degrees of
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Abstract

OEMinc's new business model is a dramatic departure from that used in the past. The company has moved steadily upstream in the supply chain, leaving more and more of the manufacturing effort to suppliers. Literature shows that extraordinary productivity gains in the production network, or value chain, are possible when companies are willing to collaborate in unique ways, often achieving competitive advantage by sharing knowledge, research and assets[1].

For its newest product, Excelsior, OEMinc has moved to an extended enterprise model involving dozens of Partners. Approximately half are Component Partners (CPs), who supply systems and components. The remainder are Assembly Partner's (APs), who integrate these components into sub-assemblies. Many components are purchased by OEMinc and drop-shipped by CPs to APs, then installed in subassemblies.

For the purposes of this analysis, Critical Safety Inventory is defined as inventory held at a site that buffers against disruptions in quality or upstream delivery and is not needed for production at that time. More specifically, the need for CSI is driven by the following:

- variability in delivery time, resulting in late parts at the AP site or at OEMinc;
- part non-conformances, which result in parts being unavailable for installation; and/or
- part damage upon installation.

The challenge OEMinc faces, which this project attempts to address, is:

"How can OEMinc mitigate supply chain risk in the context of reduced information and control?"

This project focuses on inventory management as a tool for mitigating risk. Therefore, the project definition has been further defined as follows:

To develop an effective safety inventory policy for OEMinc-owned, drop-shipped components within the Excelsior Supply Chain, with the goal of supporting production, reducing inventory cost, and enabling continuous improvement.

[1] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 5

As outlined above, OEMinc's move to the extended enterprise business model is a significant step towards its vision of being a large-scale systems integrator. The success of this transition is important for OEMinc's long-term future, in addition to being an enabler for the Excelsior.

The following approach was used:

1) Case Studies: Components were selected based on characteristics that bracketed the types of issues that might be seen in the supply chain at OEMinc. It was expected that examination of these supply chains would reveal particular issues representative of a wider selection of components.
2) Simulation analysis: A generic simulation model was created for components under the Excelsior Business model. The simulation was used to determine how many shipsets of inventory should be held at the AP site for a varying lead times, expedite lead times and risks of non-conformance.
3) Benchmarking: Representatives of peer companies were interviewed and site visits were conducted to gather information on how they manage their relationships with partner suppliers, with special attention paid to inventory management, partner management, incentives and data exchange.
4) Metrics Analysis: OEMinc's existing metrics system was assessed to determine what changes might be made given the business model shift for the Excelsior program.
5) Implementation: Based on the results of the preceding steps, a set of guidelines was developed for Partners to reach the desired state with respect to CSI management. Using a Systems Dynamics framework, the supply chain was analyzed to determine what incentives should be applied to encourage the desired supplier behavior.

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Finally, a dedication: to Malcolm Bernard MacDonald, who would have thoroughly enjoyed LFM, and provided me with a sense of wonder at life.

Figures

Tables

1. Industry Business Environment

The industry is currently defined by competition between OEMinc and a single large competitor. Since 1976, the competitor has eroded OEMinc's share in a growing market and has now taken the lead. This may be misleading as an indicator of performance, since OEMinc's products are typically of higher dollar value.

1.1. The Excelsior

The Excelsior is distinguished by its use of technology to obtain superior capabilities. OEMinc's competition has responded with a competing product, which will enter the market two years after Excelsior. OEMinc expects the Excelsior to be the fastest-selling product in the history of the industry.

1.2. Business Model Description

1.2.1 Extended Enterprise Overview

OEMinc's business model for the Excelsior is a dramatic departure from that used in the past. In recent history the company has moved steadily upstream in the supply chain, leaving more and more of the manufacturing effort to suppliers and evolving into the role of a subsystems integrator. The results of this evolution are shortened lead times, reduced raw materials inventory, less time in final assembly, and closer integration with suppliers.

This business model is a true manufacturing partnership, an extended enterprise model. The Extended Enterprise has been well defined in the book "Collaborative Advantage" by Jeffrey H. Dyer, as the "set of firms within a value chain or production network that collaborate to produce a finished product"[2]. Dyer asserts that extraordinary productivity gains in the production network, or value chain, are possible when companies are willing to collaborate in unique ways, often achieving competitive advantage by sharing knowledge, research and assets[3]. These gains are achieved by forming close relationships with a small set of partners. These partner relationships are characterized by:

- dedicated investments in the partnership, such as dedicated or specialized design investments or facilities;
- greater knowledge sharing; and
- trust[4].

Use of partnerships in complex-product industries requires a high degree of co-ordination. For example, dedicated assets are, by nature, designed to exist in harmony with the partner to whom they are dedicated. Each of the three above-listed attributes of an extended enterprise facilitate greater co-ordination of work activities and allow for specialization through the use of multiple firms versus a vertically integrated model.

[2] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 8
[3] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 5
[4] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 37

For the Excelsior, the extended enterprise involves dozens of Partner companies. Approximately half of these are Component Partners (CPs), who supply systems and components. The remainder are classified as Assembly Partners (APs), who integrate these components into subassemblies. The Partners have worked closely with OEMinc in the design of their respective systems or subassemblies. As a result, the partners find themselves with a greater share of the product in terms of manufacturing content than has been seen in the past.

The Excelsior represents a shift from a technically advanced and customized product to an even-more advanced product that can be delivered at lower cost and with shorter lead times. This represents a supply chain strategy shift away from customization and toward flexibility and velocity.

1.2.2 Operating Objectives

One of the stated operating goals for the Excelsior program is to restrict final assembly to only three days. The significance of this goal cannot be underestimated. Currently, final assembly takes significantly longer for existing products.

The business model has been designed to reduce production cost and risk through:

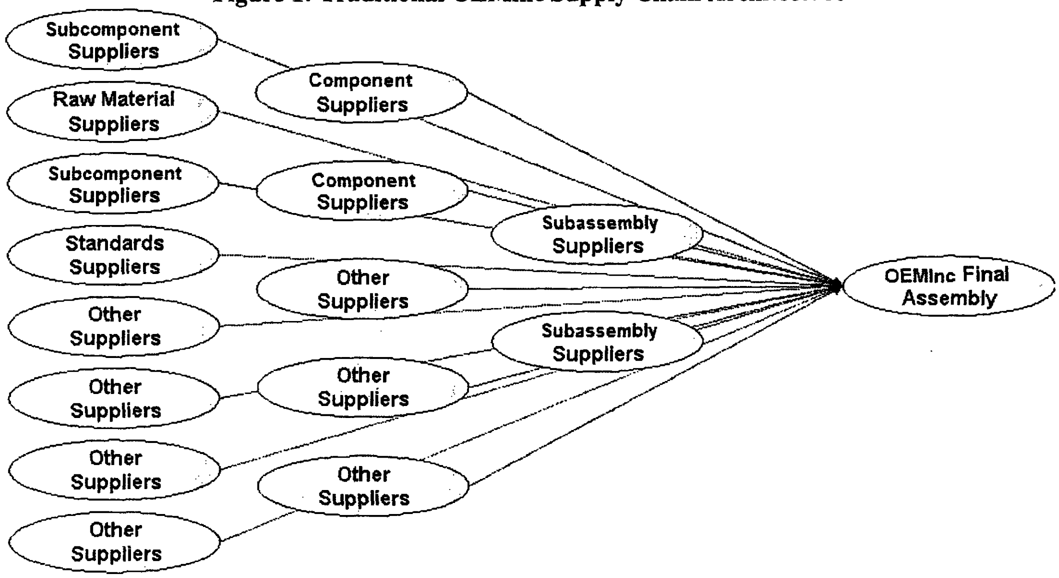
- Decreased product complexity:
  - reduced part number and part complexity;
  - increased commonality in systems and components;
  - fewer customer options;
  - an emphasis on quality assurance at the upper end of the supply chain; and
  - use of Design for Manufacture and Assembly (DFMA) principles.
- Leveraging the supply base to:
  - allow suppliers greater flexibility in end item configuration;
  - postpone acquisition of parts to reduce capital layout;
  - make use of supplier knowledge in the design, including supplier co-location with the OEMinc team.
- Application of lean principles throughout the supply chain and manufacturing process.

These objectives constitute a huge change in the way that OEMinc operates. The challenges to implement these objectives span design, manufacturing and supply chain, changing the way that objectives are enforced upon the program and its suppliers and increasing the difficulty of these objectives themselves.

1.3. Supply Chain Description

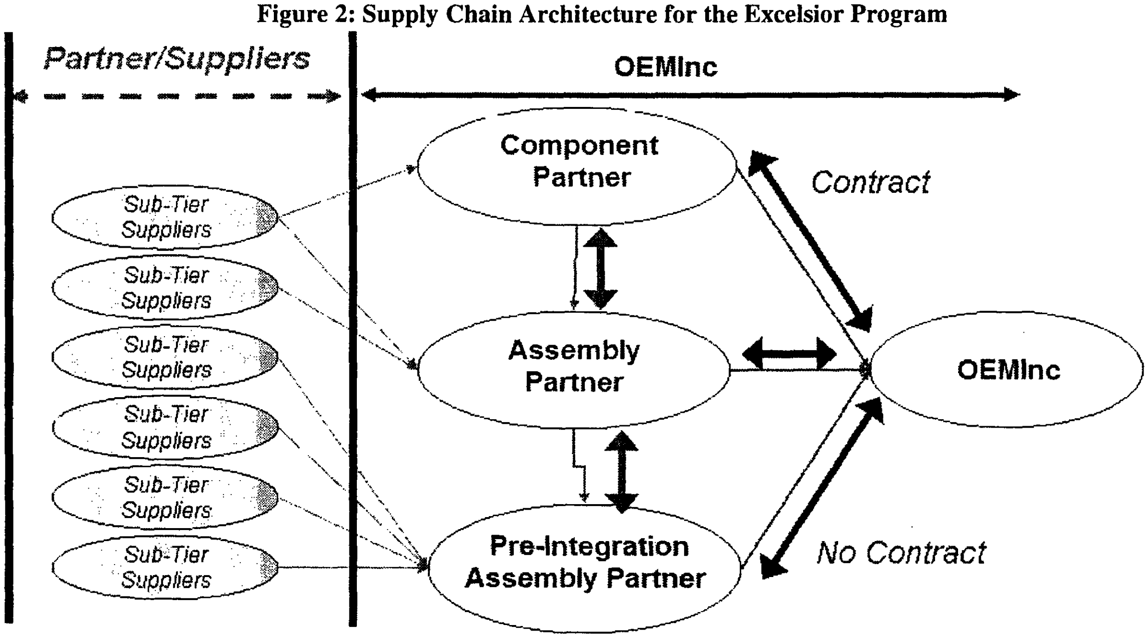
The Excelsior Supply Chain has been dramatically altered by changes to the business model. OEMinc traditionally received the majority of components such at its assembly facility, to be then integrated into the completed product. OEMinc therefore had direct contractual relationships with many of its suppliers.

Figure 1: Traditional OEMinc Supply Chain Architecture



Under the Excelsior business model, represented in Figure 4, CPs contract with OEMinc to directly supply components to APs and to OEMinc. These components are ordered to the schedule of the receiving partner. While APs also contract directly with OEMinc, there is no contract between APs and CPs.

Figure 2: Supply Chain Architecture for the Excelsior Program



Sections "stuffed" with CP components are sent to final assembly for integration into the completed product, according to OEMinc's schedule.

An implication to OEMinc of becoming a system integrator is that they are doing much less of the assembly work than it has on previous programs. While the dissolution of work to the Partners allows for a higher rate of product production and technical specialization, OEMinc has created risk by relinquishing control in the supply chain's lower tiers.

2. Problem Statement and Project Objectives

2.1. *Business Model Risk*

The Excelsior business model places significant pressure on the supply chain, primarily due to the rate of production. As stated previously, OEMinc ultimately endeavors to produce a product every three days, and must have a high degree of confidence in the ability of its supply chain to support this rate. This risk is compounded by a lack of visibility and a reduced level of control in the supply chain. OEMinc has dramatically reduced the number of relationships it has with suppliers, and has thereby reduced its visibility in the supply chain. For this purpose, visibility is defined as:

- the ability to detect problems (late delivery, quality departures) in real time throughout the depth of the supply chain; and
- the ability to monitor trends in quality and delivery throughout the depth of the supply chain in order to assess supplier performance and select improvement initiatives.

On the Exclesior program, OEMinc will have increased real-time visibility on the parts for which it contracts, however this is a much smaller subset of the overall product, including only components purchased by OEMinc and drop-shipped to APs, and components sent directly to OEMinc. On previous programs, OEMinc has used EDI and faxed communication to collect the following:

- Order acceptance by supplier, by Purchase Order (PO);
- Expected Date of Arrival by PO; and
- Date that order received by PO.

For the Excelsior, OEMinc is implementing the TRACK system to track order and acceptance for all OEMinc-owned material. The information available on TRACK is expected to include:

- OEMinc orders for volume sections by OEMinc PO;
- Acceptance of OEMinc orders by APs by OEMinc PO;
- Date of receipt of sections at OEMinc;
- Partner requests for CP components by OEMinc PO with dates;
- Acceptance of delivery dates by CPs by OEMinc POs; and
- Date of receipt of components into AP-held inventory.

As this information is kept in a single system so that inventory levels and potential future shortfalls can be detected in real time. Furthermore, capability can be added to the program to log quality defects upon initial inspection by part, which could generate a re-order for a replacement part. Part classification could be altered to indicate a non-conformance after the fact if the part is damaged upon installation, again generating a requirement for a replacement part.

By using TRACK, OEMinc can monitor parts sent by a CP to an AP and therefore will have real-time visibility in the supply chain to help anticipate problems. However, because a reduced number of parts are in the system, there is no real-time visibility OR performance visibility for parts that are outside the CP to AP loop.

This reduced visibility diminishes OEMinc's ability to anticipate potential shortfalls. Examples include:

- near-term risks with the sub-tiers, for example a critical shortage of a certain type of sub-component, or a defective production run the same sub-component;
- near-term risks with CP quality or capacity processes; and
- near-term risks with AP quality or component availability at the AP.

Furthermore, with reduced visibility, OEMinc is less able to monitor the behavior of suppliers through the chain and detect systematic weaknesses, which provides an opportunity for improvement efforts. Examples include:

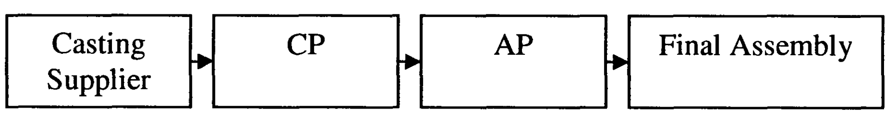
- chronic problems with sub-tier product quality;
- chronic problems with sub-tier production capacity or lead time variability; and
- chronic problems within AP assembly processes.

2.1.1 The Role of Critical Safety Inventory

For the purposes of this analysis, Critical Safety Inventory (CSI) is defined as inventory held at a site that buffers against disruptions in quality or upstream delivery and is not needed for production at that time. The need for CSI is driven by risks such as variability in delivery time, resulting in late parts at the AP site or at final Assembly; part non-conformances, which result in parts being unavailable for installation; or part damage upon installation.

Risk of Shortages

These risks exist at all stages of the supply chain and can cause a disruptive effect downstream. For example, one of the casting suppliers to a CP for a particular component could have an emergency shutdown. If product arrives late at the CP site or that of its contract assembler, the CP may not be able to deliver to the AP on time, and this could jeopardize the AP's ability to meet its delivery requirements to OEMinc. This is especially problematic given the fast rate of production in the Excelsior program wherein, if a Partner gets behind it will be difficult to recover by the time the next shipset is required, roughly three days later.



These risks can be counteracted by having the CP contract assembler hold spare castings or by having the casting supplier hold finished goods inventory. Furthermore, the CP could build flexibility into its own process to permit it to adjust the order of its assembly steps and cushion against small diversions in the delivery schedule for sub-components.

Finally, the AP could hold CSI at its site. It should be noted that the stated policy for this program is that there will be no OEMinc-owned CSI at AP sites, and that all orders will be single-shipset, just-in-time, and dedicated to a single line number.

Risk of Excess Inventory

A second and contrary risk associated with CSI at the AP sites is that excess inventory will be held, robbing the supply chain of capital and obscuring delivery and quality problems, allowing them to remain undetected and unaddressed. This is particularly problematic for the Excelsior business model. As it stands, APs will order components from CPs according to their production schedule; however the CP components are owned by OEMinc and are held as inventory on OEMinc's balance sheet. Therefore, the natural cost incentive to keep inventory low does not counter the desire to have excess components on hand in support of production in the event of any disruption. This aggravates the risk that APs will over-order to buffer against risks with CP delivery or quality, or chronic problems with component damage upon integration, instead of dealing with these issues.

In a truly lean supply chain, an inventory-starved system would be very sensitive to chronic problems with quality or delivery. As the pain is felt immediately, the issue will be highlighted and addressed. The challenge for OEMinc will be to ensure that production is supported while keeping the supply chain "lean and hungry".

2.2. Problem Summary – Inventory

Under the Excelsior Business model, OEMinc is doing much less of the assembly work than it has on previous programs. While this allows for a higher rate of production and technical specialization, OEMinc has relinquished control in the supply chain's lower tiers, thereby creating risk. Reduced visibility diminishes OEMinc's ability to anticipate the following:

- near-term risks with the sub-tiers, for example a critical shortage of a certain type of sub-component, or a defective production run the same sub-component;
- near-term risks with CP quality or capacity processes; and
- near-term risks with AP quality or component availability at the AP.

OEMinc is also less able to monitor the behavior of suppliers through the chain and detect systematic weaknesses such as:

- chronic problems with sub-tier product quality;
- chronic problems with sub-tier production capacity or lead time variability; and
- chronic problems within AP assembly processes (as OEMinc used to do much of this work).

For the purposes of this analysis, Critical Safety Inventory (CSI) is defined as inventory held at a site that buffers against disruptions in quality or upstream delivery and is not needed for production. The need for CSI at AP sites is driven by: variability in delivery time, resulting in late parts at the AP site or at final assembly; part non-conformances, which result in parts being unavailable for installation; or part damage upon installation.

Because components sent to APs are, for the most part, owned by OEMinc, the business model removes the incentive for APs to control inventory. This is not only a financial risk, as OEMinc holds these parts on its balance sheet, but compromises the objective of a Lean supply chain by burying quality problems and confounding the concept of control.

3. Problem Statement and Outline of Approach

3.1. Problem Statement

The challenge OEMinc faces, which this project attempts to address, is as follows:

"How Can OEMinc mitigate supply chain risk in the context of reduced information and control?"

Inventory can be though of as the "lifeblood" of the supply chain. This project focuses on inventory management as a tool for mitigating risk. Therefore, the project definition has been further defined:

To develop an effective safety inventory policy for OEMinc-owned, drop-shipped components within the Excelsior Supply Chain, with the goal of supporting production, reducing inventory cost, and enabling continuous improvement.

In the absence of information, OEMinc must therefore rely on ***incentives*** for partners to tell OEMinc about potential problems with delivery and quality, and ***capabilities*** of the partners to detect problems and participate in solving them. These incentives and capabilities should exist throughout the supply chain; however OEMinc can only directly influence those with whom it has a contract.

As discussed previously, OEMinc's move to the extended enterprise business model is a significant step towards its vision of being a large-scale systems integrator. The success of this transition is in itself important for OEMinc's long-term future, in addition to being an enabler for the Excelsior. Therefore, the long-term strengthening of these relationships should be an objective of any policies that involve or affect relationships between OEMinc and the Partners. With that in mind, policies should encourage:

- Dedicated investments in the partnership, such as dedicated or specialized design investments or facilities;
- Greater knowledge sharing; and
- Trust[5].

3.2. Supply Chain Objectives

The objectives of the Supply Chain are to support the company's strategic vision. The Excelsior program represents a shift in strategy for OEMinc. The company has moved from competing on quality and customization to competing on quality and supply chain speed or flexibility. This is a further step away from OEMinc's legacy of product-focused integrated, almost craft-style manufacturing, to a more modular product.

As MIT Professor Charles Fine remarked in Clockspeed[6] this modular product should be supported by a modular supply chain. Fine also tells us that in the modern business environment,

[5] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 37
[6] Clockspeed, Charles Fine, Perseus Books, 1998, p. 142

competition is moving from a paradigm of company vs. company to that of supply chain vs. supply chain. The modular design of the Excelsior supply chain permits the contribution of partners who are best-in-class at building these modules, allowing for a more competitive final product. This is the advantage of the extended enterprise as defined by Dyer.

This does not tell the whole story. The use of APs to integrate product sub-assemblies further permits a process that was previously completed by OEMinc alone to be simultaneously undertaken by numerous teams all over the world, lessening the time required.

Then what constitutes success in this supply chain? The competitive strategy dictates that the chain should foremost provide the product on-time, and with excellent quality. We also cannot forget explicit profitability objectives posed by any program. These measures address the financial and customer-facing (delivery) components of the balanced scorecard. However, there remain two others: Learning and Growth and Business Process Improvement.

Like with cost, these objectives must be pursued through the design and manufacturing processes as well as the supply chain, but we can look at the supply chain as a potential major enabler for these goals. In summary, we can state the following four broad objectives for the Excelsior Supply Chain.

- Customer-facing: Support customer demand;
- Financial: Meet the recurring cost target;
- Business Process Improvement: Adhere to business processes that are transparent and accommodating of improvement; and
- Learning and Growth: Promotion of learning amongst the partnership that will strengthen collaboration and drove overall enterprise improvement.

3.3. Approach

The methodology for the project included the following phases:

Case Studies

Selected components were selected based on characteristics that bracketed the types of issues that might be seen in the supply chain at OEMinc. The CPs supplying the components and the APs receiving the components were interviewed to determine the following:

Description of Ordering and Scheduling/ Inventory Management Processes and Systems:

- Is production build to order/stock/schedule?
- What information is used to govern Order Fulfillment/ Ordering and Scheduling?
- What are the order receipt and fulfillment processes.

Management of Raw Materials/ subcomponents:

- What replenishment policy (ies) is (are) used? What part factors influence these policies?
- How Much Safety Stock is held (Part-specific)?
- How are raw materials/subcomponents received (physical movement)?
- How are raw material/subcomponent quality problems recorded?

Supply Chain Health

- What metrics are used to gauge supply chain performance?
- What data is tracked to gauge supply chain performance?
- How much visibility will Supplier/Partner have within its supply chain?
- What is the frequency of shortages for the particular items under consideration?
- What is the process for expediting raw materials/components?
- What is the process for expediting customer orders?

The selected parts included:

Component 1: A large, expensive component, one of which is required per Excelsior. This Component has an extensive sub-tier supply chain that includes complex castings and must be considered in the analysis. Given its size, its cost, and the low chance of engineering changes, Component 1 is component for which low inventory levels are desired.

Component 2: A relatively inexpensive component with a short lead time, several are required per Excelsior, and variations of them are sent to almost all of the APs. These components are driven by frequent design changes and difficulties upon installation. Therefore, although production support might require a high level of inventory, the specter of obsolescence is a sobering counterweight.

The supply chain for each of the components was reviewed in consultation with participating CPs and APs. The idea of this effort was to interact with CPs and APs directly with these components as a catalyst for discussion. It was expected that the interviews and mapping of these supply chains would reveal particular issues representative of a wider selection of components.

<u>*Simulation analysis*</u>
A generic simulation model was created for components under the Excelsior Business model. The simulation was used to determine how many shipsets of inventory should be held at the AP site for a given lead time variability, expedite lead time, and risk of non-conformance.

<u>*Benchmarking*</u>
Representatives of peer companies who assemble complex heavy industrial products were interviewed and site visits were conducted to gather information on how they manage their relationships with partner suppliers, with special attention paid to:

- Inventory management and incentives for partners to hold the right amount of CSI;
- How prescriptive these companies are in specifying how partners manage their internal processes, and how much information about these materials and companies require in real time (i.e. quality issues and inventory levels).
- The incentives used to encourage partner orientation to the overall program goals.
- Data tracked and metrics used to drive continuous improvement.
- How these companies respond to the desire of their partners to change ordering and scheduling policy.

These findings were examined in the context of the OEMinc partnership structure and its associated challenges.

Metrics Analysis
A first-principles literature analysis of metrics systems was conducted, focusing on the balanced scorecard approach and the SCOR model. OEMinc's existing metrics system was assessed in this context to determine what changes might be made given the business model shift for the Excelsior program. Ultimately this metrics regime was selected with the following purposes in mind:

- to detect systematic problems in either quality or delivery;
- to encourage partners to perform well;
- to evaluate suppliers; and
- to identify opportunities for improvement.

Systems Dynamics Analysis
Using a Systems Dynamics framework, the supply chain was analyzed to determine what incentives should be applied to encourage the desired supplier behavior. For example, partner metrics and penalties can be specified such that the partners want to reduce materials inventory, but recognize the over-arching need to support the supply chain in a timely manner. Furthermore, the effect of proper information sharing that fosters trust will be to encourage OEMinc to respond when partners request a policy change that will help the program meet its overall goals. The effect of OEMinc's investment in continuous improvement on supplier behavior and on mutual trust and learning was examined.

Implementation
Based on the results of the preceding steps, a set of guidelines will be developed for Partners to, on a part-by-part basis, interact and establish their own standards for inventory levels of OEMinc-owned materials and components shipped to the APs by the CPs. In addition, information tracking and sharing standards were specified.

3.4. Summary of Problem, Objectives and Approach

The purpose of this study is to establish a strategy to begin to address the risks associated with the lack of visibility and greater demands associated with the Excelsior business model through the development of a strategy for Critical Safety Inventory for OEMinc-owned, drop-shipped components delivered to APs by CPs.

The policies driven by this strategy should be consistent with the following broad Supply Chain Objectives:

- Customer-facing: Support customer introduction.
- Financial: Meet the recurring cost target.
- Business Process Improvement: Adhere to business processes that are transparent and accommodating of improvement.
- Learning and Growth: Promotion of learning amongst the partnership that will strengthen collaboration and drive overall enterprise improvement.

This strategy should also strengthen the extended enterprise by encouraging dedicated investments in the partnership, increased knowledge sharing and trust.

In developing this strategy, specific parts were selected and potential supply chain issues and risks identified. Large OEMs in several industries were interviewed to glean best practices for management of partner relationships and complex-product component inventory. Policies for CSI were proposed and screened based on this qualitative work. A simulation was then used to determine exactly how much CSI should be used under the selected policy. Based on examination of the literature and supply chain objectives, adjustments to supply chain metrics were proposed. Finally, an examination of the OEMinc organization and partnership incentives informed a strategy for implementation.

4. Analysis

4.1. *Inventory Management Policy*

4.1.1 Current Practice

Currently, within the OEMinc factory, component inventory supporting assembly is ordered some number of days in advance of need to ensure availability. The length of this period is based on the supplier's past performance in on-time delivery, and the need to ensure sufficient time for the part to be received and moved to the installation site. Under existing programs, units spend longer in final assembly, and there will be several line numbers in the building at one time. Non-conforming parts can be "borrowed" from other line numbers while replacements are ordered or repairs are made, a luxury that will not be as present on the Excelsior program.

Long lead time parts can be sensitive to changes in the program schedule. If the program rate changes, it is inevitable that either the supplier will have to accelerate beyond normal working pace to provide additional shipsets, or in the case that the program slows, inventory will accumulate.

From OEMinc's 2005 Annual report, the amount of inventory held compared to revenue can be translated to five turns per year. The Excelsior Supply chain has been envisioned as a lean, just in-time, single shipset program. OEMinc-owned parts will arrive at the APs just in time to be installed, and volume sections would be immediately sent to a pre-integration-site in the continental United States, and eventually to final assembly. In this world, at a 180 product per year pace, we could expect the following levels of inventory to be held on a per-line number basis at one time:

Table 1: Estimated Shipsets of Inventory in the System under Excelsior Business model

Location	Shipsets of Inventory in the ideal state
APs (assumed 30-day cycle)	10 sets
Pre-Integration (assumed 6 day cycle)	2 sets
Final Assembly (3-day cycle)	1 set
Test spares	1 set*
Total:	***14 sets***

Note: As the relative costs of the components at each of these locations to the entire product cost is confidential and in fact, not yet established, these cycle times and the proportion of the product value that actually sits at any of these stages has been assumed for demonstrative purposes only. Many bin parts would be procured using a different system, and may be held for shorter or longer periods.

* assumed for demonstrative purposes

This comparison is crude, however given that a vast majority of the Excelsior value will be in the parts supplied by CPs and APs, it is not un-instructive. We can see that in an ideal state, at a 120 product per year pace, inventory turns would increase to 8.5/year, a significant improvement.

It is inevitable that extra critical safety inventory (CSI) will be required to buffer against variability in delivery and quality issues at each link in the supply chain. This analysis shows that there is room for CSI while still realizing a substantial improvement inherent in the business model.

4.1.2 Scope of Analysis

For the purposes of this analysis, this paper is focused exclusively on CSI for components for which OEMinc contracts, the CP components being delivered to APs. The reasons for this focus are as follows:

- OEMinc has more latitude to effectively implement policy, as OEMinc contracts with both the supplier and receiving partner; and
- The natural incentive weakness associated with the AP managing inventory it does not own makes this a particularly risky relationship from OEMinc's cost perspective.

It can be observed that inventory supporting this relationship could be held as finished goods at the CP site, or as raw materials at the AP site. This analysis is focused on the latter scenario for the following reasons:

- As OEMinc is establishing this inventory standard, it is most easily and logically applied to OEMinc-owned inventory;
- Having the inventory stages at the integration site addresses the potential for variability in the delivery of that product, and reduces the added delay of shipping the product to the AP in the event that a part is non-conforming or damaged upon installation.

This report includes recommendations as to how many shipsets of CSI should be held at the AP Site to support section integration. Furthermore, recommendations are included as to how this policy should be implemented to strengthen the extended enterprise.

As with any multi-tier supply chain, risks outside of OEMinc sphere of contract influence are real, and can have an effect on OEMinc's operations. In *Clockspeed*, Fine provides the example of how Chrysler, upon digging into its sub-tiers, found that a clay supplier was being mismanaged, forcing them to move away from supplying auto castings and into pet litter, a significant risk to Chrysler's production system[7]. This demonstrates how an OEM can be at great risk from relationships that are far from their contractual control, and for the most part out of sight.

4.2. Building Collaborative Success

In *Strategic Supply Chain Management*, Shoshanah Cohen and Joseph Roussel[8] define collaboration as "the means by which companies within the supply chain work together toward mutual objectives through the sharing of ideas, information, knowledge, risks and rewards." The degree of collaboration should be a conscious decision depending on Strategic Importance, Cultural Fit, Organizational Fit and Technology Fit. The Excelsior Business model is an example of what Cohen and Roussel would call "coordinated collaboration" between the Partners and OEMinc, the closest type of relationship

[7] Clockspeed, Charles Fine, Perseus Books, 1998, page 106
[8] Strategic Supply Chain Management, Shoshanah Cohen and Joseph Roussel, McGraw-Hill, 2004, p. 139

In "Collaborative Advantage" Dyer identified dedicated investments in the partnership, such as dedicated or specialized design investments or facilities, greater knowledge sharing and Trust[9] as the key enablers of a close strategic partnership. The following sections will further define these attributes in the context of the OEMinc Excelsior program.

4.2.1 Knowledge Sharing

The motivation behind knowledge sharing, or knowledge management is that the ability for the ***enterprise*** to learn may be the only sustainable advantage in the increasingly competitive business environment[10]. Effective knowledge management is exemplified by the Toyota supplier network in the United States. It is important also to recognize that some of the most effective type of knowledge to share is that knowledge which is of no benefit to your competition. As assets are increasingly dedicated and the extended enterprise is differentiated from its competition, knowledge of partner processes becomes more unique to the enterprise and less useful to others. Therefore, learning about Partner systems and processes has high returns for a reduced risk. Some of the methods that Toyota's US supplier network uses to facilitate knowledge management are as follows[11]:

- Bluegrass Automotive Supplier Association; or BAMA: This began as a forum for idea sharing and feedback among suppliers. There are several different forums established, of which some are organized around parts of a certain nature, while others focus on other topics that are of more general interest. Plant tours are conducted, lectures given and papers submitted for presentation.
- Consulting Teams: These are teams of Toyota staff, many very experienced with the Toyota Production System, who provide free consultation to suppliers. Importantly, Toyota does not ask for price reductions immediately after helping take cost of supplier operations.
- Voluntary Study Groups: These are groups that are more focused on generating improvement through focused study rather than fielding suggestions and feedback. The groups rotate through the operations of the members, using a formalized process to generate and implement ideas. These groups are more likely to be successful later in the development of the enterprise, as trust is developed. However, the focused plant-floor perspective is deemed superior to BAMA in the transfer of tacit knowledge.
- Interim Employee Transfers: Made easier in the case of Toyota as many of the supplier companies are corporately connected through ownership, this practice involves the transfer of Toyota employees to suppliers for work rotations.

4.2.2 Dedicated Assets

Dedicated assets can include physical assets such as production facilities or dedicated information systems that can be used only to produce a specific product for a specific customer. Human assets are also important, where partners dedicate staff fully to the combined initiative, in many cases co-locating staff at Partner sites for extended periods of time during the product design phase and even throughout the program's sustaining phase.

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[9] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 37
[10] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 59
[11] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 71

In a business environment where supply chains compete with each other for superiority, dedicated assets allow the supply chain and the product to be differentiated from an opposing supply chain/product. An example might be if a component was considered to be technically superior and provided a significant performance advantage. The component could be configured such that it could not be easily transplanted to a competing product. As a consequence, it is likely that the proximate components and systems will be configured such that a competing component could not easily be substituted. This increases switching costs and results in a mutual incentive to ensure that the extended enterprise as a whole functions efficiently and competes successfully against an opposing enterprise.

Furthermore, the production facility for that component, if configured only to produce that component most efficiently, constitutes a significant investment in dedicated assets. By producing the component efficiently, and not compromising or adding cost with flexible facilities that produce multiple products, cost and quality can be controlled and improved in a more focused manner, providing a potential advantage to the entire supply chain.

In a partnership business model, the assembled product need not, and in fact should not be completely modular in its architecture. A carefully assembled enterprise leverages partner strengths to produce a superior integrated product, one that allows for the maintenance of a sustainable competitive advantage.

4.2.3 Trust

Dyer contends that Trust is essential for these investments to truly translate to a competitive advantage and commercial success. Specifically, trust enables the following[12]:

- *Lower Transaction costs*: If one organization is concerned that on every transaction there is a risk of being cheated by the counterparty, expensive assurances may be required such as Contracting, Monitoring and Enforcement.
- *Superior Knowledge Sharing*: For example, if an organization believes that by asking for help with a quality problem, it will be penalized and told to fix it, this information sharing probably won't happen, however if there is the belief that through co-operation, the problem can be averted to mutual benefit, knowledge sharing would increase.
- *Investment in Dedicated assets*: With the promise of a long-term positive relationship, these investments come with lower risk and can be more easily justified.

Trust can be defined as one party's confidence that the other party in the exchange relationship will fulfill its promises and commitments and will not exploit its vulnerabilities[13]. While, this seems nice in principle, it may be useful to think of the purpose of trust as to encourage shorter-term behavior in order to mutually benefit in the longer term.

[12] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 88
[13] Ibid

4.3. Metrics

4.3.1 Literature Review

The Merriam-Webster Dictionary defines a metric as a "basis standard or standard of comparison". According to Cohen and Roussel[14], Supply Chain metrics must:

- translate Financial Targets and Objectives into effective measures of Operational performance;
- translate Operational Performance into more accurate predictions of future earnings or sales; and
- drive behavior within the supply chain that supports the overall business strategy.

A standard framework for metrics is the Balanced Scorecard approach, advanced by Kaplan and Norton of Harvard Business School[15]. This approach classifies metrics into four categories, each of which should be given equal attention:

- Financial: Key Value Metrics from the Investor viewpoint.
- Customer: Key Value Metrics from the Customer viewpoint.
- Internal Business Processes: Key Value Metrics from the Internal viewpoint.
- Learning and Growth: Key Value metrics from the Innovation viewpoint.

The Balanced Scorecard demands that the organization first define a goal and strategy and ensure that goals within each of the four categories are aligned with this overarching philosophy[16]. Furthermore, relationships between the four categories should be explored to better understand the levers that drive business success as defined by the measurement system.

A refinement is the SCOR model approach. This framework has a specific set of metrics that can be selected at varying levels of abstraction. The amount of metrics customization generally increases with the metric level. For example, Level 1 SCOR Metrics, as defined by Roussel and Cohen, are associated with one of five specific performance attributes: Supply Chain Reliability, Supply Chain Responsiveness, Supply Chain Cost, Supply Chain Flexibility and Supply Chain Asset Management[17]. These Level 1 Metrics can be seen in Table 5.

Level 2 Metrics can be specifically associated with SCOR process categories. These categories represent the combination of one of the five SCOR Processes of Plan, Source, Make, Deliver and Return, and one of the three Process Types of Planning, Execution and Enabling.

The *Planning* Type refers to a Process that aligns expected resources to meet expected demand requirements. For example, Planning to Return constitutes the work completed to prepare for Returns. The *Execution* type refers to processes triggered by actual demand. An example might be Forecasting, which is a Planning process, but supports the sustaining enterprise. Finally,

[14] Strategic Supply Chain Management, Shoshanah Cohen and Joseph Roussel, McGraw-Hill, 2004
[15] The Balanced Scorecard: translating strategy into action, Robert S. Kaplan and David P. Norton, Harvard Business School Press, 1996.
[16] Design and Analysis of an Enterprise Metrics System, Nicol, Robert, Leaders for Manufacturing Thesis, 2001
[17] Strategic Supply Chain Management, Shoshanah Cohen and Joseph Roussel, McGraw-Hill, 2004, p. 279

Enabling Types refer to processes that prepare, maintain, or manage information or relationships upon which planning and execution processes rely[18].

Level 2 Metrics are significantly more measurable than Level 1 metrics, and can constitute the basis for comparison of the company's performance over time, and for direct comparison with organizations that employ a similar Operations Strategy. Some examples of Level 2 Metrics include:

- Cash to Cash Cycle Time (Plan)
- Inventory Days of Supply (Source)
- Capacity Utilization (Make)
- Delivery Performance to Customer Commit Date (Deliver)

4.3.2 Using Metrics

For Inventory

Inventory should not be the focus of a metrics system, but it is a barometer of supply chain health. Rather, the desired behavior is the support of production at an efficient cost structure. Therefore, metrics that relate to inventory will connect to it through these behaviors and the measures of them. In examining the Balanced Scorecard, we see that such metrics fall into all four categories, specifically:

- *Financial: Key Value Metrics from the Investor viewpoint*:
    a. Average amount of CSI on hand.
    b. Cost of expedite orders.
- *Customer: Key Value Metrics from the Customer viewpoint:*
    a. Fill rate at the APs.
- *Internal Business Processes: Key Value Metrics from the Internal viewpoint*:
    a. Adherence to CSI policy.
    b. Level of compliance in data sharing with respect to order and acceptance, component shipping, component receipt and consumption.
- *Learning and Growth: Key Value metrics from the Innovation viewpoint.*
    a. Reduction of CSI standards in a controlled fashion as warranted by process improvement.

It is necessary that these metrics, which are positioned at different locations in the evaluation framework and are related to many other important aspects of supply chain design and execution, are aligned with CSI strategy. In the following sections, we will discuss how existing OEMinc supply chain metrics can be adjusted to ensure this cohesion.

4.3.3 Current OEMinc Supply Chain Metrics

Currently, OEMinc broadly employs a form of the SCOR model to evaluate its supply chain performance. This framework is decomposed to the Internal (Cost, Efficiency), External (Reliability, responsiveness, flexibility) and Stockholder (Profitability). Table 5 outlines those categories selected by OEMinc at the high level.

[18] Supply Chain Operations Reference Model Version 7.0 Overview, the Supply Chain Council, 2005, p. 9

Table 2: Current OEMinc Metrics Framework

	Performance Attribute or Category	Level 1 Metric	Working Definition
External	Supply Chain Delivery Reliability	Fill Rates	Fill Rates measures the percentage of installation plans picked in the warehouse
		Perfect Order Fulfillment (POF)	POF measures the % of orders delivered on time and in full to customers commit date and match of order, invoice & receipt
		Delivery Performance	Delivery Performance measures the % of orders delivered "on time and in full' to customer request date & commit date
	Supply Chain Responsiveness	Order Fulfillment Lead Time (OFLT)	OFLT measures the number of days from order receipt at supplier to the ship date excluding transportation time
Internal	Supply Chain Cost	Cost of Goods Sold (COGS)	COGS is a measure of the direct cost of material & labor to produce a product or service.
		SG & A Cost	Sales, General, and Administration Costs measures the indirect cost of sales, administration, engineering, and lab to support a product or service
	Supply Chain Asset Management Efficiency	Cash to Cash Cycle Time	Cash to Cash Cycle Time measures the number of days that cash is tied up as working capital
		Inventory Days of Supply	Inventory Days of Supply measures the number of days that cash is tied up as inventory
		Asset Turns	Asset Turns is calculated by dividing revenue by total assets including both working capital and fixed assets
Shareholder	Profitability	Gross Margin	Gross Margin is calculated by subtracting COGS from Revenue and is most often expressed as a % of the remaining $ to sales.
		Operating Income (Margin)	Calculated by subtracting COGS and SG & A from Revenue, and is most often expressed as a % of the remaining $ to sales.
		Net Income	Calculated by subtracting COGS and SG & A and Taxes from Revenue and is most often expressed as a % of the remaining $ to sales.
	Effectiveness of Return	Return on Assets	Calculated by dividing Net Operating Income by Total Net Assets

Some of these metrics are not specific to the supply chain. If we subtract those that are not, we end up with the set outlined in Table 6.

Table 3: Current Supply Chain-Focused Metrics Framework

	Performance Attribute or Category	Level 1 Metric	Working Definition
External	Supply Chain Delivery Reliability	Fill Rates	Fill Rates measures the percentage of installation plans picked in the warehouse
		Perfect Order Fulfillment (POF)	POF measures the % of orders delivered on time and in full to customers commit date and match of order, invoice & receipt
		Delivery Performance	Delivery Performance measures the % of orders delivered "on time and in full' to customer request date & commit date
	Supply Chain Responsiveness	Order Fulfillment Lead Time (OFLT)	OFLT measures the number of days from order receipt at supplier to the ship date excluding transportation time
	Supply Chain Asset Management Efficiency	Cash to Cash Cycle Time	Cash to Cash Cycle Time measures the number of days that cash is tied up as working capital
		Inventory Days of Supply	Inventory Days of Supply measures the number of days that cash is tied up as inventory

4.3.4 Further Developing Supply Chain Metrics for the Excelsior Program

Financial

In the context of the Excelsior Supply Chain, financial targets and objectives are specified at the program level as not exceeding the total non-recurring cost and meeting the recurring cost target. With respect to non-recurring cost, the supply chain contributes in the form of systems that support operations and initial investments in supply chain infrastructure, specifically the common visibility ordering and scheduling, and an initial investment in learning and capability building in the supply chain. Non-recurring cost decisions have been made, so there is little value in establishing metrics for these items. The role of the supply chain is more significant with respect to the recurring cost. This cost will be comprised, in general and simplified terms, of the following:

- *Financial: Key Value Metrics from the Investor viewpoint*:
  a. Cost of safety inventory for materials procured in producing the product:
     i. Materials procured directly by OEMinc and sent to final assembly.
     ii. CP components held at OEMinc or the AP facility.
  b. Transportation:
     i. Cost of moving CP components to AP sites.
     ii. Cost of moving subassemblies to the Pre-Integration partner and to final assembly.
  c. Supply chain overhead
     i. Dedicated supply chain management staff.
     ii. Systems dedicated to materials tracking.

These items should be tracked under the "Internal – Supply Chain Cost" portion of the SCOR framework. As we can see, these costs are inextricably linked to the manufacturing and design processes. While not specifically labeled a supply chain cost, the implications of a supply chain failure are ultimately financial. These are translated into operational objectives through metrics related to supply chain delivery and flexibility.

Customer-facing

Customer-facing metrics measure quality and delivery performance at the flight line. While these items are already tracked at OEMinc, some of their key drivers are characteristics of Supply Chain performance, and relate specifically to CSI at the AP sites:

- *Customer: Key Value Metrics from the Customer viewpoint:*
    a. Number of part shortfalls at AP locations.
    b. Expedite lead times for CP Components.
    c. Regular lead times for CP Components.
    d. Regular lead time variability for CP Components.
    e. Cycle times at AP locations.
    f. Non-conformance rates at AP locations.

Internal Business Process

Especially in the early phases of this program, adherence to pre-defined processes will be crucial for gaining control of the supply chain, setting precedent and establishing trust. The following metrics would serve to encourage this behavior:

- *Internal Business Processes: Key Value Metrics from the Internal viewpoint:*
    a. Compliance of AP in updating WIP/ CSI and on-dock levels for component inventory, addressed through automation and data in the TRACK system.
    b. Average # days inventory logged into CSI by AP after receipt.
    c. Adherence of AP to CSI standard.
    d. % of orders by APs made outside specified lead time.
    e. CP Lead variability from specified delivery time.
    f. CP labeling consistency to order.
    g. Number of days until order acceptance by CP.
    h. Percentage of orders outside specified lead time accepted by CP.

Learning and Growth

As discussed previously, the OEMinc extended enterprise can be strengthened through the dedication of assets, increase in trust and the sharing of knowledge. Although progression along this path is difficult to measure, any metrics that one would apply would be located in the *Learning and Growth* quadrant of the balanced scorecard:

- *Learning and Growth*
    a. Knowledge Sharing:
        i. Amount of days spent visiting each other's facilities.
        ii. Number of improvement initiatives undertaken jointly.
        iii. Completion of a menu of pre-defined review and inspection and co-ordination activities, activities, such as End to End Value Stream mapping or Productive Joint Partner/OEMinc meetings.
    b. Trust:
        i. Percentage of shortfall incidents for which advance notice was provided.
        ii. Level of Turnover in roles where there is direct interaction with Partner staff, low turnover means greater familiarity and increased trust.

iii. Number of Times OEMinc has had to intervene in changing supplier practices such as enforcing CSI standards or applying penalties.
iv. OEMinc's own consistency in applying its stated policies.

c. Dedicated Assets:
i. Number of staff dedicated to each other's facilities.
ii. Engagement of partners in use of common information systems.

4.3.5 Adjustments to Supply Chain Metrics

The following table lists suggestions for Level III metrics that should be included for monitoring the Excelsior Supply Chain. This table is not intended to be comprehensive. The definition of these metrics can of course be refined, but these suggestions capture the information required to comprehensively monitor inventory management and Extended Enterprise development.

Table 4: Expanded OEMinc Metrics Framework

	Performance Attribute/ Category	Level 1 Metric	Level II or III Metrics
External	Supply Chain Delivery Reliability	Delivery Performance	• Number of part shortfalls at AP locations. • Non-conformance rates at AP locations
External	Supply Chain Responsiveness	Order Fulfillment Lead Time (OFLT)	• Expedite lead times for CP Components • Regular lead times for CP Components • Regular lead time variability for CP Components • Cycle times at AP locations
Internal	Business Process	Process Standardization	• AP assembly process variability.
Internal	Business Process	Adherence to Standards	• % of orders by VPs made outside specified lead time. • Compliance of AP in updating WIP/ CSI and on-dock levels for component inventory. • Average # days to accept product by AP after receipt. • Adherence of AP to CSI standard. • CP Lead variability from specified delivery time. • CP labeling consistency to order. • # of days until order acceptance by CP. • % orders outside specified lead time accepted by CP.
Internal	Supply Chain Cost	SG & A Cost	• Cost of safety CSI. • Cost of moving CP components to AP sites • Cost of moving sections to final assembly • Supply chain overhead • Cost of dedicated supply chain management staff • Cost of systems dedicated to materials tracking.
Learning and Growth	Development of Extended Enterprise	Knowledge Sharing	• # of days spent visiting each other's facilities. • # of improvement initiatives undertaken jointly. • Completion of a pre-defined review, inspection & co-ordination activities, such as VSM or Productive joint Partner/OEMinc meetings.
Learning and Growth	Development of Extended Enterprise	Trust	• % of shortfall incidents for which notice provided. • Turnover in roles directly interacting with Partner staff. • # of times OEMinc intervenes to change supplier practices. • OEMinc's consistency in applying its stated policies.
Learning and Growth	Development of Extended Enterprise	Level of Dedicated Assets	• # of staff dedicated to each other's facilities. • Engagement of Partners in use of common systems (Delmia, TRACK)

4.4. Benchmarking

4.4.1 Best Practices in Context

In order to get a sense for how other large OEMs manage partner relationships for complex products, three companies were selected in order to examine how they manage their closest suppliers, and in particular how they provide the proper incentives and ensure the sufficient flow of information. There was also particular interest in how third-party managed inventory is handled.

The selected companies are denoted here as Company 1, Company 2 and Company 3. In the case of Companies 1 and 2, as they are Excelsior Partners, visits were conducted at the Partner site. For Company 3, interviews were conducted with a former Supply Chain director from Europe (now at OEMinc), and a current supplier improvement engineer with its North American Division.

Some of the learnings from this exercise were as follows:

- ***Penalties have not worked:*** Both Company 1 and Company 3 emphasized how the imposition of Penalties for quality diversions or delivery failure did not produce a positive result. Much time and resources have been dedicated to finding out who was at fault, and at the end of the day it was very difficult to reap much financial gain from penalty imposition. Company 3 prefers a more pro-active approach whereby problem suppliers are required to post staff at the assembly facility in the case of a quality risk, and Company 3 sends out focused consulting teams to work with suppliers at their facilities where a pattern of problems is observed.

- ***No formal learning Incentives or Metrics used:*** Although the benchmarked companies acknowledged the desire to encourage learning and increase knowledge sharing, they do not use a metric for this behavior because it is so difficult to measure.

- ***Coordination and Information Sharing:*** It was found that real-time information exchange was much more limited than what might be expected. Company 1 exhibited the most extensive use of information exchange through an ordering system by which each Company 1 and each Partnership member could view order and accept for their components, as well as forecast need dates. Parts with a history of problems are denoted as "CMR Reds", and the Company 1 manager responsible for these components must report on an extensive set of metrics related to these components on a regular basis with senior management[19].

  In each case, the emphasis for information exchange was in Product Development. The OEM makes an extensive effort to understand Partner processes, strengths and weaknesses up front. This co-ordination involves the supply chain as well as design, manufacturing and procurement. Key risks, including commodity price risk and sub-tier

[19] Ibid

production capacity are identified and managed using a consulting approach. Once the program is set up, this up-front work allows for a reduced amount of real-time information exchange.

- ***Inventory Management:*** The following strategies have been used to reduce shortfall risk for high-level partner-supplied components:
    - Company 3 controls the delivery of components to its facility through its own delivery network. Its up-front work with suppliers reduces risk.
    - Company 2 is configuring its tier I module assembler network for extreme geographic proximity to Company 2's facility. Furthermore, many of the sub-components these assemblers purchase are required to be held at Company 2's Supplier Logistics Center, where it has visibility into inventory.
    - Company 1 requires that its partners hold, at the partner's cost, finished goods inventory at the Company 1 warehouse. The level is set by Company 1.

- ***Takeaways and Contrasts:*** Perhaps the key point of differentiation between any of these business models and the Excelsior model is the misalignment of incentives that we see on the Excelsior. APs will manage inventory owned by OEMinc, an exact reverse of the incentives on the Company 1 model. So, while OEMinc can benefit from the practices discussed above, more information sharing on an ongoing basis will be needed. Therefore, this benchmarking leads us to the following conclusions:
    - Penalties, if applied, should be simple, accompanied by extensive pro-active consultation, and transparent.
    - Up-front learning at the early program stages is essential.
    - Shared systems that confirm order and acceptance are a minimum for information sharing.
    - While the application of a formal metrics for learning and information exchange will be difficult, it could be extremely beneficial.

Figure 3: Benchmarking Summary

	Company 1	Company 2	Company 3	OEMinc Excelsior PMI
Ownership of Inventory at Assembly	Partner	Company 2	Company 3	OEMinc
Control of Inventory	Company 1	Company 2	Company 3	Partner
Inventory Standards	Company 1	Partner	Partner, Unless Company 3 Gets Involved	OEMinc
Overall System Metrics Tracked	Data Not Obtained	• Inventory Turns • On-Time Delivery • Order Cycle Time • Cost of Quality • Safety • Product Cost Index	Data Not Obtained	
Partner Metrics Tracked	CMR Reds - Prioritized due to history & importance. Review at Senior Level. • days late to assembly • days late to commercial customer • $ Delinquent • Level of Commitment • Quality of Commitment	Traditional - Specific Numerical goals in PPM are set. • PO On time, • PO Compliance, • Prime Quality escapes.	Traditional - Specific Numerical goals in PPM are set. • On-Time Delivery Performance • Defects per Million	
Learning Metrics	Do Not Measure Learning Initiatives	Do Not Measure Learning Initiatives	Do Not Measure Learning Initiatives	
Real Time Data Tracked	Order/acceptance/ Inventory levels at Company 1	Have Visibility of Partner Inventory	None	
Facilities	Entrenched Supply Base	Module Suppliers Close	• Demand dedicated facilities. • Many also work with Company 3 Externally, or Company 3 is part owner.	TRACK
Systems	Data Not Obtained	Just visibility of Partner Inventory	Data Not Obtained	
People	Data Not Obtained	3 P events include Partners	Data Not Obtained	

	Company 1	Company 2	Company 3	OEMinc Excelsior PMI
Frequency/ Types of Exchange of Contact	• Regular Manufacturing Review Meetings include Engineering, Supply Chain, Contracts and Manufacturing • Negotiation to manage non-conformances and Damage issues • "CMR Reds" are Reviewed weekly • Company 1 has complete sub-tier visibility and visits many key sub-tiers to assess capacity and capability. • Design stds. & quality reqs.	• In the early phases, will be having a 3 P EVERY MONTH. • During the sustaining phase, Kaizen events are held, but involve suppliers on an as-needed and as-available basis. • Not a great deal of inv. Sourced parts tend to be relatively simple - few sub-tiers	• Plants deal with day-to-day issues related to delivery. • Quality defects - supplier would have to set up staff in the Company 3 Plant and do QA there. • When a supplier reaches the top 10 wrt problems - get detailed attention • Company 3 Demands complete understanding of Partner processes. Do not bid on price but on cost. See a company they can work with, they will allow them to improve.	Concurrent Engineering, Tooling Industry Capacity Assessment, Ordering and Scheduling Consultation

4.5. *Inventory Policy*

4.5.1 Framework

As previously discussed, case studies and simulation analysis were used to develop CSI management policy. The rationale for this approach was as follows:

- Through case studies of particular components, the issues that will arise in controlling inventory under the natural uncertainty of a complex supply chain and competing interests within that change will be noted for further examination;
- Based on this analysis, potential CSI management options were identified and screened for practicality and strategic fit;
- Using simulation analysis, the preferred CSI management system was analyzed, and actual levels of CSI were specified based on varying settings for exogenous variables.

4.5.2 Case Study Analysis

With respect to the optimal management of component inventory, there are several factors that could drive differences in how CSI should be managed. It is ideal that parts be selected for case study analysis with the goal of encompassing the full range of categories that might require varied inventory policies, for example:

- Component value.
- Component Size/ Shipping Cost.
- Shipping lead time and risk.
- Rate of obsolescence and/or expectations of nonconformance.
- Number of locations/ partners to which a component is delivered.
- Likely location where the component would be sent in the event of a shortfall or a nonconformance (i.e. to final assembly or to final assembly).

A preliminary assessment of component options has pointed to the following as candidates for analysis:

Table 5: Components Selected for Case Study

Components	Reason?	From	To
Component 1	High Value and Low Volume Core component shipped to one location with supporting hardware to multiple locations. International logistics with supporting hardware to Japan.	CP 1 Northeast US	Southeast US, supporting hardware: Japan, Final assembly, Central US.
Component 2	Low Value High Volume. High degree of variation and obsolescence. In the past, a high level of non-conformance has been observed, much of which may be attributable to a greater degree of customization. Lead times are short, and detection of faults could take place at the Airframe partner as well as Final Assembly.	CP 2 Southwest US	All APs.

For each component, the producing CP and at least one of the receiving APs was interviewed to characterize the following:

- Order fulfillment systems and processes.
- Manufacturing lead times.
- Expectations regarding firm need dates from receiving party.
- Raw material ordering and scheduling processes and systems.
- Component make-up and sub-tier processes and lead times.
- Finished goods and raw materials inventory management and holding.
- Expedite processes.
- Supply chain metrics, data collection and visibility.
- Partner concerns.

The results are summarized in Table 8. Interviews were held at OEMinc's with facility with senior CP 2 staff stationed there for the design effort. What we can see in the case of CP 2 components is that sub-tier visibility is not of major interest due to the fact that raw materials are of a commodity nature. However, CP 2 is extremely concerned that they receive fair enough notice of final need dates outside of their lead time, which can vary from 1-20 days depending on the part. CP 2 plans to use a build-to-order system. Of chief concern with respect to Component 2 are the design configuration and the communication of changes. The design of Component 2 is extremely sensitive to these changes, which are most prevalent in early program stages.

In the case of Component 1, we see a very different picture. Component 1 is a very long-lead time, expensive and relatively complex component. On a previous program, its lead time is in the order of 300 days. Thankfully, CP 1 is expected to dramatically reduce this lead time through the use of a more modular design. Component 1 has been sub-divided into four sub modules, of which two will have assembly outsourced, and the remaining two will be assembled by CP 1, who has taken a number of steps to ease this transition:

- These module suppliers will be located near CP 1's facilities, allowing for rapid adjustment in the event of interruptions or quality problems and increased learning opportunities.
- Suppliers are required to hold raw materials inventory at CP 1's central SLC, where CP 1 will have visibility and can specify raw materials inventory levels to be held at the supplier cost.

Through these steps, CP 1 now has a process that it controls at the upstream and downstream ends, with contracted labor at a mid-stage. It should be noted that the longest lead time components, castings, are contracted directly by CP 1 for modules that it assembles.

Table 6: Supply Chain Survey Data

Company	CP 2	CP 1	Pre-Integration Partner	AP 1
Ordering and Scheduling				
Work Package	Component 2	Component 1	Pre-Integration	Forward Section
Build to order/ build to stock?	Order	Order	Order	Order
IT for order fulfillment	BCPS (ERP)	JD Edwards Oneworld Flows to Prod. Control	SAP – management contracted to Perot	OEMinc partner Network
IT for ordering and scheduling	BCPS (ERP)	From Production control to MRP for ordering	SAP – management contracted to Perot	Package Builder (Proprietary)
How are orders received from the customer?	EDI, flowing to BCPS	Manually fed to JDE	OEMinc provides schedule - TRACK	OEMinc provides schedule – TRACK
How are orders sent to suppliers?	Min-Max, Web-EDI or Discrete e-mail order	Suppliers access online MRP, get an e-notice	EDI from SAP	Via OEMinc Partner Network. Suppliers have 6 mo visibility.
Raw Materials				
Replenishment policy for Raw Materials	Depends – MRP and Kanban	Depends, Bin stock for cheap, JIT for higher level	Want <= 1 shipset CSI, want kitted VMI as much as possible.	Want a min-max system – use TRACK to give CPs visibility
How often is RM inventory checked?	Daily cycle count, Yearly Inventory	No Response	No Response	No Response
How are RM quality problems Recorded?	Non-Conformance Database TipQa	On the common MRP system	Don't seem prepared for this	No Response
Metrics				
Metrics used to gauge supply chain performance?	Specific System/Dbase & one person per site.	"6-Pack"	Not established	No Response
Data tracked to gauge supplier performance?	• On-Time Delivery • Depth of Delay • Administrative Quality • Technical Quality	• PO On-Time • PO Overdue • PO Compliance • Prime quality escapes	Not established	No Response
Visibility within the supply chain	Response Invalid	Have visibility for RM held at their SRC, otherwise just order acceptance	None	None

In general, as a new entity, the Pre-Integration Partner does not seem to have given a great deal of thought to Supply Chain issues. As much as possible, they are focusing on Third-Party Logistics providers and suppliers to arrange for just-in-time delivery of kitted work packages. As OEMinc is the party contracting with CPs, the Pre-Integration partner appears to be taking the position that OEMinc is responsible for ensuring that parts arrive at the right level of quality at the time requested.

AP 1 is a relatively mature organization and hopes to make use of the systems it now uses to relate with suppliers, such as min/max vendor managed inventory. Again, we see an emphasis here on pushing supply chain responsibility to the CPs and by default, to OEMinc.

A quick review of the table above reveals no commonality in the MRP systems used for ordering and scheduling. When one thinks of system integration across the partnership, it seems clear that complete standardization with legacy systems is unlikely. Any shared system will have to be newly developed for this purpose.

4.5.3 Potential Inventory Management Options

Based on this information, we can propose the following three systems for CSI management:

Table 7: Comparison of CSI systems

	Benefits	Drawbacks	Orientation with Incentives	Implementation Issues
JIT with CSI	• Lean Orientation, tie ordering closely to production, keep inventory visible. • Ensures parts in place for Long delays	• Need for designated Safety Stock – Complex • Accommodate design changes – need lead time	• Encourages standardization in assembly • Encourages Supplier responsiveness • Discourages "part-swapping" • OEMinc must explicitly apply incentives	• Metrics more complex – need to monitor both CSS level and EO level.
Early Order	• Simplicity • Easy to Adjust	• EO detaches the order from the need. • Hides inventory.	• Encourages "part-swapping" • OEMinc must explicitly apply incentives	• Less data exchange, more difficult to measure
Min/Max	• Provides supplier with Flexibility • AP Does not have to control	• Requires Supplier Flexibility • Overly discrete and complex for low inventory levels. Does not apply to high-value low volume.	• Lessen incentive to standardize flow	• Requires real time inventory data

<u>Just-in-Time (JIT) with designated Critical Safety Inventory (CSI):</u> By this method, parts will be ordered immediately in advance of need, and a designated number of spare ship sets will be kept to buffer against variability. The incoming ship sets will be cycled through the CSI set on a First-in-First-Out basis.

Early Order (EO): By this method, parts will be ordered immediately some period in advance of need, and this spare lead time will form the buffer.

Min/Max: By this method, parts will be ordered immediately some period in advance of need, and this spare lead time will form the buffer.

Based on this qualitative analysis, the Min/Max system was disregarded because:
- the system would lessen the incentive for the AP to standardize cycle times;
- real-time inventory tracking would be required. Given the fast pace of the program, by the time new inventory was logged in at the AP location, the information would be dated by program standards; and
- we expect that CSI levels will be in the order of 1-2 shipsets, therefore Min/Max seems unnecessarily cumbersome.

It is important to note that the other two systems are essentially not different from the perspective of Safety Inventory levels. An Early Order system whereby parts are received seven days in advance of need is the same, for a 2-day takt time, as a CSI system where three spare shipsets are used and parts are received one day in advance of need. While non-conformances or damage upon installation would be noticed or occur at the time of need, replacement parts could be borrowed from subsequent line numbers in the case of the EO Policy and from the designated safety stock in the event of the CSI policy.

So, while from a numerical perspective, the systems are the same, for the following reasons the CSI policy has been selected for detailed analysis:
- the designation of inventory as safety stock provides an important metric that can be used to encourage improvement and evaluate AP performance;
- communication of the CSI standard for a particular part will allow rapid assessment of parts on-hand against this standard, an important visual cue which can help to encourage a lean enterprise; and
- the signal for ordering new components will be simply and directly driven by the status of inventory on-hand.

It should be noted that a true JIT system with CSI is impractical, as the high-frequency and normally distributed variability of delivery time is better addressed by a small EO period. However, under a designated CSI system, inventory will be used to protect against large discrete interruptions such as non-conformances or customs delays.

It should also be noted that during the program's early stages, the takt time will be significantly higher, in the order of 30 days. This much slower takt time will demand separate policies.

4.5.4 Simulation

Using a simulation package licensed to OEMinc, a generic simulation model of the Supply chain between the CPs and APs was built. The following rules were employed:

- Scheduled production was used for products 1-102, beyond that, a takt time of three days was used.
- At the beginning of the simulation a number of components were generated to stock up as CSI.
- APs receive need dates from OEMinc, these dates are considered firm.
- APs order from CPs by giving the required lead time plus a nominal Early Order period.
- CP variability in meeting the order requirement is in addition to that planned for within the lead time request. Therefore, variability is low as it attempts to capture the real risk of the CP being late.
- The CP will not complete components early, but will begin precisely the length of the specified component lead time in advance of AP need.
- Parts are inspected just prior to installation, and at that time, a random number generator assigns the part as conforming or non-conforming depending on the given probability. If the part is non-conforming, a part is released from CSI, and a Kanban is sent to restore CSI to the specified level.
- CSI components are produced on expedite lead time, shorter than normal lead time.
- If the part is non-conforming and no conforming part remains in CSI, then a Part Shortfall Incident is recorded.
- No more than one part shortfall per 1000 line numbers was considered acceptable.

The independent variables for which the simulation was varied were:

- ***Probability of a Critical Non-Conformance:*** This is a non-conformance that cannot be dealt with at the AP site quickly enough that the repair does not influence the integration schedule.
- ***CP Normal Lead Time***
- ***CP Normal lead time variability:*** Generally considered quite small as much of the variability would be planned for within the Lead Time
- ***CP Expedite Lead Time***
- ***CP Expedite Lead Time Variability:*** Also quite small

The amount of CSI and size of the nominal EO period were adjusted until the number of shortfalls per 1000 line numbers was one or less. The following results were obtained for the amount of CSI associated with each level of non-conformance, lead time and expedite lead time:

Figure 4: CSI Levels Suggested by Lead Time and Non-Conformance Rate

Non-Conformance Rate	LT = 3 EXP < 3	LT = 3 EXP = 3	LT = 10 EXP = 6	LT = 10 EXP = 10	LT = 30 EXP = 6	LT = 60 EXP = 10	LT = 30 EXP = 25	LT = 60 EXP = 25	LT = 60 EXP = 50
40%	5	5							
30%	3	4	9						
20%	2	3	4	5	7	9			
10%	2	2	2	2	2	2	6	6	
2%	1	1	1	1	1	1	1	2	2
0%	0	0	0	0	0	0	0	0	0

Where the square contains no numbers, there is no reasonable level of CSI that will permit the supply chain to be reliable. It should be noted that there was no strong relationship detected between the amount of required CSI and the lead time variability. However, standard deviations of lead time of only 0.5 days and 1.5 days were used, as it is expected that much of this variability will be encapsulated within the lead time requested by the CP. The following relationships were determined through examination of the results:

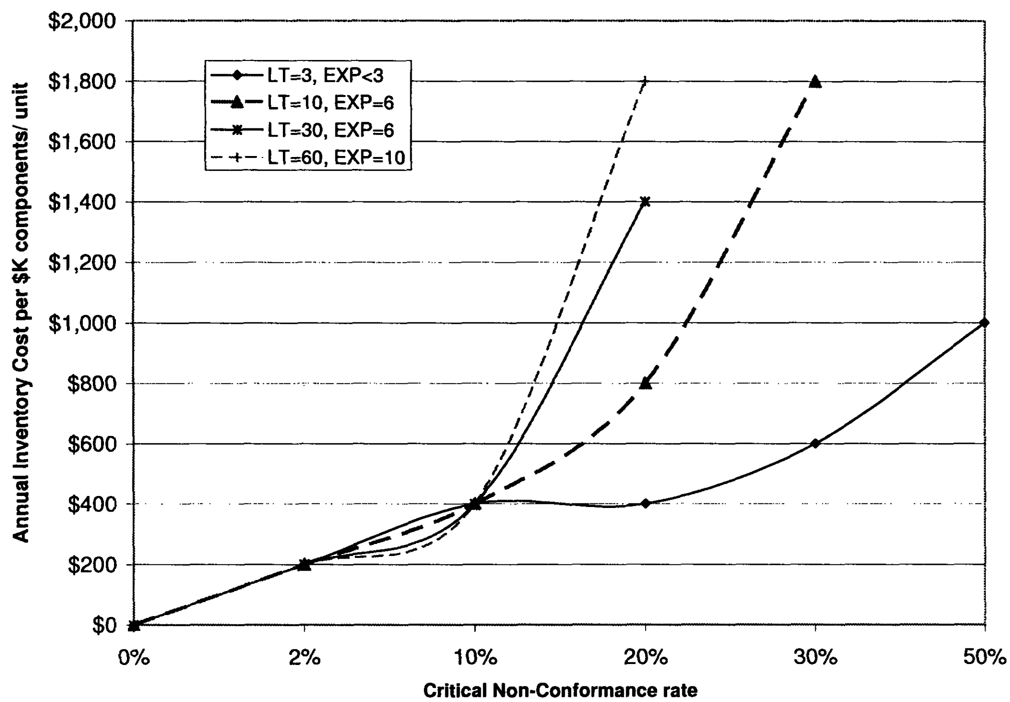
- An Early Order period of minimum 2 days or 2 x the Standard Deviation of lead time would be appropriate for non-conformances levels of 20% or lower.
- For non-conformance rates of 10%-20%, use a minimum of 4 days;
- For non-conformance rates of 20%-30%, use a minimum of 8 days;
- For non-conformance rates of 20%-30%, use a minimum of 10 days.

For products 1-15, it is recommended that an Early Order system with detailed inspection upon receipt be employed. Under existing program rules, APs are responsible only for a visual inspection while the providing CP must conduct component testing. While this measure will be more fully discussed later in the report, the use of this system in the program early stages will allow for the focused detection and investigation of the most common problems related to CP quality and delivery, allowing for focused and high-value improvement efforts. Furthermore, as the time between line numbers will be high, significant savings can be realized by not having excess inventory on hand between line numbers.

4.5.5 The Importance of Quality

As we can see, and as expected, from an inventory perspective, there is value in reducing Critical non-conformance rates and lead times, in particular expedite lead time. The set of curves in Figure 8 shows the potential payback of these efforts per million dollars of components per shipset of OEMinc-owned drop-shipped components.

Figure 5: Benefits of Quality



Note: 20%/ year inventory holding cost assumed

It is important to clarify that non-conformances as recorded by OEMinc on existing programs includes both what are denoted here as Critical, as well as Non-Critical problems. Clearly, if spread across the range of components, there is sufficient value of having a clear definition of what constitutes a Critical vs. a Non-Critical non-conformance, and equipping the AP to deal with frequent "quick fixes" so less CSI will be required. While this will not significantly decrease repair/scrap costs, and therefore would not naturally be an initiative championed by a quality organization, the inventory savings will be significant.

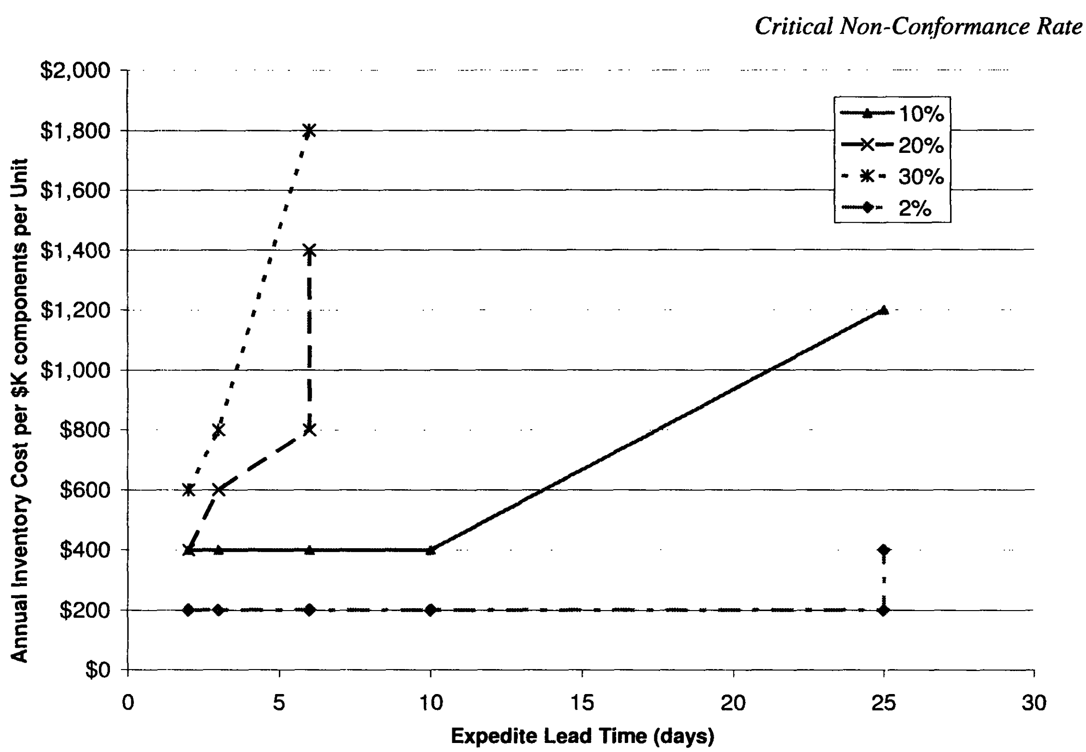
For example, in examining non-conformance records for one type of component on a sustaining program for the period December 2004 – November 2005, it was found that there were 129 part numbers for which at least one non-conformance was logged, be it a significant repair, or a part that could be used as-is but did not conform. Of these components, sixteen displayed incidents of critical non-conformance, where the component had to be scrapped, replaced or returned. The Critical non-conformance rate for these components was 11% lower than the overall non-conformance rate. It should be noted that OEMinc used to build these components itself, and has the ability to make many required adjustments to incoming product. The APs on the Excelsior program are unlikely to have this capability. Merely by ensuring that APs are equipped to deal with non-critical problems, the non-conformance rate from a CSI perspective could be lowered significantly without any other improvement effort. In this manner, the required CSI level could be reduced. As shown in Figure 8, for the example given, this would result in an annual savings of over $800 per $1000 of component value on each product for a component with lead time of 10 days and expedite lead time of 6 days.

This incredible potential for savings also demonstrates the value of being fully conscious of the real Critical non-conformance rate for each component, and ensuring that investments are made to lower this rate. If CSI policy is connected directly to non-conformance, as advocated here, then CSI levels can be trusted by all parties in the extended enterprise and CSI can act as a barometer for quality. The value of improved quality from a pure materials perspective, while not specifically addressed in this document, is relatively obvious.

4.5.6 The Importance of Flexibility

In this case, flexibility refers to the ability to recover quickly from a supply chain interruption, be it a non-conformance or a late component. This capability is provided by the ability to receive components quickly when in real need; expedite lead time. As we can see in Figure 7, at a given non-conformance rate, there exists a level of expedite lead time above which the CSI requirements begin to increase. Higher non-conformance parts are more sensitive to this problem. We can see the benefits of increasing expedite capability on the need for CSI, and its cost. For a component with a 10% nonconformance rate, lowering expedite lead time from 25 days to 10 days can save $800 /year per $K of component value on each unit.

Figure 6: Benefits of Short Expedite Lead Time



Note: 20%/ year inventory holding cost assumed

4.6. Analysis Summary

On sustaining programs, component inventory supporting OEMinc assembly is ordered some number of days in advance of need to ensure availability. The length of this period is based on the supplier's past performance in on-time delivery, and to ensure sufficient time for the part to be received and moved to the installation site. Units currently spend longer in final assembly than the Excelsior will, and there will be several line numbers in the building at one time.

In an ideal state, for the Excelsior model, inventory turns would increase significantly, leaving room for CSI. However, it is inevitable that extra critical safety inventory (CSI) will be required to buffer against variability in delivery and quality issues at each link in the supply chain.

This report includes recommendations as to how many ship sets of CSI should be held at the AP Site to support section integration. Furthermore, recommendations are included as to how this policy should be implemented to strengthen the extended enterprise through the development of trust, dedicated assets and improved knowledge sharing.

Trust can be defined as one party's confidence that the other party in the exchange relationship will fulfill its promises and commitments and will not exploit its vulnerabilities. This strengthens the extended enterprise through Lower transaction costs, increased knowledge sharing and increased investment in dedicated assets. These assets allow the specialization and optimization of a supply chain, improving the ability of this chain to triumph over competition. Effective knowledge management is made more complex in a network of companies vs. a single entity, but is all the more important as there is so much more to learn.

The OEMinc Metrics framework has been examined and metrics specified that can be applied to the partnership as a whole, or to Partners. Metric categories were added to measure adherence to business process and strengthening of the extended enterprise, both categories that increase in prominence under the extended enterprise model.

Several peer OEMs in complex-product industries were selected in order to examine how they manage their closest suppliers, and in particular how they provide the proper incentives and ensure the sufficient flow of information. There was also particular interest in how third-party managed inventory is handled. Interviews and site visits provided the following conclusions:

- Penalties have not worked;
- No formal learning Incentives or Metrics are used;
- Real-time information exchange was much more limited than what might be expected. In each case, the emphasis for information exchange was in Product Development; and
- Shortfall risk for high-level partner-supplied components has been reduced through the direct control of component movement in the chain, through geographic concentration of suppliers, and the specification of incentives more favorable to the OEM.

Case study analysis of the component entitled Component 2 shows significant concern on the part of CP 2 with respect to the communication of design changes. CP 1 has significantly reduced lead times for the Component 1 to increase responsiveness. On the other hand, APs show a reluctance to take direct responsibility for the level of OEMinc-owned product on site, instead deferring to OEMinc or the CP to manage its availability.

A simulation analysis was used to evaluate specified levels, established by OEMinc, for a policy of CSI kept at the AP, and a short and specified EO period. Criteria were established, applicable to any component, based on the expected Critical non-conformance rate, and expedite lead time. This analysis shows the importance of strictly defining, controlling and improving upon the critical non-conformance rate and the ability to expedite parts when needed to meet the specified CSI level.

4.7. Recommendations

The following recommendations can be generated from this analysis:

- For units 1-15, components should be ordered well in advance of need and inspected in detail, including testing if possible, upon arrival. At minimum, one set of CSI should be kept during this period,
- During this period, Lead Time Variability, Non-Conformance levels, Non-conformance Type, and Expedite Lead Time should be monitored to establish a baseline for CSI levels. Non-conformances should be examined in detail, and AP capability to address the most frequent "quick fixes" should be developed on a case-by-case basis. Each of these individual business cases can be assessed based on the cost of building capability vs. reduced inventory holding and reverse logistics costs driven by a lower level of returns and CSI.
- For unit numbers greater than 15, OEMinc should employ a system of a preset and controlled level of CSI kept at AP sites and used on a first-in-first out basis. When a component arrives, it is immediately logged as CSI, and becomes WIP when moved to the plant floor immediately in advance of need. This CSI Level should be derived based on expectations of non-conformance rates and expedite lead time using the relationship described previously, and the supply chain model if needed for further data.
- The following Early Order periods should be permitted. These periods are useful in addressing the "noise" of normal lead time variability.
    - For non-conformances levels of 20% or lower, use 2 days or 2 x the Standard Deviation of lead time.
    - For non-conformance rates of 10%-20%, use a minimum of 4 days.
    - For non-conformance rates of 20%-30%, use a minimum of 8 days.
    - For non-conformance rates of 20%-30%, use a minimum of 10 days.
- Partner CSI levels should be monitored using the TRACK system to ensure compliance with specified levels. Dangerously low levels of CSI should be addressed through expedite orders.
    - If low CSI levels were the result of a series of non-conformances, which could be due to poor incoming component quality, the AP should be given a reasonable amount of time to get CSI levels back up to standard. The issue of which party is at fault for the non-conformance should be addressed separately.
    - It is the AP's responsibility to detect trends of increased Critical Non-Conformance or longer than expected expedite lead times and petition for more CSI.
- Non-conformance levels and Expedite lead times should be monitored on at least a quarterly basis by OEMinc and CSI levels adjusted as necessary. Trends of lower or higher than specified CSI levels should also warrant a review of these levels in light of data regarding their key drivers.

- OEMinc should develop focused multi-partner initiatives to lower expedite times and non-conformance rates, including.
  - Incentives for CPs to lower expedite lead times; and
  - Detailed monitoring in early phases; and
  - Offers of consultation by OEMinc staff.

5. Implementation

5.1. Organizational Context

Implementation of these recommendations must be designed in the context of a thorough understanding of the extended enterprise as an organization. The following sections describe the extended enterprise using the Three Lenses approach taught at the Sloan School of Management. Under this design, the organization can be viewed from three perspectives: the Political, the Cultural and the Strategic[20].

5.1.1 The Strategic Lens

Strategic design of the Excelsior enterprise is an important issue for analysis, especially given that the enterprise is evolving and does not now resemble what it will in sustaining mode. The Excelsior program will ultimately be run by the final assembly organization, which will be directly responsible for:

- setting the overall production schedule using Bill of Material Exports;
- receiving and assembling AP sections and required components in order to complete the Unit; and
- ultimately, ensuring the product is delivered on time and at the right level of quality.

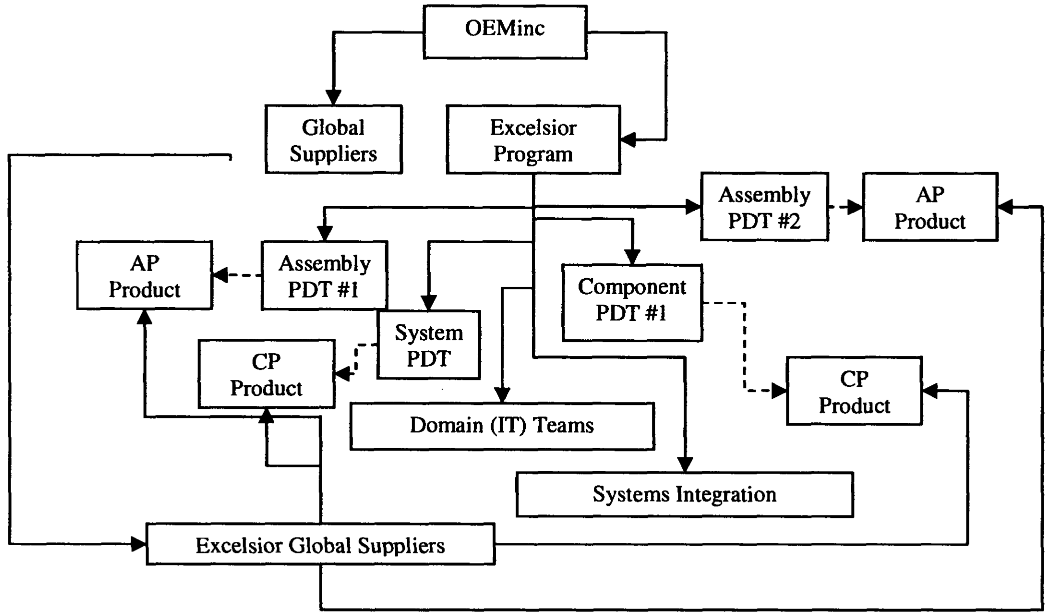
The final assembly organization is still being formed. At this point, the program is essentially in the hands of the Product Development Teams, or PDTs. These teams are responsible for a particular component set or physical section of the Excelsior. These PDTs will provide final assembly with an integrated product design, a set of quality standards for incoming components and manufacturing processes for AP work. They have dotted-line control over the Global Supplier representatives who hold the reins in dealing with the Partners. Figure 1 provides a high level overview of the organization as it stands. The Domain teams, who report to Excelsior Program Management, are responsible for building the information systems and processes for ordering and scheduling. Worldwide Logistics, who also report to Excelsior Program Management, advise on supply chain standards and component logistics.

Potential weaknesses of this structure are as follows:

- Worldwide Logistics does not have a close enough relationship to the Partners in order to support their responsibility. Detailed product and manufacturing process understanding is needed to develop supply chain standards, and Worldwide Logistics does not have direct access to this information.
- The PDTs have the relationships to develop these standards, but are occupied with ensuring that the product and quality system are compliant. The focus is now shifting to supply chain, but the PDTs also do not have the centralized set of supply chain focused and trained staff who take an overall view that conforms to having a unified supply chain strategy. This is necessary to meet overall supply chain goals and ensure consistency in dealing with partners who may work with multiple PDTs.

[20] Carroll, J. S.. Introduction to Organizational Analysis: The Three Lenses. Cambridge, MA: MIT Sloan School of Management, unpub.ms, 2002

Figure 7: Existing Excelsior Program Structure



- Final assembly will ultimately control the entire supply chain, but its yet-undefined structure means that the organization may be thrown a product "over the wall" without the embedded relationships needed to adapt supply chain standards as the program progresses.
- The goal of learning and Partner relationship development is not explicitly stated by Program Management and is not being explicitly acted on by any of these players.
- All interaction between CPs and APs is facilitated formally by OEMinc. This may be seen as necessary for the purposes of quality control, but does not permit the development of flexible working relationships.

These conditions challenge the concept of 3-D Concurrent Engineering as proposed by Charles Fine in Clockspeed[21]. Under this framework, product, process and supply chain are designed simultaneously with consideration of the challenges facing each. By having supply chain standard development some organizational distance from product design, it becomes more difficult to develop a rational set of supply chain standards, such as CSI.

5.1.2 The Political Lens

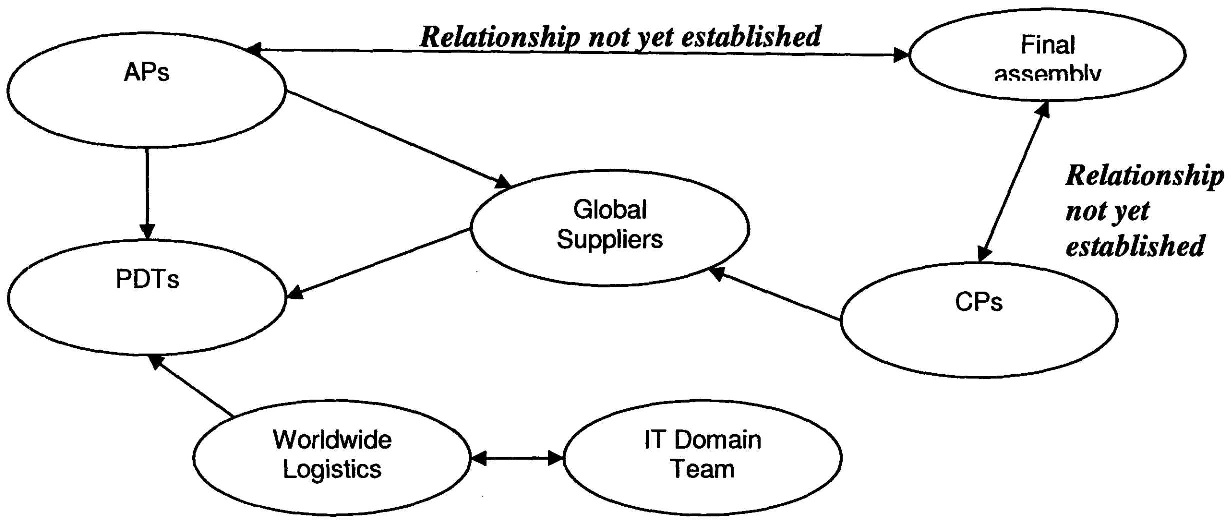
Using the political perspective to analyze the organization requires examining the flow of power within the company, irrespective of formal structure. The idea behind this is that organizational function can be explained by who holds the power and who is trying to obtain it. The following diagram shows how power flows between groups of stakeholders. An arrow to a stakeholder indicates that the stakeholder holds power in the relationship. We can see here that the most powerful players are:

- Global Suppliers: Hold the reins of the relationships with the CPs and APs.
- The PDTs: Have detailed product knowledge and control, as well as formal responsibility over Global Suppliers, which, it has been demonstrated, they are able and willing to use.

[21] Clockspeed, Charles Fine, Perseus Books, 1998, page 124

- Final assembly: Although the relationships are not yet in play, final assembly will ultimately have some level of influence over the CPs and APs.

Figure 8: Political Relationships



All interests should be compatible in the sense that, ostensibly, all players, at least at the corporate level, have a stake in seeing the Excelsior program succeed, however the following factors drive diversions in stakeholder interests:

- Final assembly's responsibilities and the level of resources they will have to manage them, especially with respect to the partner supply chain are unclear.
- The PDTs are extremely powerful, but their future in sustaining mode is not clear.
- Worldwide Logistics does not have any real power except a mutually cooperative relationship with the IT Domain team.
- Final assembly is not, at this time, really connected to any of the players except the partners, and this relationship will not be cemented until sustaining mode.

The IT Domain team and Worldwide Logistics are very interested in seeing CSI policy implemented successfully in the manner described. While the focus of the PDTs is diverted due to the time criticality in developing the design, they also seem open to a clearly defined policy rooted in analysis. Global Suppliers is now the sole conduit for Partner contact, and this rigidly controlled relationship is contrary to an effective policy that permits strengthening of Partner-Partner and Partner-OEMinc relationships at a functional level.

At present, final assembly is ambivalent toward business rules for OEMinc-owned drop-shipped inventory as they consider this to be outside their realm of responsibility. However if their responsibilities and resources are clarified, and these resources include the development of an PDT structure with final assembly, their interests would align with the PDT's. As the focus of the PDTs shifts to supply chain, the ability of Worldwide Logistics to access the partners in a positive fashion with respect to CSI policy will increase through the PDT connection.

It may not be possible to align the interests of the partners with a CSI initiative in the short term, as CPs will eventually see that my recommendations place light on their capabilities, and the APs will see their hands being tied with respect to CSI on hand. It will be the responsibility of the PDTs and later, final assembly to ensure the partners that working to implement CSI Policy will be to their benefit, and that they will be treated fairly.

Measures to allow the less powerful interests (Worldwide Logistics and the IT Domain Team) are not explicit; however these groups do have a "Vote of Confidence" from Excelsior Leadership. As the focus of the PDTs shifts to supply chain, these groups, as purveyors of a solution, will become more influential as long as that solution is communicated effectively and meets the customer need.

5.1.3 The Cultural Lens

OEMinc is relinquishing direct control of its supply base and relying on Partners to do a greater share of the work. This move to systems integration is well understood by OEMinc staff, and a move to implement data-driven CSI business rules is merely a symptom or example of this change and this does not vary among stakeholder groups.

For the supplier managers in Global Suppliers, this is most significant. Their continuing role in managing suppliers requires a more broad-based view of design, production and supply chain management. This differs from their existing responsibilities, which include the development and execution of contracts and management of relationships. Therefore, they need to pull individuals from the rest of OEMinc and relinquish some control, a change that is not being easily expected.

For the PDTs, whose strengths lie in engineering, the project is a symbol of the change to 3-D Concurrent Engineering (Product, Process and Supply Chain). These groups are technically competent and focused. The development of CSI business rules on their behalf symbolizes a learning opportunity and the potential for outside help. As project development people, they are used to change and initiatives with finite timelines.

The recommendation of a CSI management strategy that recommends greater co-operation with outside entities, the need to adjust the business rules as the supply chain develops, and an emphasis on Partner monitoring for consistency and quality does not divert from the basic assumptions of the "New" OEMinc, but enforces them. A recommendation that final assembly become intimately involved with the Partner supply chain and that business is a mere extension of the principle that the co-operation, team-building and the ability to be flexible are paramount.

5.1.4 Three Lenses Summary: Organizational Recommendations

The OEMinc Excelsior organization within the extended enterprise has been examined using the three lenses approach developed at MIT[22]. Potential weaknesses of this strategic arrangement of the organization include the fact Worldwide Logistics does not have a close enough relationship to the Partners in order to support their responsibility, the nascent state of centralized supply

[22] Carroll, J. S.. Introduction to Organizational Analysis: The Three Lenses. Cambridge, MA: MIT Sloan School of Management, unpub.ms, 2002

chain capability within the PDTs, the as-yet-undefined structure of final assembly, OEMinc's failure to cite learning and enterprise development as program goals, and the absence of an avenue for interaction between CPs and APs.

From a Political perspective, diversions in stakeholder interests with respect to CSI standards in particular are driven by risks surrounding the future of the PDT skillset and connection to the Partners within final assembly. Furthermore, the control of Partner relationships by Global Suppliers presents a challenge to integration across the enterprise.

From a cultural perspective, there do not appear to be significant challenges within OEMinc. This organization has undergone a great deal of change, and should be primed for a shift to greater co-ordination with partners. The caveat might be that there is a general reluctance to share data openly at OEMinc, which could be a problem in building the extended enterprise.

In an organization that has undergone such change, the Political Lens elevates in importance as the strategic framework seems less stable and reliable. However, the strategic lens helps to inform the political framework. For example, the absence of final assembly from the existing organizational chart explains its political disconnection from many initiatives involving the Partner relationship. The lack of formal connection between Worldwide Logistics and the Partners diminishes its power.

A lean supply chain and strengthening of the extended enterprise will require an organization that can facilitate trust, tie policies such as CSI directly and logically to production realities and needs, and drive continuous improvement through joint Partnership efforts. This analysis leads to the following recommendations with respect to the design of the Excelsior organization as it evolves to sustaining mode:

- In the near-term, the PDTs should appoint Supply Chain focals who are mandated to administer a CSI management strategy as articulated by Worldwide Logistics and the IT Domain team. This allows Worldwide Logistics to leverage the PDT influence over the Partners.
- The PDT structure, pared down, should be maintained within final assembly so that organizational knowledge and partner relationships are maintained.
- Partner Metrics should be adjusted to include participation and success in pan-partnership improvement efforts, and commitment to knowledge sharing.
- The Supply chain design and maintenance function currently managed by Worldwide Logistics should ascend in responsibility and be integrated into final assembly at a high level with some solid line control over the "mini-PDTs".
- OEMinc should form three-party Supply Chain and Quality teams consisting of representatives from OEMinc, the AP in question and the CP in Question. These teams should ensure that the Supply Chain is ready for production and be prepared to monitor the supply chain and production processes through units 1-15, detecting key quality and delivery risks and adjusting inventory policies as needed. These teams should co-locate to the AP site for high-risk components.

This will:

- Break down the relationship between OEMinc and the Partners from a single channel controlled by Global Suppliers to a functionally-focused supply chain channel that reports ultimately to final assembly through the "Mini-PDTs"
- Help to align the interests of the CPs and APs by providing a forum for them to express their opinions and concerns about a topic that will greatly affect their ability to do business.
- Demonstrate OEMinc's commitment to investing in the relationship and in mutual improvement efforts.
- Provide useful quality and delivery data that can be used to prioritize efforts to improve AP ability to handle less serious non-conformances, identify problems with CP performance, and establish the necessary levels of CSI at the AP site.

5.2. Sustaining Program Actions

5.2.1 Focused Tri-Party Quality Teams

In order for CSI Policy as articulated in this document to be effectively implemented, OEMinc needs to make the investment to tie this policy to production system reality, and the connection must be visible not just to OEMinc, but to the CPs and APs. Therefore these stakeholders should be involved in collecting the data and completing the analysis for setting CSI standards.

This can be done through Tri-Party quality teams at the AP site representing OEMinc, the AP and the key CPs. These teams should be focused primarily on the highest-risk components, but every CP should be represented on one team at each site. OEMinc representatives and APs at a given site could obviously cover multiple components from multiple CPs.

The mandate of these teams in the early stages of the program would be as follows:

- Develop an estimate for Non-Conformance for each component.
- Categorize each these Non-Conformance rates according to the seriousness of the remedial action required.
- Develop an estimate for lead time variability for each component.
- Prioritize improvement efforts and set targets for the CPs and APs respectively, reducing the actual incidence of each category of non-conformance and incidents of late delivery.
- Assess the business case for augmenting AP capabilities so that non-critical non-conformances can be dealt with at the integration site.
- Establish the required CSI levels on a component by component basis.

Teams from the various integration sites should meet centrally to share findings and compare initiatives. This will help to send a consistent message to CPs who may be dealing with multiple sites for a single component, and would require consistency. Furthermore, the learning that could be generated from this knowledge sharing would be valuable.

The development of these teams is perfectly aligned with the goal of strengthening the extended enterprise as it:

- increases ***dedicated investment*** through the allocation of staff directly to the partnership in a purely collaborative fashion;
- increases ***trust*** in the presence of positive results; and

- provides a key forum for ***knowledge sharing***.

Furthermore, this will allow OEMinc to better-maintain detailed knowledge of Excelsior sub-components and the processes used to manufacture them. Given that OEMinc may, at some point in the future want to in-source some of these processes as they become keys to technical superiority, this knowledge is of strategic importance.

5.2.2 Ongoing Data Collection Requirements and Program Maintenance

In order for established CIS levels to remain appropriate for the state of the supply chain risk, these levels must be re-examined in light of new knowledge of, and changes in, critical non-conformance rates and delivery variability. The following principles should be adhered to in keeping these levels current:

- Specific incidents of shortfalls should be investigated to determine the root cause.
- Partners should be incentivized to anticipate shortfall risk and communicate their concerns to OEMinc so that the shortfall may be avoided.
- CSI levels should be formally reviewed on a quarterly basis.
- If one of the Partners believes that the CSI standard is inappropriate, they can petition for a change in the standard through a data-driven process, using only expedite lead time, lead time variability, and critical non-conformance as drivers for the change.
- Data should be shared across AP sites so that the same component from a single CP is not treated differently among AP locations unless warranted by local considerations, such as variances in AP capabilities.
- Improvement efforts should focus on reducing the levels of non-conformance of all types and increasing AP capability to reduce the size of the Critical Non-Conformance category.

The following data will need to be tracked in order to properly maintain these business rules:

- Non-conformance rate and classification of non-conformance:
  - Damaged upon arrival - repairable/non-repairable.
  - Damaged upon installation - repairable/non-repairable.
  - Defective manufacture or not in accordance with design – useable/ unusable.
  - Missed labeling or other.
- Initiatives taken to deal with each non-conformance.
- Part arrival relative to promise date (# Days early or late).
- Time between arrival and entry into CSI.
- Daily computer tally of CSI on-hand by component.
- Daily tally of outstanding expedite orders.
- Detailed root cause analysis for each part shortfall incident:
  - what precipitated the event;
  - who was at fault;
  - why the system did not prevent it; and
  - what changes should be made.

This will permit OEMinc to determine whether the CSI standards are being adhered to, how AP capabilities are measuring up to the flow of non-conformance, whether current CSI standards are in fact correct, and, ultimately, where improvement efforts must focus.

5.2.3 Incentives – Systems Dynamics Analysis

An interesting refinement of the analysis supporting CSI business rules was developed using Systems Dynamics to examine the incentives of each player category in the Excelsior Supply Chain. This framework allows the practitioner to gain a fuller understanding of how supply chain conditions and actions relate, and to identify levers that will promote the desired behavior from these players.

In general, for the Excelsior supply chain, the behavior that is desired can be summarized as follows:

OEMinc:
- efficiently, transparently and consistently manage a CSI policy that supports the supply chain in a cost-efficient fashion;
- learn as much as possible about the processes and systems of Partners and their suppliers; and
- make the required investments in facilitating improvement both internally, and with the Partners.

APs:
- adhere to CSI Policy as mutually defined in consultation with OEMinc;
- advocate for policy adjustments where warranted;
- anticipate shortfalls or supply chain interruption and share this knowledge so that they might be averted; and
- invest in improvement in non-conformance management and assembly standardization.
- share data among the partnership.

CPs:
- produce to lead times and expedite lead times;
- anticipate shortfalls or supply chain interruptions and share this knowledge so that they might be averted;
- invest in improvement in quality and delivery; and
- share data among the partnership.

The following model has been developed that defines the relationships among the three Partnership entities. Systems Dynamics nomenclature has been used here. Component inventory has been modeled as a stock and flow system between the CPs and OEMinc. Variables or factors that influence other variables or factors in a positive sense are shown by arrows with a "+". Those with a negative influence are denoted by a "-". Sets of such relationships that form a loop are signified by the Loop number and name. Loops that are re-enforcing are denoted with an "R" and the loop number, i.e. "R1", while those that are naturally balancing are denoted as "B" and the loop number, i.e. "B1". The significance of each loop in the real system is provided by the loop description.

Figure 12 represents the flows, factors and variables that influence the movement of inventory across the supply chain. This representation includes potential penalties that OEMinc might apply either for:

- A pattern of poor erratic performance. In the case of the CPs, this would apply to high variability in delivery or a high non-conformance rate. For the APs, it would mean a pattern of diverting from the CSI standard, a problem with damaging parts upon installation, or the repeated failure to address non-critical non-conformances in a timely manner.
- A specific failure that causes a part shortfall.

For the CP, the important elements of performance include their own process as well as their sub-tier management. For the AP, their own assembly process is most important, as well as their ability to accurately predict their needs from CPs. It is assumed that costs are only incurred by OEMinc when production is delayed due to a quality or delivery issue.

Information shared by the APs or CPs could take one of two forms:

- Ongoing performance data such as cycle times, sub-tier reliability and sub-tier quality.
- Real-time data such as Raw materials and finished goods inventory as well as notification of a specific shortfall risk.

A greater level of information sharing could equip or encourage OEMinc to invest more in helping them improve. OEMinc could respond to specific shortfall incidents by applying penalties and by investing in helping the supplier improve. However, this could cause the partner may want to avoid sharing information early enough, thinking they can solve the problem and avoid the penalty. Information the partner shares on its near-term process health can allow OEMinc to anticipate problems, and therefore intervene. A history of erratic performance will also result in OEMinc applying penalties. This causes the Partner to want to improve, but not in a collaborative fashion as it is no longer wanting to share information.

The model shows eleven loops, described as follows:

Balancing Loop B1: Shortfalls drive OEMinc to invest in continuous improvement at the CP Site, causing this improvement to take place.

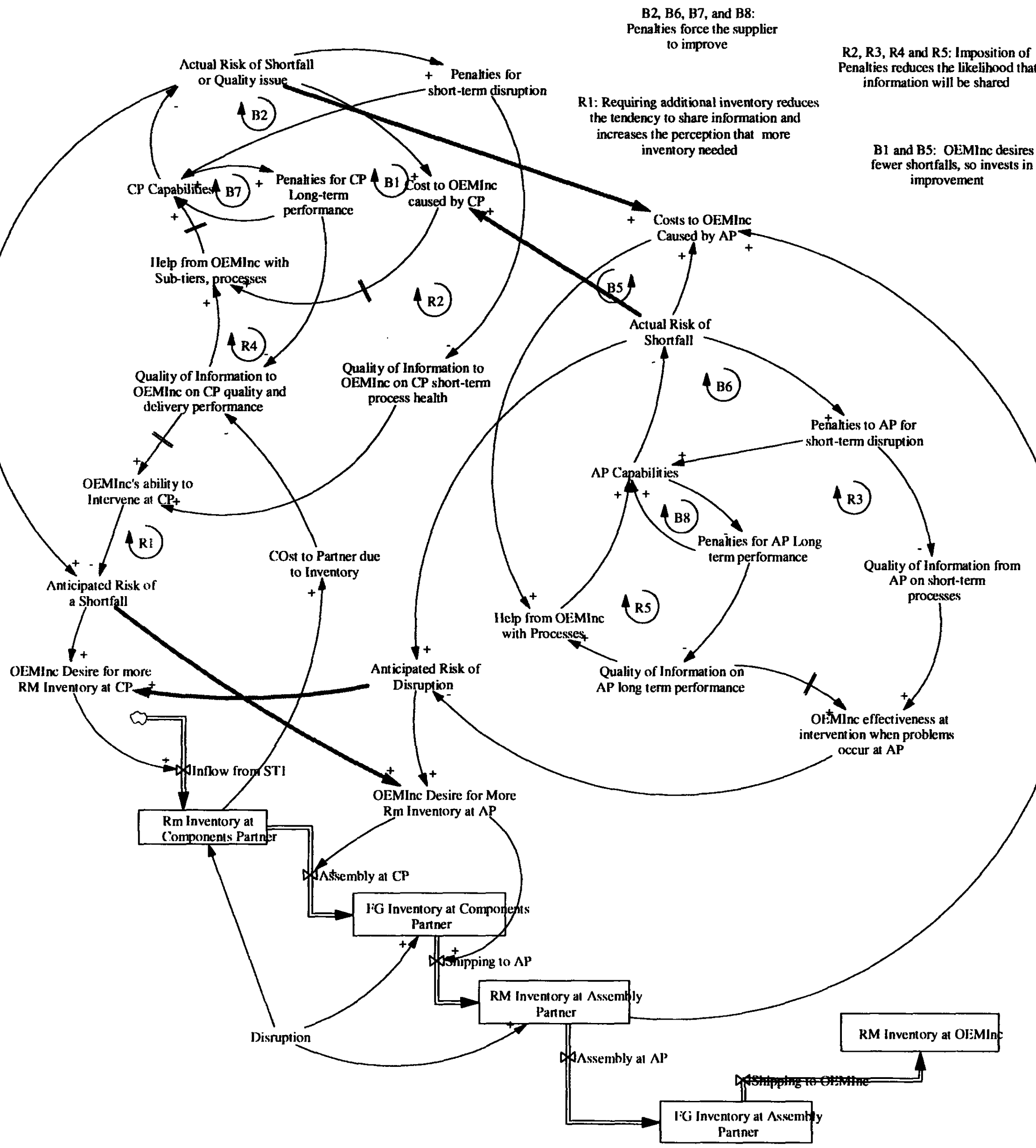
Balancing Loop B5: Shortfalls drive OEMinc to invest in continuous improvement at the AP Site, causing this improvement to take place.

Balancing Loop B2**:** Specific shortfall incidents cause penalties to be applied to the CP, providing the incentive to avoid these incidents in the future.

Balancing Loop B6: Specific shortfall incidents cause penalties to be applied to the AP, providing the incentive to avoid these incidents in the future.

Balancing Loop B7: A pattern of poor performance not related to a specific shortfall causes penalties to be applied to the CP, providing the incentive to improve.

Figure 9: Potential set of Influences and Incentives with Penalties



Balancing Loop B8: A pattern of poor performance not related to a specific shortfall causes penalties to be applied to the AP, providing the incentive them to improve.

Re-enforcing Loop R1: If OEMinc were to institute a policy of requiring CPs to hold additional finished goods inventory to buffer against risk, the level of information sharing by the CP might diminish.

Re-enforcing Loop R2: If OEMinc were to institute penalties for short-term disruptions deemed to be the fault of the CP, that partner would be less likely to inform OEMinc of potential shortfall risks that might be deemed their fault.

Re-enforcing Loop R3: If OEMinc were to institute penalties for short-term disruptions deemed to be the fault of the AP, that partner would be less likely to inform OEMinc of potential shortfall risks that might be deemed their fault.

Re-enforcing Loop R4: If OEMinc were to institute penalties for patterns of poor performance on the account of the CP, that partner will be less likely to share its performance data.

Re-enforcing Loop R5: If OEMinc were to institute penalties for patterns of poor performance on the account of the AP, that partner will be less likely to share its performance data.

It should be noted that it is assumed here that OEMinc can tell the difference between shortfalls attributable to behavior by the AP, and those that are caused by the CP. If that is not the case, the thicker red arrows come into play, confusing the cause and effect relationships by adding several new loops. The following lessons can be taken from an examination of these relationships:

- Penalties for specific shortfall incidents might discourage near-term information sharing, however the penalties also provide the natural balancing of encouraging the supplier to improve. Near-term information sharing is essential for avoiding shortfalls. If the partner were to believe that by sharing this data, the penalty risk could be avoided, information flow would increase.
- Penalties for a pattern of poor performance not related to a specific shortfall may discourage the supplier from sharing important learning data, but do act as a balancing loop by making the partner "Feel the Pain".
- Currently OEMinc does not have the right to require the CP to hold finished goods or raw materials inventory. If OEMinc were to require this inventory at CP cost in the event of a specific shortfall incident or pattern of poor performance, it is likely that CPs might not to share information. However, the belief that OEMinc will respond also with focused support in dealing with these issues might negate this risk.

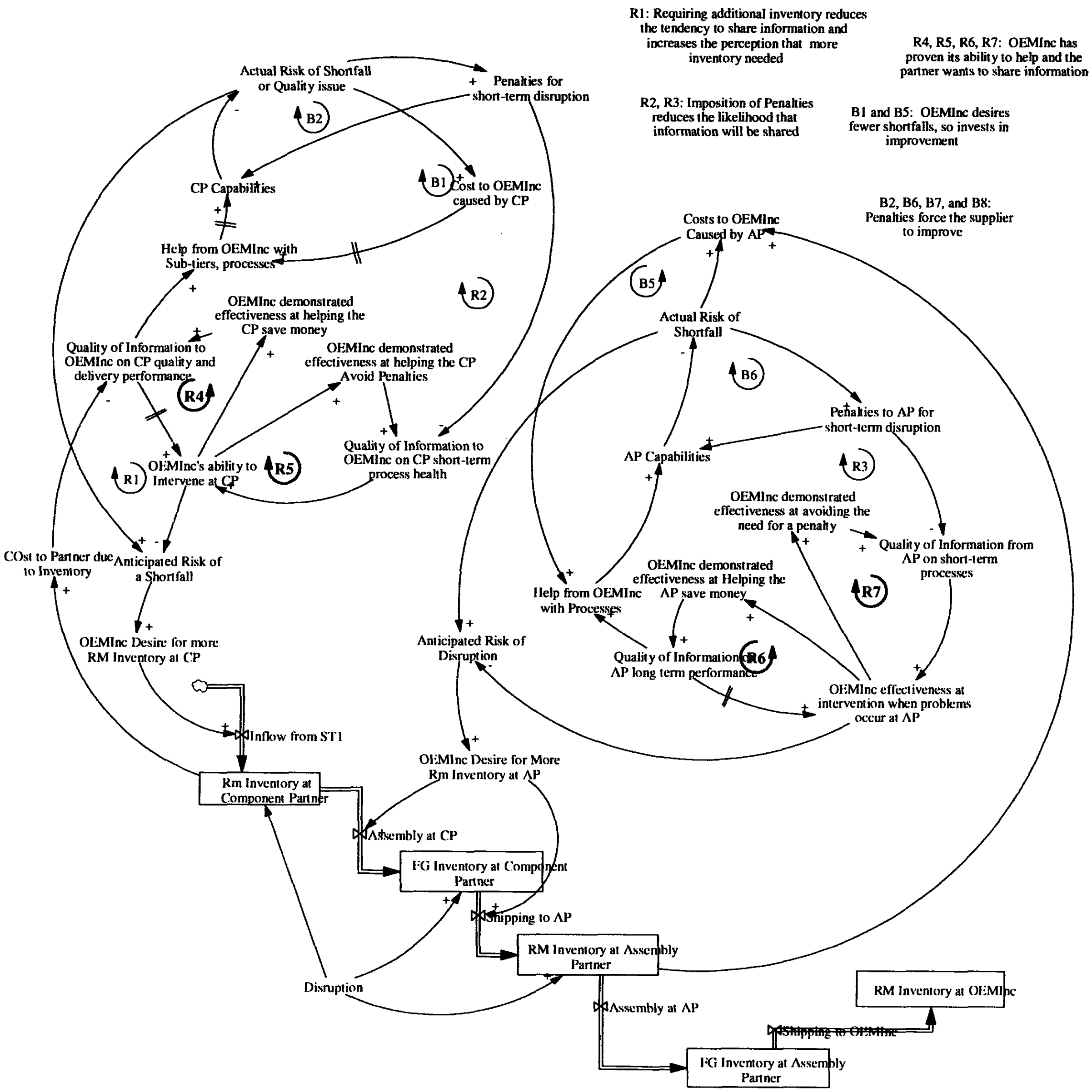
Figure 13 illustrates an improved configuration of incentives. The actions that have been taken here are:

- To eliminate the penalties for patterns of poor performance, and
- To add two new factors:
    - The demonstrated ability of OEMinc to help the Partner save money through improvement in its processes, and
    - The demonstrated ability for OEMinc to help the partner avoid specific shortfall incidents that would incur penalties.

With these changes, a number of loops have been eliminated, the following remain:

Balancing Loop B1: Shortfalls drive OEMinc to invest in continuous improvement at the CP Site, causing this improvement to take place.

Figure 10: Improved set of Incentives



Balancing Loop B5: Shortfalls drive OEMinc to invest in continuous improvement at the AP Site, causing this improvement to take place.

***Balancing Loop B2*:** Specific shortfall incidents cause penalties to be applied to the CP, providing the incentive to avoid these incidents in the future.

Balancing Loop B6: Specific shortfall incidents cause penalties to be applied to the AP, providing the incentive to avoid these incidents in the future.

Balancing Loop B7: A pattern of poor performance not related to a specific shortfall Causes penalties to be applied to the CP, providing the incentive to improve.

Balancing Loop B8: A pattern of poor performance not related to a specific shortfall Causes penalties to be applied to the AP, providing the incentive them to improve.

Re-enforcing Loop R1: If OEMinc were to institute a policy of requiring CPs to hold additional finished goods inventory to buffer against risk, the level of information sharing by the CP might diminish.

Re-enforcing Loop R2: If OEMinc were to institute penalties for short-term disruptions deemed to be the fault of the CP, that partner would be less likely to inform OEMinc of potential shortfall risks that might be deemed their fault.

Re-enforcing Loop R3: If OEMinc were to institute penalties for short-term disruptions deemed to be the fault of the AP, that partner would be less likely to inform OEMinc of potential shortfall risks that might be deemed their fault.

Re-enforcing Loop R4: OEMinc encourages information sharing by having proven its ability of helping the CPs save money due to process improvement.

Re-enforcing Loop R5: OEMinc encourages information sharing by having proven its ability of helping the CPs avoid penalties from short-term interruptions.

Re-enforcing Loop R6: OEMinc encourages information sharing by having proven its ability of helping the APs save money due to process improvement.

Re-enforcing Loop R7: OEMinc encourages information sharing by having proven its ability of helping the APs avoid penalties from short-term interruptions.

The philosophy behind this approach is to make shortfalls an anathema through using a "stick", while using a "carrot" to encourage the behavior that will allow these incidents to be avoided. Specific shortfall incidents require pain to be felt, and they should not be taken lightly. A penalty is both an incentive, as well as a reason to investigate the incident. The investigation itself is wasteful, but if resources are dedicated to this task in the form of a Three-Party quality team at the AP site, real and useful information should be obtained. Since Partners will specifically not be penalized if they give notice of a potential shortfall, there should be no associated incentive to avoid information sharing.

Ultimately, if a co-operative relationship has been established between OEMinc and its partners, and the benefits of information sharing have been demonstrated, improvement efforts should result which would create a virtuous circle of increasing trust and facilitating greater improvement.

5.2.4 Conclusions on Program Actions

As the program develops, data must be tracked so that OEMinc and its Partners can update CSI levels as needed, avert shortfalls in real time and detect chronic problems as they occur. This data includes the non-conformance incidents and their source, the ability of CPs to consistently meet their commit dates, CSI levels, and root-cause analysis of shortfalls.

A Systems Dynamics analysis demonstrates that Penalties for specific shortfall incidents might discourage near-term information sharing. However, this can be mitigated if Partners were to believe that by sharing this data in a timely manner, the shortfall could be averted, and penalty risk reduced. Penalties for a pattern of poor performance not related to a specific shortfall may also discourage the supplier from sharing important learning data.

6. Conclusions

The Excelsior business model presents OEMinc with significant challenges, including the mitigation of shortfalls and quality risk when supply chain visibility has been reduced and the strengthening of the Excelsior Extended Enterprise to allow for operational excellence and effective competition.

Inventory can be thought of the "lifeblood" of the supply chain. This project examines inventory management as a tool for mitigating risk. The analysis focuses on Critical Safety Inventory (CSI) of components produced by CPs and sent to APs. The AP-CP part flow is a key source of uncertainty in the supply chain. OEMinc will own these parts, but not control the ordering or delivering of them, resulting in a reduced level of visibility. Furthermore, the APs, who control the ordering, do not have an incentive to keep CSI levels down.

Dyer[23] contends that the extended enterprise can be strengthened by promoting dedicated investments in the partnership, greater knowledge sharing and trust. Within the context of the Balanced Scorecard approach, we can state the following broad objectives for the Excelsior Supply Chain:

- Customer-facing: Support the 4-month customer introduction;
- Financial: Meet the recurring cost target;
- Business Process Improvement: Adhere to business processes that are transparent and accommodating of improvement; and
- Learning and Growth: Promotion of learning amongst the partnership that will strengthen collaboration and drive overall enterprise improvement.

The challenge OEMinc faces, which this project attempts to address, is as follows:

To develop an effective safety inventory policy for OEMinc-owned, drop-shipped components within the Excelsior Supply Chain, with the goal of supporting production, reducing inventory cost, and enabling continuous improvement.

The linchpin of this policy is the establishment of specified CSI levels which are rationally and transparently tied to partner performance and capability. It is proposed that these levels be established, enforced and kept up to date in the sustaining mode.

Metrics allow the company to measure progress against supply chain objectives and to determine whether policies such as specified CSI levels are being followed. The OEMinc metrics framework has been examined in the context of the challenges presented by the Excelsior Business model. It has been concluded that, based on the need to strengthen the extended enterprise and the more demanding pace of the Excelsior program, metric categories should be added to encourage adherence to business process and strengthening of the extended enterprise through promotion of trust, dedicated assets and knowledge sharing.

[23] Collaborative Advantage, Jeffrey H. Dyer, Oxford University Press, 2000. Page 37

The success of an adjusted system of metrics or set of inventory policies requires careful attention to the details of implementation and maintenance. Through benchmarking at three OEMs in complex-product industries, practices were identified, including:

- the relative lack of emphasis on penalty systems;
- the absence of formal learning or trust metrics;
- a shifting of attention from real-time data exchange to extensive information sharing during early program phases; and
- alternative methods for aligning incentives.

Given the markedly different incentives on the Excelsior, it was posed that while policies on penalties and up-front learning are transferable, a method of encouraging knowledge exchange, dedicated assets and trust must be implemented.

An ARENA simulation analysis was used to evaluate specified levels, established by OEMinc, for a policy of CSI kept at the AP, and a short and specified EO period. Criteria were established, applicable to any component, based on the expected Critical Non-Conformance rate, and expedite lead time. This analysis shows the importance of strictly defining, controlling and improving upon the critical non-conformance rate and the ability to expedite parts when needed to meet the specified CSI level.

With a set of CSI levels, a revised metrics framework and a set of best practices in hand, the challenge of implementation was addressed, first through an examination of the Excelsior extended enterprise through the "three lenses" approach[24]. Potential weaknesses of this strategic arrangement of the organization include:

- the fact that the Excelsior Worldwide Logistics team, responsible for developing supply chain policy, does not have a close enough relationship to the CPs and APs to support their responsibility;
- the nascent state of centralized supply chain capability within the PDTs;
- the as-yet-undefined structure of final assembly;
- OEMinc's failure to cite learning and enterprise development as program goals; and
- the absence of an avenue for interaction between CPs and APs except that facilitated by OEMinc.

Diversions in stakeholder interests with respect to CSI standards in particular are driven by risks surrounding the future of the PDT skillset, and connection to the Partners within final assembly. Furthermore, the control of Partner relationships by Global Suppliers presents a challenge to integration across the enterprise. The OEMinc Culture, while naturally conservative, has recently been formed by significant and accelerating change, and does not represent a significant barrier to policy implementation.

In order for CSI Policy as articulated in this document to be effectively implemented, OEMinc needs to make the investment to tie this policy to production system reality. APs and CPs should be involved in collecting the data and completing the analysis for setting CSI standards. A

[24] Carroll, J. S.. Introduction to Organizational Analysis: The Three Lenses. Cambridge, MA: MIT Sloan School of Management, unpub.ms, 2002

Systems Dynamics analysis demonstrates that Penalties for specific shortfall incidents might discourage near-term information sharing. However, this can be mitigated if Partners were to believe that by sharing this data in a timely manner, the shortfall could be averted and penalty risk reduced. Penalties for a pattern of poor performance not related to a specific shortfall may also discourage the supplier from sharing important learning data.

8. Recommendations

Tri-Party quality teams representing OEMinc, the AP and the key CPs should be established teams at the AP sites. These teams should be focused primarily on the highest-risk components, but every CP should be represented on one team at each site. Their mandate would be to establish non-conformance rates for each component, identify "low-hanging fruit", where AP capabilities could be enhanced to handle "quick fixes", established lead time and lead time variability by component, and agree on CSI levels needed. For units 1-15, these teams should track Lead Time Variability, Non-Conformance levels, Non-conformance Type, and Expedite Lead Time to establish a baseline for CSI levels. Non-conformances should be examined in detail, and AP capability to address the most frequent "quick fixes" developed on a case-by-case basis.

For line numbers greater than 15, OEMinc should employ a system of a preset and controlled level of Critical Safety Inventory kept at AP sites. This CSI Level should be derived based on expectations of non-conformance rates and expedite lead time. Partner CSI levels should be monitored to ensure compliance with specified levels.

The following data will need to be tracked in order to properly maintain these business rules concerning CSI:

- Non-conformance rate and classification of non-conformance:
    - Damaged upon arrival - repairable/non-repairable;
    - Damaged upon installation - repairable/non-repairable;
    - Defective manufacture or not in accordance with design – useable/ unusable;
    - Missed labeling or other.
- Time and cost in dealing with each non-conformance;
- Part arrival relative to promise date - # Days early or late;
- Time between arrival and entry into CSI;
- Daily computer tally of CSI on-hand (including that being repaired or made useable by the AP) and WIP by component;
- Daily tally of outstanding expedite orders; and
- Detailed root cause analysis for each part shortfall incident:
    - What precipitated the event;
    - Who was at fault;
    - Why the system did not prevent it; and
    - What changes should be made.

This will permit OEMinc to determine whether the CSI standards are being adhered to, how AP capabilities are measuring up to the flow of non-conformance, whether current CSI standards are in fact correct, and, ultimately, where improvement efforts must focus.

Once this baseline understanding and level of control has been established, OEMinc should develop a focused multi-partner initiative to lower expedite lead times and non-conformance rates, including incentives for CPs and offers of consultation by OEMinc staff.

From an organizational perspective, the following additional recommendations can be made:

- The PDT structure, pared down, should be maintained within final assembly so that organizational knowledge and partner relationships are maintained.
- Partner Metrics should be adjusted to include participation and success in Pan-partnership improvement efforts, and commitment to knowledge sharing.
- The Supply chain design and maintenance function currently managed by Worldwide Logistics should ascend in responsibility and be integrated into final assembly at a high level with some solid line control over the "mini-PDTs".

The result will be the adjustment of the relationship between OEMinc and the Partners from a single channel controlled by Global Suppliers to a functionally-focused supply chain channel that reports ultimately to final assembly through the "Mini-PDTs". Teams from the various Integration sites should meet centrally to share findings and compare initiatives. The development of these teams is aligned with the goal of strengthening the extended enterprise, as it:

- increases ***dedicated investment*** through the allocation of staff directly to the partnership in a purely collaborative fashion
- increases ***trust*** in the presence of positive results; and
- provides a key forum for ***knowledge sharing***.

With respect to the management of incentives in the supply chain, Systems Dynamics analysis has led to a series of recommendations:

- Explicit Penalties should be applied for disruptions that are not co-operatively averted through information sharing. This encourages information about the threat of a disruption to be shared early.
- Penalties for short-term disruption should drive Partners to share MORE near term data. This will occur if they are convinced that the data sharing will result in collaboration which will reduce the probability of a shortfall and the probability of a penalty. This requires investment and performance by OEMinc in collaborative improvement teams to establish credibility.
- Explicit penalties should not be applied for extended periods of poor performance not related to a disruption. The data the supplier may withhold in this case is too valuable to the enterprise, and it could be more damaging to the relationship to apply penalties when OEMinc cannot be seen to have incurred related cost.
- An incentive must be created for Partners to want to improve their processes and therefore share data. This can be advanced by ensuring the partner that process improvements will result in savings that *they will retain*.
- The quality of information sharing should be established as a key performance metric for Partners.
- Partners should be measured based on the number and significance of collaborative improvement efforts related to their processes.

These objectives constitute a huge change in the way that OEMinc assembles Units. The challenges span design, manufacturing and supply chain, changing the way that objectives are enforced upon the program and its suppliers and increasing the difficulty of these objectives themselves. In pursuing the Excelsior, OEMinc has taken a bold leap to raise the bar by offering a cutting-edge product at a price and with a level of responsiveness that are more than competitive. The challenge will be in execution.