The Complete Bill of Materials: A Study in Collaborative Manufacturing

by

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Abstract

The effects of the bill of material on outsourced manufacturing environment are studied by gathering information on costs to implement a new bill of materials (BOM) transfer process, the potential gains to maintaining a complete bill of material versus the partial or complete embedding of data, and surveying the high-tech electronics manufacturing industry's practice in communicating the bill to their partners. This thesis deals with a telecommunications products company fictitiously named Telcom and its contract manufacturing partners. While much of the cost involved is the price of implementing an Information Technology system to handle manufacturing collaboration, the heart of the issue is the management of the BOM data. Thus, the inclusion of the often undocumented cost or benefits of migration and ongoing coordination and support would further complicate the decision to implement. Furthermore, downstream efforts in supporting this process change and the manufacturer's interests in providing quality and timely service to their partners implies a need to transmit the fully detailed or "exploded" BOM. In some cases, the company's engineers were reluctant to express support for the exploded BOM due to the expected significant workload increase, the perceived added cost in maintaining extra part numbers, and the low expectation of returns for the endeavor. When approached by the prospect to receive standardized formatting but a partially embedded BOM however, the manufacturers expressed concerns regarding lead time elongation and quality degradation. The results on the comparison of the expected costs and benefits of implementation suggest a need for a delivery of a consistently formatted and complete bill of material.

Thesis Supervisor: Dr. James M. Masters
Title: Executive Director, MLog Program

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Chapter 1 Introduction

1.1 The Supply Chain Strategy

Since the global technology industry came to a screeching halt at the close of the second millennium, there has been overwhelming interest in developing the leanest supply chain. While there are many reasons to streamline the supply chain, the primary themes revolve around decreasing the lead time, reducing cost and optimizing production. There are many ways to accomplish these goals which include better inventory management, closing gaps between supply chain partners, and reorganizing activities across the chain to the most suitable partner. Inefficient management of outsourced design and manufacturing relationships leads to higher total material costs, lower productivity and the most impact, missed market opportunities.

1.2 The Outsourcing Model

In order to better optimize their operations, the technology industry turned to the outsourcing model. While divesting their manufacturing operations refocuses the company strengths in design and development, it also adds to the complexity of the supply chain. The added layer increases the need for communication and coordination. To make outsourcing both cost-conscious and time-efficient, efforts must be made to forge a closer relationship between the company and the manufacturing partner (See Figure 4). This tactic sounds very similar to the integration of the manufacturing partner and it has been stated that "the challenge of keeping ahead of the competition across the many dimensions of technology and markets required by an

integral system" [6]. The contradiction suggests that proper supply chain management should not be static but rather dynamic.

In the economic boom of the late 1990s, it was not critical for the telecommunications companies to optimize based on cost. Instead, the companies integrated to decrease lead time for a faster delivery of products to market. When the market environment shifted after the internet businesses collapsed, the telecommunication industry was amongst the hardest hit companies who no longer have the privilege to grow fast. Instead, the companies must cut cost to increase profitability. Companies rush to rediscover its core competencies which often meant disintegrating and divesting ventures outside of their primary business focus. Outsourcing was found to be an ideal solution since companies are still able to benefit from economies of scale while focusing its efforts on design and engineering and reduce inventory.

1.3 Company Overview: Telcom

Telcom is the fictitious name given to a leading telecommunications company developing wired and wireless network devices. This study focuses on Telcom because the company has recently implemented a product collaboration software package to enable and enforce its new process. This package is the industry-leading suite of applications that keeps the engineering design, procurement, manufacturing, suppliers and customers on the same page about ever aspect of complex, changing product information throughout the product lifecycle. With this software package, every entity authorized in the supply chain has appropriate visibility to critical product information which is crucial for decision making and closeness within the product chain.

1.4 Objectives

The purpose of this research is to examine Telcom's benefits and costs for creating and maintaining fully exploded bills of materials, or BOMs for short, in their manufacturing collaborative system and how both Telcom and its manufacturing partners benefit from having the visibility and change control of the fully exploded BOMs. The motivation to study the value of fully exploded BOMs stems from the fact that rolling out a new BOM change management process is a large task with high costs. Furthermore, these costs multiply with a full scale roll-out across the company and the supply chain. While the perfect BOM has the expectation of reducing error rates and increasing productivity, Telcom hopes to understand the value of that information to their telecommunications business and benchmark against the industry standard. Even though Telcom operates within the telecommunications industry, this study and its findings may have application for other businesses that heavily outsource manufacturing operations. To estimate the value of the complete BOM, the objectives of the thesis include:

1. Understanding the company's return on investment for creating and maintaining the fully exploded bills of materials in a manufacturing collaborative system.
2. Identifying the benefit to the company and its manufacturing partners of having the visibility and change control of the fully exploded BOM.
3. Identifying the new BOM change management system and evaluate how it changed existing practices/processes and the impact.

1.5 Scope of Project

The time committed to correct erroneous BOM data is not the only cost factor in maintaining a more complete bill of material. In a large multi-divisional company, the

engineering data is not often shared with other groups internally. This lack of information flow costs the company because groups often re-engineer pre-existing parts already in use in other products. An understanding of the potential cost saving would provide companies more incentive for maintaining fully exploded BOMs. This potentially creates stranded material which increases inventory costs.

This thesis evaluates the costs and benefits of a supply chain strategy in which Telcom and its partners are closing their gaps through implementation of collaborative planning software. It weighs the risks and rewards of varying degree of BOM explosion and makes supply chain strategy recommendations for Telcom's design groups and their partner's manufacturing teams. Furthermore, this thesis explores the industry practices to help formulate those supply chain strategy recommendations.

1.6 Methodology

This work was completed in three parts:

1. Determine the cost and benefit of the maintaining fully exploded BOMs to Telcom by interviewing and collecting data from Telcom's new software deployment team, supply base engineers and physical design engineers. Interviews with the company's engineers and design leads in various divisions provide an understanding of the BOM explosion effort and the benefits to them specifically for exploding or embedding the BOMs. The company's personnel can describe their incentive for requiring BOM explosion and the barriers to process compliance.

2. Interview Telcom employees and several Telcom's manufacturing partners to evaluate the benefit to Telcom and its partners from having the visibility and change control of the fully exploded BOMs. In addition, the research seeks to understand the partner's current use of the BOM data provided today and how they would use lower level (fully exploded) BOM data if it were to be provided. Speaking to the electronic manufacturing service partners builds a case for BOM explosion or BOM embedding from an overall supply chain perspective. The inclusion of their thoughts in conjunction with Telcom's internal staff provides a more accurate calculation of potential cost and benefits at a global scale.
3. Compare the process's cost and value against the industry standard with data collected from Telcom's partner manufacturers. While this procedure is difficult because of each company's uniqueness in business processes, the data collected gives a glimpse into the industry's interest in BOM management.

The conclusion from the above three steps provides a fundamental understanding of the costs and benefits of maintaining fully exploded BOMs in Telcom's outsourcing business and serves as a starting point for futures studies on value of closer supply chain collaboration.

1.7 Structure of Thesis

The next chapter provides background on Telcom and its outsourcing process. It touches on the current market environment of BOMs and its influences on the supply chain. It also outlines the current practices of the information transfer between the manufacturing partners. Furthermore, this chapter introduces the BOM transfer alternative for Telcom and its EMS partners and discusses its strengths and weaknesses.

Chapter three gives the results of the various interviews conducted within Telcom. The divisions contacted for this research includes two groups, A and B. These two groups are selected because of their different part procurement needs and also assembly procedures. Group A develops mobile network solution. Group B's product family includes optical, switching and other standard telecommunications enabling solutions. A discussion of the current and projected BOM processes outlines the perceived cost and benefits to the embedded or exploded BOMs. In addition, a look into the migration process gives an example of the required efforts for the BOM full explosion process compliance.

Chapter four contains the partner's views regarding BOM explosion. The EMS partners interviewed provide a unique perspective of the BOM process as both a provider and a recipient of the BOM. The possibilities of both forms of BOM are discussed to analyze the potential gains through either BOM format.

The next chapter describes several businesses also utilizing the outsourcing model and investigates its costs and benefits of BOM management. While the discussion does not focus on the exploding of bills of materials, it is important to investigate the interests of companies in the BOM. Also, this chapter shows the gains of these companies in properly managing data interfaces with their partners.

The next chapters consist of the discussion of the overall costs and benefits of the embedded and exploded BOM. The chapter provides and examination of the potential barriers to

fully exploding the BOM, the pitfalls for embedding stock lists in drawings, and the overall effects on the supply chain following either strategy. Finally, this thesis concludes with a recommendation for further research into this area of study and possible solution for Telcom regarding the complete BOM.

Chapter 2 The Outsourcing Process: The Bill of Materials

2.1 What it is/What it does

In a manufacturing environment, information is constantly relayed between the different nodes of the chain. The BOM supplies information about what to build and what parts should be used to build it. On a lower level, the BOM also dictates where the parts should be procured.

Are your bills of material 100% accurate?

In researches of the past, perfect BOMs (BOMs with 100% accuracy and detail) are found to be nonexistent. In fact, the attitude has always been accepting of some errors or missing data. Because the information technology infrastructure was fractured even within a company, consolidating the various systems of a large company like Telcom is a costly task. As the inaccuracies are shared across the supply chain, the partnership experiences a bull-whip effect. In fact, finding the source of the error decreases productivity and increases lead time. Even the most integrated systems are subjected to human errors. While one omitted line in the originating BOM can seem minor further up the chain, this research finds that the associated overhead cost and labor can be significant. In some cases, the inaccuracies would cause problems in inventory management and allocation. In a more serious scenario, the manufacturer may make the wrong make or buy assumption and initiate unnecessary processes to secure needed parts. Thus the conclusion shows that "the only acceptable bill of material is 100% accurate" [5].

2.2 Current practices

The typical flow of the BOM is as follows (See Figure 3):

1. The design engineer designs the product and creates the BOM.
2. The design engineer pushes data to SBE (product engineer).
3. The product engineer pushes the BOM to the partner via FTP or E-mail.
4. The partner receives the transmission and verifies the BOM against the drawing.
5. If the BOM has problems (line omits, duplicates, or other confusing data), notes are made and the BOM is returned to the origination point. Otherwise, the BOM is manually entered into the Partner's Manufacturing Resource Planning (MRP) system.
6. The partner transmits their internally created BOM to their suppliers.
7. The process continues down the chain.

2.3 Fully Exploding the Bill of Material

2.3.1 New Practice Overview

To allow more standardization within Telcom and provide more control and visibility downstream, collaborative manufacturing software is deployed. The new process seeks to establish control over parts data across the company. At Telcom, work will be completed to ensure the quality of the data. The first steps are to highlight key data issues that have the greatest negative impact on the EMS partners. In most cases, Telcom has found that the embedded BOMs create a bottleneck for labor intensive searching and validation. Effects are also present later in the lifecycle of the product create issues because of the lack of where-used function for proper change management

The decision to move to a new system appeals to the following goals:

- Promote standardization.
- Allows stability and the ability to only update affected parts.
- The knowledge will be more dispersed. At the present, the knowledge is limited to the lead engineer. The new system may reduce bottlenecks and delays.
- The centralized storage of part listings may Telcom to negotiate better prices through greater buyer power.
- Faster and more accurate information would decrease inventory, so suppliers do not drive in more unnecessary material.
- There will be more control in tracking changes. This will allow the vendors to understand what versions they are building.

The new practice will change the way the company's outside manufacturing partners do business. They will gain visibility and change control of the fully exploded BOMs. Research has shown that the new system decreases the change management activities time from a few weeks to 24 – 48 hours [17]. The elimination of more than ten days in processing time can be directly correlated to monetary savings.

Also, the strategic management at a higher level (Consolidated planning rather than planning at a project level) of commodities leads to cost reductions and provides Telcom with a tool to better negotiate EMS prices. For example, by actively considering commodity prices that are often assumed from vendor quotes, the company could reveal up to sixty percent price reduction of some products. In fact, the product costs at Telcom follow the 80/20 rule where

twenty percent of products equal eighty percent of procurement cost. There is an opportunity for some supply chain reductions.

2.3.2 What it is/What it does

The software system enables a new process. Findings have linked up to 80% of a product's final cost to decisions made during the product's design, development phase or sourcing [17]. The new process allows the partners and suppliers to receive data formatted for entry into their own system without human interaction. Even if the partner is not chosen to be fully committed to Telcom's new systems and avoids complete integration, the data will be received in platform-independent PDX (Please see Glossary) files.

Additional data information storage is a key benefit to this software. The maintenance of approved vendor lists allows the partner flexibility in sourcing and at the same time, restricts the partners to a level of quality dictated by the originating company. The data management process control will now be centralized. This allows for visibility across functional teams and creates synergy within the corporation.

Data generated includes approved parts, vendors lists and changes and revisions information. But what makes this system valuable is not just the data entered into it, but how the data would be utilized. The where-used function increases the productivity of the engineers allowing them to search for parts in the systems that would be affected by a certain change and also allow EMS partners and Telcom commodity managers to identify potentially stranded material. The purchased assemblies can be accessed for inspection. Also, the BOM could be

compared to view the net differences. Because not all ECO (Engineering Change Orders) are complete, there is a low level of confidence in manual inspection. The new software and process may help reduce processing times involved in manual investigation.

2.4 Chapter Summary

Currently, the BOM management between companies involves manual efforts. From the file FTPs to the manual entries into the partner's MRP system, the practice includes many entry points for human errors. Because the process is not automated, the BOM is only about fifty percent exploded for the worst case scenario (ninety-five percent being the best case) and needs to be combined with the embedded on-sheet stock lists (Please see Glossary) to convey the entire picture. Because the BOM can be partially exploded, it may contain some redundant information that is both exploded and embedded. The allowance of duplication in embedded information violates the spirit of the search for a perfect BOM and will change in the future and may cause confusion and extra effort to distinguish the duplicates.

Chapter 3 Telcom

3.1 Overview

While Telcom has already committed to adding and implementing a product collaboration system, the decision still needs to be made regarding the requirement to fully explode the BOM. Currently, the designers operate independently and manage their BOM in a fashion agreed upon by their vendors. Because most work is done manually, a uniformed process was not established to standardize the practice company wide. In fact, the company not only tolerates different styles of maintaining the data, it also uses different software packages. The different styles include the following:

- Varied location of the BOM
- Different transaction processes
- Different software packages leading to very different view of the BOM
- People used "work-arounds" to circumvent obstacles.

The issues with these vigilante approaches to BOM management are an increased risk of errors and an inability to transfer knowledge between groups and to the next team managing the process.

The new process enabled through the product collaboration system allows for the standardization of data and processes. With a large contractor base, the company was looking for a way to more efficiently manage the BOM. But because the migration incurs a large amount of cost and overhead labor, a poorly enforced effort will only lead to a more sophisticated system

with without any data improvement. It is possible to simply attach the mechanical drawings and the associated BOMs into the new system without entering the parts and assembly data and assigning product structure. Even then, with the large size of the company, Telcom must arrive at a compromise for an abbreviated initial migration. The compromise calls for a large scale population of the software's data bank but embeds the information about parts and assemblies characterized as inseparable or lack a Telcom part number. The inseparable parts in this case are parts that are purchased by the EMS partner as one piece and would not be separated to be contracted to multiple vendors.

The compromised solution involves a mixture of appropriate (exploded) data and some documents detailing the common commodity items (e.g. nuts and screws) that do not have Telcom part numbers. The issue at hand is to understand how the partially embedded BOM could affect Telcom. While the current migration supports this model, the eventual goal would be to completely explode the parts and assemblies from the drawings. But some initial transition results reveal a large cost in completely exploding the BOMs into the new application. The effort involves not only the design engineers of the Telcom Corporation; it includes the education and even a commitment of application change with the EMS partners.

3.2 Divisions

3.2.1 Division A

Telcom is focused on providing the most cost-effective and highest performance wireless product offering. This group partners with industry leaders to provide the customer with the most

complete wireless solutions. This includes the 3G solutions, software supporting networks, and other wireless network products.

This group is in the midst of converting their BOMs to the new system. The migration includes the conversion of the currently deemed revenue important products and also filling in additional information for previously converted BOMs. Other possibilities include moving products around the world for cost benefits. And in other cases, there is the possibility that products currently being manufactured will be moved to a different EMS.

Migration

The initial starting position will be that every drawing will need to be manually inspected for one or more of the following issues:

- Checking the issue in the title block if chose to use this issue as the software revision
- Identify invalid BOM relationships and resolve recursive calls
- Make sure that a BOM was not missed because of its location or format.
- Determine what type of manufacturing information will be needed on the AML.
- Determine if a part is a simple or intermediate type and whether design drawing files should be included with the part
- Determine if the on-sheet stock list warning flag (a flag indicating the inclusion of embedded information) needs to be added to the exploded BOM.

For the data already migrated, the process will be as follows:

1. Determine the list of business critical products of Division A.

2. For a top level BOM, extract the BOM.
3. Determine all of the custom designed mechanical parts from that BOM.
4. Determine which of these custom designed parts have no child parts or documents other than their own drawing document. This becomes the list of custom designed parts to inspect for embedded BOMs.
5. Submit this list as a batch request to migration script. This script will extract CAD and PDF files, and text files for BOM relationship and item master data for these parts and any child parts it identifies from the stock list on the drawing.
6. Review each PDF and all new BOM relationships for issues.
7. Clean and correct if necessary any issues found with the extracted data. This may mean updating a drawing.
8. Collect up additional metadata needed for the new system (Product Line, manufacturer etc).
9. Add to the internal parts database any parts that are supplier managed.
10. Import the new items, BOM relations, AML data and file attachments on an ECO. In some cases there will be no new BOM children but the CAD data files will be added only.
11. Return to step (2) and extract the BOM for the next product in the list.

Some embedded BOMs exist in the steady state and will need to be migrated. In the steady state migration, the CAD information is needed for verification. The transition was anticipated to be slow. It is also expected that working with around 1600 drawings and their children simultaneously is not practical. Efficiency and cost conscious thinking suggests that the newest or the most business critical products should be addressed initially. Moving the less critical products should be delayed for a future migration.

Results

For migration of the data, an engineer from Telcom spent the last 3 months working in both data migration and data validation.

An Engineer submitted twenty top level drawings for extraction in several batches. Of the twenty, nine were found. On those nine an additional twenty-seven children parts were found. Of those twenty-seven children parts the drawing was found in nineteen cases. The computer run-time used in extracting these twenty-nine drawings was four minutes per drawing, Extrapolating from these results he broadly guessed that it may take somewhere in the range of fifty to one hundred hours of computer time to extract these top level drawings and their children. This is the better part of a week running the script twenty four hours a day, seven days a week. In fact, it takes around fifteen to twenty hours to reach a point when the engineers could start reviewing the results.

For the previously migrated data or the data already in the new system, the engineer is just filling in the missing pieces. The migration started by looking at approximately sixty drawings. After running the scripts, around forty to fifty of the custom designed parts needed to have additional CAD data added. Five of the parts were completely excluded from the new database. In a couple of cases, a loop was found where a drawing called itself. Currently, he has faced an obstacle at the validation stage where contacting designers of previously migrated BOMs are proving to be more difficult. These designers have moved on to another project and

do not have fully committed time to the process/software implementation. After two weeks on hold, the data is still waiting to be validated.

Other problems encountered include missing CAD files, completely missing BOM children, and in most cases, the automatic scripts just would not run due to the inconsistency in the drawings.

The engineer in Division A has been operating with exploded BOMs. In particular, the circuit packs have already been moved to the product collaboration software while the hardware is still embedded. The product engineer concedes that moving to a complete explosion creates a considerable amount of work but the effort will help the company in the long run. But in the meantime, partial explosion will not be favorable and would create obstacles to BOM import automation for the partners. Additionally, he felt that generating part numbers for items like screws, nuts and rivets wastes resources and may create little value overall.

3.2.2 Division B

This group contracts out all of its manufacturing to outside vendors. In order to convey the designs to the partners, Telcom currently initiate the file transfer via FTP. The file transfer includes CAD model files, drawings and also PDF files for format compatibility. When new changes orders are created, the affected drawings will be sent including the assembly information. The actual BOM in this case is embedded in the front page of the drawing. The exact position on the page is not consistent. Without a consistent formatting of the BOM in the drawings, BOM migration through automated extraction cannot be performed.

Migration

Once the conversion to the new practice takes place, there will be a multiple stage process to migrate the data to the new system. Initially, only the business critical products will be converted. The original BOMs available in the drawings will be used to complement the exploded information. This scenario will hold true until an ECO is requested. At that point, the BOM will be fully exploded and only the exploded information should be accessed. Ideally, the drawing should be updated with any changes, but regardless of the embedded BOM, the partner should rely on the fully exploded BOM. Because there will be partially embedded information in some situations, the users should refer to the exploded BOM first and only use the embedded drawings to supplement missing data.

The product lifecycle includes many iterations of BOM transfer. There are approximately two to three iterations of each product before pre-production. There is another cycle for data cleanup and an additional transfer after the customer addresses the quality issues. During the first six months, the changes are addressing the reliability issues. The frequency and scale of changes decrease after the initial six months. After the design changes settle, any alterations are mostly per customer requests and not something that Telcom would control. These correspondences are done immediately via email and the telephone. The changes are pushed to the supplier and can only be viewed when Telcom is ready for them to act on the designs.

When approached about the error rates and potential for improvement with the new BOM process, the engineers contend that the issues encountered by the suppliers are more often a data integrity problem (i.e. incorrect data). There are very few cases when the EMS would incorrectly interpret the data. But one issue that can be addressed through the product collaboration implementation is standardizing the parts organization with a universal Telcom part number. The lack of a local part number may lead to a supplier dealing with a part equivalent but then orders a wrong part. The engineers expect that a full explosion avoids confusion and will instill a higher demand for data completion and accuracy.

Results

In order to move the first set of business critical data to the new system, Telcom engineers used a combination of automated scripts and manual labor for the migration. For the scripts to be effective, the drawings must be standardized so the formatting can be verified. The engineers and the migration team found a high standardization cost (added time and manual efforts) associated with preparing older documents for migration. Experiences reveal that a significant lag will occur before the designs meet requirements. In some cases, the delay may be six months to a year. But to prepare the drawings for new products, the engineers agreed that the impact will not be significant. In addition to preparing the drawings to explode the BOM, any parts or assemblies not assigned Telcom part numbers will need to have a one assigned. The part number request, which involves an extensive search and validation within Telcom, would take an hour to couple of days. The product engineers do not yet have a vested interest implementing a new business process and ramping up their knowledge of a new software package. The benefits will be realized upstream where they manage commodity costs or downstream where the

partners actually use the BOMs. Proper supply chain management requires adjusting incentives for compliances and better education throughout the links in the chain.

Chapter 4 The Manufacturing Partners

4.1 Partner A

Introduction

Partner A is one of the world's leading electronics contract manufacturers. The company provides manufacturing solutions and is committed to the use of leading-edge technology. It pledges to deliver cost-effective manufacturing. This company works with Telcom in many aspects from manufacturing needed parts to assembling procured parts of secondary vendors.

4.1.1 Partner A – Site A

Telcom contracts Partner A to build in the wired equipment product family. To deliver the designs and product definitions to Partner A, the BOM is received in 2 different ways, FTP and Email. In addition, the BOM is received in 2 different formats, Microsoft Excel spreadsheet and embedded into a drawing. Upon receipt of the BOM file, it is manually entered into Oracle, Partner A's MRP. This type of transaction is manual and requires human intervention to enable the flow of information. No form of automation is used.

When the files are either received with Telcom part numbers, Partner A's engineer does 3 things:

1. Lookup based on the Telcom part numbers (Partner A's part numbers references both the manufacturing part number and a Telcom part number.

2. If a Telcom part number is not found, then the stock list is reviewed to verify whether there is a mistake or the code is new.
3. Request is submitted to create a new part number or questions sent to Telcom.

For this size of data, it usually takes Partner A between 0.5 to 2 days to enter the BOM into the system. But on top of this overhead time, the EMS partner has questions for Telcom 100% of the time. From the partner's perspective, there are no perfect BOMs. In order to get the questions answered, all of the questions are collected and sent back to Telcom.

Typical issues that arise are:

- A discrepancy in the AVL (Approved Vendor List)
- Quantity errors
- Missing or obsolete parts

For this vendor, it was found that a Telcom part number is easier to use. In addition, the BOM provided in the drawings are more detailed and have better information about the revision. The drawing contains a notes section that has information with telephone numbers and contact names. This extra information could make it easier to verify the spec. A Microsoft Excel BOM format will not have the complete information regarding the Revisions. The new changes may have been sent in a new drawing, but the part numbers on the spec sheet may not have changed. This inconsistency adds additional work for both the Partner A's employees and the Telcom team.

Telcom has direct contact to the secondary vendors. Sometimes, Telcom has sent the vendors an updated drawing or BOM that includes a new revision which Partner A is not aware of. This has caused problems. In general, Partner A creates a BOM internally and sends the information through their internal MRP. The Telcom transmission would be sent as a confirmation. Partner A's vendors use Telcom part numbers to cross reference the drawing to the correct version. This partner does not explode the BOMs for purchased assemblies into their MRP system. They only enter the appropriate levels into their own system because their manual processes are costly.

4.1.2 Partner A – Site B

Partner A at Site B has been responsible for building the complex printed circuit assemblies (they do not yet build the individual printed circuit board assemblies) for Telcom. Because of the complex printed circuit assemblies' technology and the usage of primarily commoditized items, the bills of materials are fully exploded. In this case, the argument for a full explosion of the BOM is to allow Telcom to leverage their large volume orders to reduce supplier prices. But from a Partner A's engineer's perspective, it is critical for them to receive the BOM without any embedded information. This vendor fully explodes BOMs for subcontracted (purchased) assemblies into their MRP system because they feels that allowing a partial embedding of data will only push the tasks to their partners. Partner A in site B believes that an early explosion will reduce the overall lead time by front loading the explosion effort.

Partner A's Site B facility has started receiving transmissions from the new application. They have been receiving a complete Bill of Material and use an automated process to enter the

information into their local MRP system. It is critical for Partner A to ensure the entire BOM is captured in this transfer because parts are sourced out and their partners need the appropriate information to build to specification. In addition, the appropriate vendors for each part are specified in the BOM which shortens the lead time to procure the raw materials.

The engineer expressed concern after receiving an embedded BOM. Because his organization has been receiving a fully exploded BOM, the embedded drawings pose an obstacle to their processes. First of all, the inclusion of the drawings will put a stop to Partner A's automated process. What was a quick process to transfer information from Telcom has become a manual procedure. In addition, because of the embedded BOM, Partner A's procurement practice requires additional steps of negotiating with a vendor. Also, the partner would need to assign appropriate part numbers to the embedded assemblies, and add this information manually. The following are several risks of using embedded BOM:

- a potential of human error in data entry and translating to Partner A's locals system
- a chance to miss the embedded parts or misinterpret the embedded information
- an addition of effort and time to perform the manual entries and procure the parts
- an engineer would need to visit several locations (drawings) to capture the entire product
- losing certain part would mean a complete stop to the manufacturing process
- incomplete information could lead to quality issues
- added costs
- decreased efficiency
- added time.

When the possibility of ignoring the embedded drawings and passing on the entire drawing and the associated models to their vendors, Partner A's engineer was adamant and insists that passing on embedded material is leaving an uncertainty in the supply chain and passing off the effort to a downstream company. The work to enter the information into a company's MRP system is a necessary step to ensure a shorter lead time and better managed quality.

4.2 Partner B

Introduction

Partner B manufactures automatic test equipment and interconnection systems that deliver competitive advantage to the world's semiconductor, electronic and network systems companies. For Telcom, Partner B manufactures high-performance circuits and backplane assemblies. They also manufactures wired equipment systems like Partner A. This partner currently manages twenty to thirty part numbers and twelve to fifteen programs for Telcom.

Partner B has not yet moved to the new system. They currently receive all of their BOMs embedded in drawings. The idea of having a centrally organized process of BOM management is extremely appealing to Partner B. The ability for communication shifting from a push method from Telcom to a pull system will diminish the need for phone calls, emails, or other time consuming activities. Instead of waiting for Telcom to transfer the necessary manufacturing files to its partners, Partner B can enter the shared system and obtain needed information as they are provided and approved. More specifically, Partner B expresses a strong interest for the use of

exploded BOMs. The current embedded methods are inflexible to changes making big drawing adjustments a requirement for even small alterations to the BOM.

Like the other EMS partners, Partner B does not employ Telcom's new software themselves but has experience working with the software with other partners. Before implementing, the partner uses manual processes to input the BOM received from Telcom into their local system. Partner B part numbers are assigned to each part or assembly. Even with a new system, Partner B in this particular location intends to stay with manual entries to their local MRP.

Results

For Partner B, the benefits of the exploded BOMs are the availability of the approved vendor lists and to avoid ambiguity. Today, for a typical Telcom product, Partner B parts account for fifty to ninety percent of components. For the remainder of the parts, Partner B needs to contract secondary vendors. Because Partner B currently explodes the BOM manually as part of their process, embedding the bill of material will not be an issue. The partial embedding of information concerns them but does not pose a great risk because they will depend primarily on the exploded BOM when available. The BOMs for subcontracted (purchased) assemblies into their MRP system by translating the Telcom part numbers into local part numbers. Since this partner manufactures the majority of the components required by Telcom, the parts needing explosion is the minority and not a large effort. In fact, Partner B understands that implementing the software is a large effort but agrees that any effort towards a full explosion will benefit them.

4.3 Partner C

Introduction

The youngest of the three partners, Telcom desires a closer and more structured relationship with this partner. Partner C delivers innovative electronics manufacturing services (EMS). Partner C operates a highly sophisticated global manufacturing network with operations in Asia, Europe and the Americas, providing a broad range of services to leading OEMs (original equipment manufacturers). A recognized leader in quality, technology and supply chain management, Partner C provides competitive advantage to its customers by improving time-to-market, scalability and manufacturing efficiency.

The company manufactures the circuit packs for the Division A of Telcom. Partner C has been in production with the new system for approximately nine months. Here, the BOM is extracted from Telcom's system in the universal PDX format and manipulates it to import in to Partner C's own MRP system. While the data received are not perfect, the fact that an MRP system is a date driven planning system impels the need for human intervention in an otherwise fairly automated process.

The bill of material received are most often exploded with approximately twenty percent of the data embedded. Because the product is not entirely manufactured, Partner C separates the BOM into assemblies that are purchased and ones that will be built. With Telcom, an embedded BOM is a signal to Partner C to purchase the parts and they would not manually search the

attached drawings for stock lists for upload to a local MRP system. But this assumption is not always correct and some individual scrutiny is needed to identify specific embedded BOMs for manufacturing and manual loading. For Partner C, this is considered unnecessary and does not pose a risk to their contract manufacturing services.

Where the danger lies is when the BOM is exploded but not meant to be manufactured by the partner, rather bought. The automated process uploads the BOM into the MRP systems which triggers a sequence of activities downstream. From procuring supplies for manufacturing to requesting pricing for materials to the preparing of facilities for production, an error not caught early inflicts cost and additional lead time for product delivery. While acknowledging that scenario is not rampant, an occurrence could be costly. An occurrence has set the operations back several days.

One reason for Partner C not having wholly accepted the complete explosion of BOMs is the current relationship of Telcom, Partner C, and the subcontractors. Today, Telcom has the ultimate decision to make or buy specific parts. Partner C takes direct dictations from Telcom for procurement practices. Thus, specifications on the purchase parts are relayed directly from Telcom to the subcontractors. The part is manufactured without Partner C involvement and the completed part is purchased and assembled. This allows Partner C to ignore the embedded BOMs and refers to them only for inspection and assembly. For this reason, Partner C sees no danger for embedding purchased parts information. In the future, if Telcom does require Partner C manage the subcontractor information; an explosion of BOM is a necessity. In addition, a flag

indicating from Telcom to differentiate the make and buy parts is critical to avoid confusion and wasted efforts.

Results

However Telcom present the bill of material to Partner C, a clear strategy and agreement must be in place regarding the formatting, the content, and the responsibility of the information. Currently, it appears that there are many assumptions made on the Partner C side which may be potential sources of error. Closer collaboration may be mutually beneficial for Telcom and Partner C.

Chapter 5 Industry Overview

5.1 The Technology Supplier

Telcom has implemented a software suite that promises to facilitate bringing products to market rapidly, improve product quality, and reduce materials and manufacturing costs. The seamless integration of design and manufacturing systems provides the security, access, and business process capabilities to enable an entire product chain to collaborate in real-time. With this product, the company can:

- Introduce new products faster through manufacturing collaboration which can decrease the initial manufacturing intervals.
- Decrease ramp-to-production time and cost
- Reduce product costs
- Improve product quality
- Improve ability to meet customer demand
- Efficiently manage global, multi-tiered supply chain

5.2 Other Practices

In order to better understand the industry's practices of maintaining a complete BOM, it is important to examine other EMS companies and even other high-tech industries. Sanmina and Teradyne have been providing manufacturing services and along with Hitachi and Diversified Systems, have implemented similar product collaboration software.

5.2.1 Sanmina

Sanmina-SCI Corporation is an independent global provider of customized, integrated electronics manufacturing services (EMS). The company provides these services primarily to original equipment manufacturers (OEMs) in the communications, computing, multimedia, industrial controls, defense and aerospace, medical and automotive industries. Sanmina provides comprehensive services through its expertise in product design, engineering, and volume production of complete systems, components and subassemblies. .

A study of industry practices has shown a consistent effort to search for the perfect BOM. Sanmina has contracts with other companies similar to Telcom. In their experiences, the companies have a common goal to shorten the lead time, improve quality and reduce cost, the purpose of supply chain management. To Sanmina, a clear and complete transfer of BOM information is critical to successfully achieve those objectives. So in order to empower their partners' abilities to delivery quality products fast, many companies choose to provide the BOM in a format indicated by Sanmina. In addition, the newer companies have always operated without embedded information. Only the larger corporation that started doing business in legacy systems still rely on embedded data for the BOM.

5.2.2 Diversified Systems

DSI is a one-stop shop for IT services and solutions that can help organizations create and effectively implement their strategies. The company and their customer leverage their collective knowledge to design and deploy advanced applications to support business decisions.

While the company has always delivered its orders better than the industry standards, increased competition drives the need for improved processes that will increase quality, speed, and value. The company works with many products and suppliers which complicates its supply chain. In order to deliver value, the company needs to better manage its parts manufacturing to gain better pricing. This allowed them to share the savings with potential customers to win business.

After implementation, Diversified had three days to enter the complete BOM and AVL and validate the Manufacturer and Manufacturer's part number for each part for the first iteration. The company was able to deliver twelve of the first fifty units five days from the receipt of the customer order. The company gained competitive advantage by being able to confidently produce faster, more accurate, value-add responses to new business requirements. The finished products were delivered faster by shortening the Sourcing process substantially—from several weeks to as little as four hours. By eliminating manual, paper-bound processes, the focus was shifted to improving sourcing productivity. All of the benefits lead to increased profitability through better volume pricing and managing inventory-related cost overruns while improving customer satisfaction through better quality management and speed-to-market.

5.2.3 Hitachi

Hitachi, Ltd. develops a highly diversified product mix ranging from electricity generation systems to consumer products and electronic devices. The company operates in seven industry segments: Information & Telecommunication Systems, Electronic Devices, Power & Industrial Systems, Digital Media & Consumer Products, High-Functional Materials & Components, Logistics, Services & Others, and Financial Services. Hitachi's primary products

include computers, software, power plant projects, electronic appliances and synthetic and ceramic resins. Their high-tech manufacturing operation is dependent on a complex supply chain similar to Telcom.

Looking to compete in a depressed world market, companies like Hitachi need to better realize their return on investment. The company was looking for quick deployment and instant communication of their product information and changes. After choosing to implement a new system, the company was able to operationalize BOM sharing after three months. While several divisions were not a part of the initial changeover, Hitachi looks to totally automate the distribution and synchronization of the product content across their e-Supply Chain.

The success of the Hitachi implementation relies on a quick deployment and the ability to manage critical business interactions. The relatively short time frame of the system implementation means a shorter learning curve period. In the economic environment where businesses often fail to differentiate and rely on pricing, Hitachi chose efficacy and cost savings as their strategy.

5.2.4 Teradyne

Teradyne, Inc. is a supplier of automatic test equipment, high-performance interconnection systems and electronic manufacturing services. Teradyne's interconnection systems products and services include high-bandwidth backplane assemblies and associated connectors used in electronic systems, and electronic manufacturing services of assemblies that include Teradyne backplanes and connectors.

Teradyne has been providing manufacturing services to many companies. The company found product collaboration software extremely beneficial to their processes. In fact, one engineer even referred to the product collaboration application as the "Cadillac" of systems. Teradyne finds that larger and older companies are slow to embrace new technology and are unable to transform their older business processes. The company finds that exploding the BOMs using the collaboration software offers them flexibility and scalability.

Chapter 6 Recommendations

Moving to a new software and process is a lengthy and costly effort. While calculations such as return on investments are calculated prior to the change, many hidden costs are immeasurable. For instance, because companies value their distinct entity and would choose to maintain some secrecy about their cost structure, firms would have difficulty evaluating the potential learning curve of the partners.

6.1 Overcome Barriers to Implementation

During the initial cutover, it is evident that this would be a large effort and a transition team was put in place to coordinate and assist in the migration. The migration has the responsibility to operate the scripts in automating the process of data entry into the new database. The design team's duties include sorting through their drawings and models to ensure the formatting of their documents are standard. Without this additional task by the designers, the automated scripts would not run and manual intervention would be needed. In addition to setting up the drawings and relocating the BOM to an appropriate location, the engineers needed to locate the necessary files and define what parts and assemblies would need to be exploded and what could stay embedded in the drawings. According to the engineers, the effort required to located a part currently without Telcom part numbers in their system and assign or request one is the lengthiest process.

The difficulty during this step is a poorly defined and understood set of rules of what needs to be exploded and what can be embedded. While the expectation is to explode all of the parts and assemblies with Telcom part numbers, some engineers would choose to embed all parts or assemblies if any part/assembly at that level is found to be without part numbers. This postpones the transition effort and leaves the work for later. The rule established requires that if a change order is placed for a certain product, the assemblies involved would have to then be exploded. By pushing back the explosion tasks, future changes would require more time and could exceed cost and deadline expectations of customers due to the additional work.

After the migration team moves the data, the engineers would need to review their data and validate the accuracy of the data. Because the scripts are automatic and highly dependent on the quality of the engineers' work, some errors and omissions may occur. In fact, the additional validation tasks needs to be repeated anytime the scripts are involved in the data transfer. But in the steady state, this validation would be a self-check.

6.2 Cost Benefits of Implementation

While the new software is restrictive and requires standardization, an allowance of partial explosion would defy the effort to normalize the data. Noticing some shortcuts taken by engineers in their efforts during transition, it is expected that similar customization of rules will take place in the future. While a product collaboration package would still be an excellent tool for maintaining some form of rules and order in data storage and information transfer, features such as where-used and cost savings expectations would not be realized. Because the explosion

is incomplete, the manufacturers would not be able to fully integrate with Telcom and collaborative manufacturing would only be partially realized.

Partial explosion can cause confusion with the EMS partners. Currently, Partner A manually loads the data that interests them into their own manufacturing resource planning system. While this is the exact step that Telcom had hoped to deemphasize through the new process, a partial implementation could jeopardize the expected results. In fact, Partner A's initial reaction to receiving the data through the new software was that they would continue their current manual process. This type of response troubles Telcom and is a clear indication that the partner requires further education. In addition to partner's non-cooperation in the new process, there is also the inherent confusion built in to the system through partial explosion. Telcom has instructed that the BOM will hold mixed information holding both exploded and embedded parts of the same level. The possibility of duplicated items could add to the confusion although Telcom instructs their partners to focus on the explode BOM.

The true cost of fully exploding the BOM may never be known but it is clear that there will be overhead involved in maintaining the consistent data across all levels. The added costs include establishing controls across the company to maintain standards, some policing to ensure proper implementation of the new processes, and performing unneeded tasks purely to satisfy homogeny. Partial explosion achieves some of the primary goals of implementing the software suite. A centralized data storage and retrieval system is in place without the full explosion.

6.3 Added Costs

Overall, the added costs of implementing the product collaboration package include the additional IT costs, the migration efforts and the maintenance needed to properly follow through with this process. But specifically to the embedded BOM, explosion of product data involves some of the same overheads. The creation of Telcom part numbers and maintenance of the additional information can create some costs although it has been debated. In fact, the quote for the part number management cost has been speculated to be as low as zero while some contends that rates such as $2000 - $5000 per part number are possible (This cost data is stated by some engineers while others claim that there is no data corroborating any tangible cost associated with part number maintenance). The true cost is likely between the extremes and consists of the lookup costs, the migration time, and the effort involved returning to the drawings to edit the parameters. When asked to estimate the effort to revisit an established product to fully explode the BOM, the answer given was approximately six weeks with one full time employee.

On the other hand, keeping the embedded data pushes the costs down the partners. As mentioned by a Telcom EMS partner, the job has to be done somewhere in the chain. By putting forth the effort early on in the chain, Telcom would save the partners days to weeks. In some cases, the effects of embedded BOMs are detrimental and could halt the manufacturing process entirely. Any embedded data would prevent automatic scripts from running. Without entering the BOM information into their MRP system, the partner would not be able to build and assemble the products. The added cost of manual input into local MRP systems at each stage, the individual inspection of the BOMs and the associated drawings for the missing parts, and the cost of errors in production and delivery of finished goods displease the partners. Also, it is

stated that controlling data structures with exploded BOMs is much easier than digging for buried data in drawing. One partner states that their sole purpose is to better support Telcom and exploding the BOM would allow for a speedy delivery of better quality products.

Finally, while the added cost of exploding the BOM resides primarily with Telcom, some groups within the company views the cost issues as a "Pay me now, or pay me later" syndrome. Although there are definitely up-front costs with exploding embedded information, some engineers challenge that in the long run the savings far outweighs using embedded data.

6.4 Process

Understanding the process compliance curve is critical to the successful implementation of the new system and explosion of the BOM. In fact, simulations and studies show that the actual effects of a new process implementation lag the compliance of the process by two months or more (See Figure 2). With a company jockeying for a strong position in a growingly competitive field, decision must be made with the understanding that costs will be realized much earlier than the benefits. In this case, the results of fully exploding the BOM could remain hidden until several scenarios occur including the following:

- The partners adapt to the new software.
- The engineers redesign their products to incorporate more common parts.
- Manufacturing is relocated from one partner to another and new relationship is established.

If the environment of the partnership is expected to remain constant, proposing a sweeping unifying of process could be extraneous.

6.5 Recommendations

The management of the bill of material has a growing importance in the globalized economy. The commitment of firms to upgrade its relationship with its EMS partners is critical to maintaining a competitive edge in the tough marketplace and allows each company to more efficiently operate. While many opinions towards the explosions of BOMs exist, a constant theme of better integration throughout the chain is echoed. Software like the product collaboration package adopted by Telcom has a growing popularity amongst electronic manufacturing firms. And coupled with the IT implementation is the need for better data inputs. Standardizing the software and increasing data explosion adds flexibility in sourcing and provides the tools for faster flow of data through the chain.

The companies agree that some products such as the complex circuit assemblies requires complete explosion but thoughts vary on products such as metal shelving for the circuit assemblies docking. The reason for the disparity is the use of common parts in products like circuit packs and a better management of these commodities could reap tremendous benefits across the supply chain. In the shelf systems, the engineers defend the use of embedded BOMs because of uniquely designed parts and also what they claim as inseparable parts. Although it is true that parts like sheet metal assemblies will possibly never be manufactured separately and in some cases, the manufacturers do not require BOM, commoditized parts such as fasteners and rivets could still be managed to decrease procurement costs.

From the research, it shows that the exploded BOM will benefit the supply chain partners. This does not mean that they are seeking immediate full explosion, but the partners have

expressed that more BOM explosion will benefit their companies and processes. While not all vendors are prepared to automate their processes to work with new software, standardizing the part numbers, approved vendor lists, and reaching a mutual understanding about the levels of explosion will improve the overall performance of the supply chain. What this research found was that assumptions are made within the partnership and some of these misconceptions could cause delays in product delivery. With proper agreements in place, fully exploding the BOM adds robustness to the data. Essentially, a consistent strategy and well-communicated expectations creates value in the chain with the new process. But a misaligned approach to the BOM such as the following could create undesirable results:

- Partial explosion that varies from division to division or even BOM to BOM.
- A fully exploded BOM that does not have complete information about vendors.
- Duplicate information or inconsistent information between the embedded BOMs and the exploded data.

Older telecommunications companies and firms in other electronic manufacturing industries have the problem of managing culture and changing well established practices. Depending on the age and size of some of these electronic firms, shifting the paradigm will vary in effort and cost. What has been the trend with the younger and smaller companies has been to fully explode BOMs to provide data clarity to vendors. The partners researched have experience in dealing with the fully exploded BOM and would like to unify their processes. Although with some vendors, the migration of older data is not necessary and the efforts should focus on future designs, researching each vendor's preferences would be costly; the recommended action is to commit to fully exploding the BOM.

Chapter 7 Conclusion

7.1 Conclusion

This paper compares and synthesizes a series of interviews and studies on the impact of the BOM in collaborative manufacturing. Moreover, it delves in to the pros and cons of delivering a complete exploded BOM versus embedding some information on drawings. The results demonstrate that a company wide process change is not often welcomed throughout the divisions due to the vastly different nature of the businesses. But the standardization provides Telcom with the flexibility and leverage to seek lower cost vendors while shortening lead times and improving quality. Although the migration to the new process may reduce the productivity of a company through stressed resources, the added value of a unified BOM format and partnerships leads to a more complete view of the company's cost and design strategy. When the commodities could be collectively managed by a central entity, savings towards procurement cost could be realized. Finally, comparative studies of the industry and Telcom shows a clear drive towards closer manufacturing ties in outsourcing which in this case is the delivery of a consistent and complete bill of material.

7.2 Suggestions for Further Research

What is revealed in the research is that there are some hidden and indirect costs associated with maintaining a fully exploded bill of material that is quantifiable. The sharing of data is limited in a large multi-divisional company. This lack of information flow costs the company by groups often re-engineering pre-existing parts already in use in other products.

Because one of the driving motivations of pursuing a new IT software and business process is better part management, an understanding of the potential cost saving would provide companies more incentive for maintaining fully exploded BOMs.

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Glossary

AML – Approved manufacturers list. This is a list of appropriate manufacturers that the partners are authorized to procure parts.

AVL – Approved vendors list. This is the same as the approved manufacturers list.

Bill of Material (BOM) – The bill of materials defines the product structure in terms of materials.

Bull-Whip Effect – The phenomenon that small changes upstream can create oscillations and very large swings further down the chain.

CAD – Computer aided design. This is the use of computer programs and systems to design two- or three-dimensional models of physical objects such as mechanical parts.

Child Parts – The parts that are subparts of a larger part. In a hierarchical product structure, a part's subcomponents are its child parts.

Complete BOM – The product listing that has assembly information at all levels without any embedded information (Please see Embedded BOM).

Custom Designed Parts – Parts that are designed specifically for Telcom, not off the shelf parts.

ECO – Engineering change order. The request to alter a previously approved and agreed upon design.

Embedded BOM – The embedded BOMs are product lists are represented on a mechanical drawing. The BOM in this instance is listed on each drawing instead of represented in a consolidated form.

EMS – Electronic manufacturing service. These companies are contracted to provide manufacturing and assembly capabilities to other companies.

Exploded BOM – Please see Complete BOM.

FTP – File transfer protocol. This is the means to transfer files to remote locations.

IT – Information Technology.

On-Sheet Stock Lists – This is how the BoM was represented prior to the new process. The on-sheet stock list is a listing of parts associated with a part and is embedded into the part's drawing (Please see Embedded BOM).

Parent-Child – The relationship between a part and the components that make up the parts.

Parent Parts – The parts that have subcomponents.

PDF – File format used by Adobe Acrobat. A standard format preferred for file sharing.

PDX – A file type standard defined by an XML encoding scheme that enables supply chain partners to exchange product content, changes and subsequent manufacturing information.

Where-Used – A function in the BOM program that allows the user to query the system for products that use a certain part.

XML – XML is a markup language for documents containing structured information.

Tables

Table 1: EMS Partners

	Process	Embedded BOMs - Currently	Embedded BOMs - Effects
Partner A –Site A	Manual	Yes	No Effect
Partner A – Site B	Fully Automated	Just started seeming them	Critical
Partner C	Semi-Automated	Very Small percentage, < 2%	Not big deal unless assumptions change
Partner B	Manual	Yes	The less of embedded BOMs the better

Figures

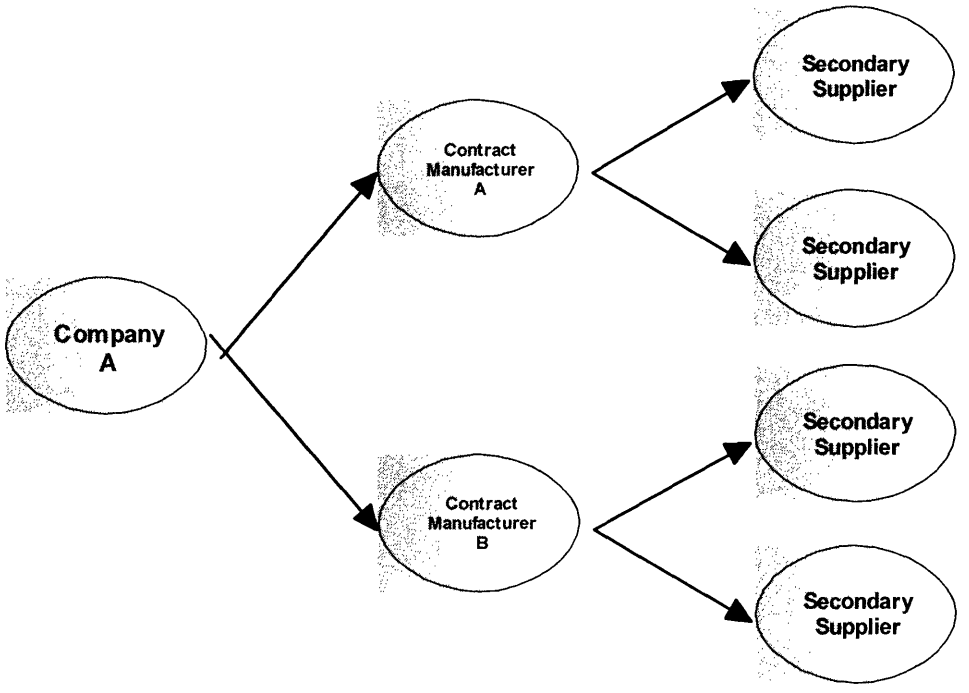

Figure 1: Supply Chain Structure

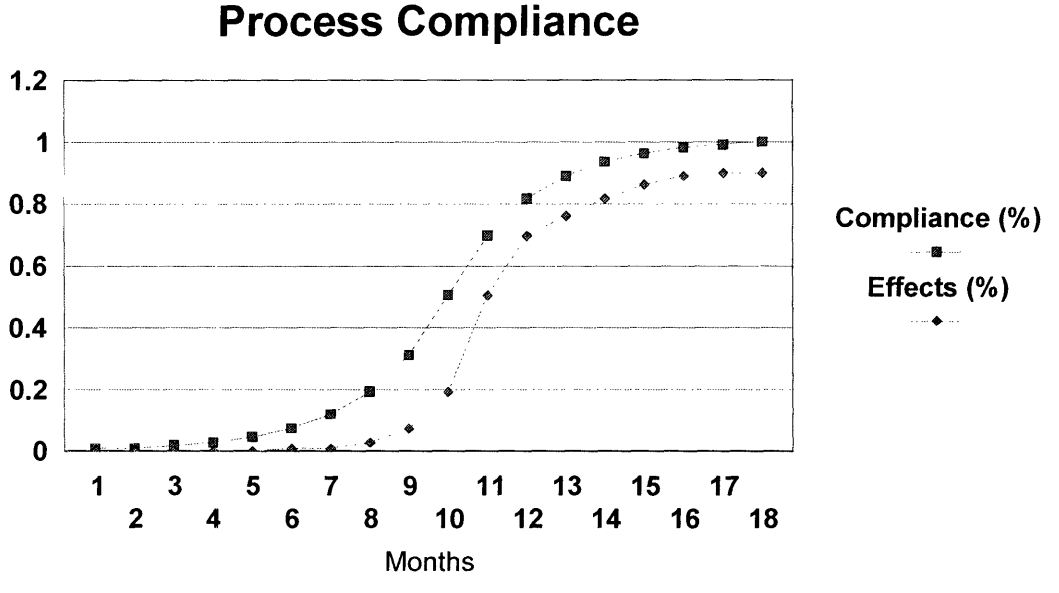

Figure 2: New Process Compliance

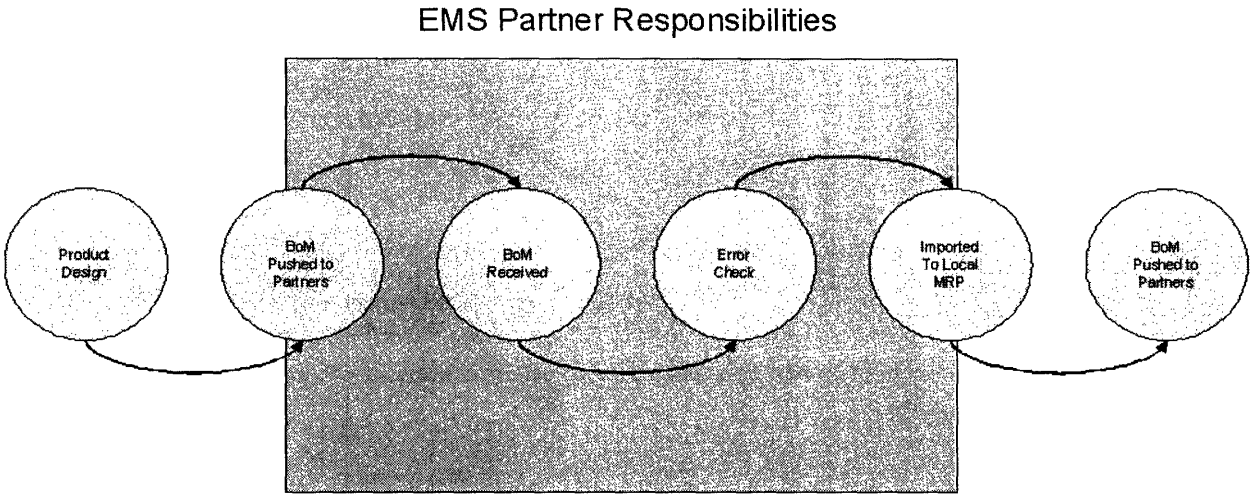

Figure 3: Traditional BOM Flow

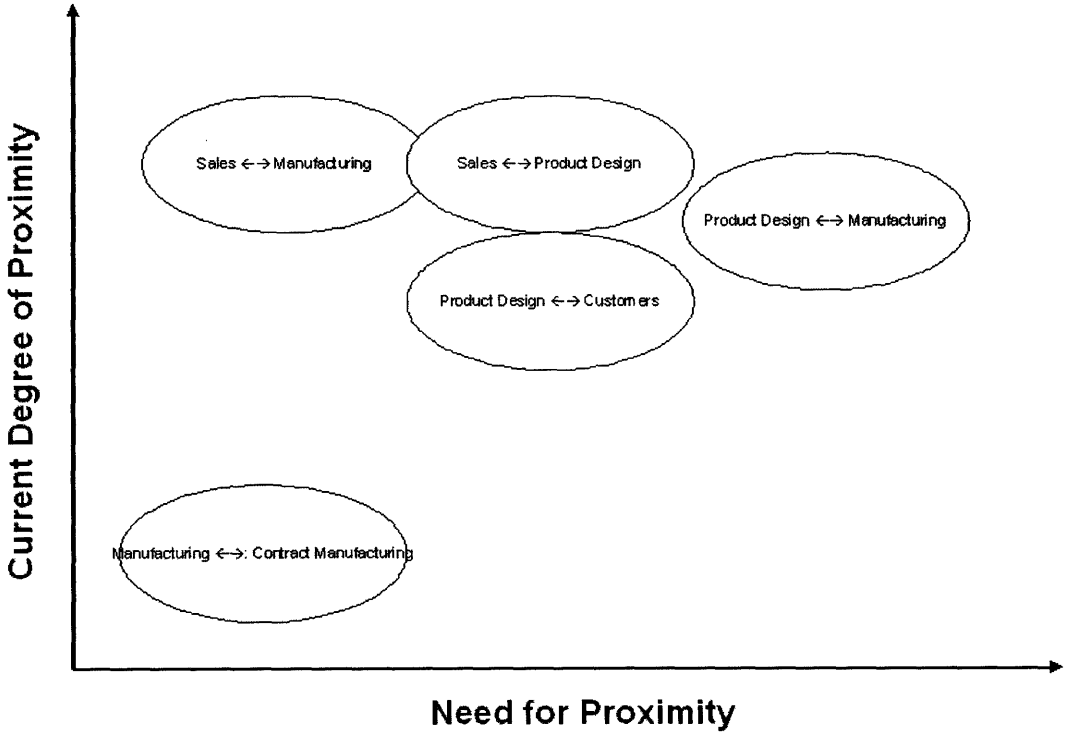

Figure 4: Closer Ties Between Functions